Pak Matiari-Lahore Transmission Company (Private) Limited

巴基斯坦默蒂亚里-拉合尔直流输电项目公司

The Registrar,
National Electric Power Regulatory Authority.
NEPRA Tower Attaturk Avenue (East), Sector G-5/1, Islamabad.

Subject: Application for Special Purpose Transmission License (Original)

I, Wang Bo, being the duly authorized representative of the Pak Matiari-Lahore Transmission Company (Private) Limited by virtue of Board Resolution dated February 7th 2017, hereby apply to the National Electric Power Regulatory Authority for the grant of a Special Purpose Transmission License to the Pak Matiari-Lahore Transmission Company (Private) Limited, pursuant to Section 19 of the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997.

I certify that the documents-in-support attached with this application are prepared and submitted in conformity with the provisions of the National Electric Power Regulatory Authority Licensing (Application and Modification Procedure) Regulations, 1999, and undertake to abide by the terms and provisions of the above-said regulations. I further undertake and confirm that the information provided in the attached documents-in-support is true and correct to the best of my knowledge and belief.

A [Demand Draft/ Pay Order] in the sum of Rupees [222,156/-], being the non-refundable license application fee calculated in accordance with Schedule II to the National Electric Power Regulatory Authority Licensing (Application and Modification Procedure) Regulations, 1999, is also attached herewith.

Date: 31/3/2017

::

Wang Bo

CEO of
Pak Matiari-Lahore Transmission Company (Private) Limited

Address: No.177-A, Street-6, DHA, Lahore, Pakistan
Tel: +92-42-3574 6855 Fax: +92-42- 3574 6869

30th March 2017
The Registrar,
National Electric Power Regulatory Authority.
NEPRA Tower Attaturk Avenue (East), Sector G-5/1, Islamabad.

Declaration for the Qualified Applicant

On 27th March, 2017, China Electric Power Equipment and Technology Company Limited ("CET" or the "Sponsor"), as the sponsor for ± 660kV HVDC Matiari-Lahore approximately 878 km Transmission Line Project (the "Project"), was granted the Letter of Intent (the "LOI") dated 27th March 2017(No.1(102)PPIB-A001/17/PRJ/O-48576) for the Project by Private Power & Infrastructure Board ("PPIB") .

Pursuant to the LOI, CET is required to submit, within one (1) month from the date of issuance of the LOI, petitions before National Electric Power Regulatory Authority ("NEPRA") for the approval of tariff (the "Tariff Approval") and for grant of special purpose transmission license (the "Transmission License") under Regulation of Generation, Transmission and Distribution of Electric Power Act 1997.

Pak Matiari-Lahore Transmission Company (Private) Limited (the "Project Company") has been incorporated dated 16th September 2015 (Corporate Universal Identification No.0095286, issued by Securities and Exchange Commission of Pakistan) under the *Companies Ordinance, 1984* to act as a special purpose vehicle to undertake the Project, which is under actual control of CET as explained below. The Project Company will act as the qualified applicant for the Tariff Approval and Transmission License for the Project pursuant to the LOI.

Investment and share-holding structure of the Project Company is as follow:

State Grid International Engineering Limited, as a wholly-owned subsidiary of the Sponsor, is duly incorporated under the laws of Hong Kong. Zhong Cheng Xin International Limited and Zhong Zhuo Yue International Limited, shareholders of sixty-ninety point ninety-eight percent (69.98%) and thirty percent (30%) of the total shares of the Project Company respectively, are wholly-owned subsidiaries of State Grid International Engineering Limited. Furthermore, Mr. Wang Bo and Geng Jialing, directors of the Project Company, respectively hold one (1) share of the Project Company.

Based on the above, we hereby declare that Pak Matiari-Lahore Transmission Company (Private) Limited, as the executor for the Project and contracting party of main transaction documents of the Project, will submit the petitions for the Tariff Approval and Transmission License as the qualified applicant and take full responsibility to the above applications.

Attachment 1:Share-holding structure chart
Attachment 2:Certification of incorporation and other supporting documents

Yours Sincerely,

Jia Zhiqiang
General Manager of
China Electric Power Equipment and Technology Company Limited

RESOLUTION OF BOARD OF DIRECTORS

Board of Directors of Pak Matiari-Lahore Transmission Company (Pvt) Limited hereby make that the following resolutions in the board meeting held on February 7th,2017.

RESOLVED THAT Pak Matiari-Lahore Transmission Company (Pvt) Limited (a company incorporated under the laws of Pakistan with its registered office located at House No.177-A,Street No.6,Phase-A,D.H.A, Lahore, Pakistan), Pakistan. Pak Matiari-Lahore Transmission Company (Pvt) Limited is hereby authorized to file application for the grant of Special Purpose Transmission License for submission at National Electric Power Regulatory Authority (NEPRA) in respect of its ±660kV 878 km HVDC Transmission Project(the Project) and in relation thereto, enter into and execute all required documents, make all fillings and pay all applicable fees, in each case, of any nature whatsoever as required.

FURTHER RESOLVED THAT in respect of application for the Grant of Special Purpose Transmission License(including any modification to the application for the Grant of Special Purpose Transmission License) for submission to National Electric Power Regulatory Authority, Mr. Wang Bo as Chief Executive Officer be and hereby empowered and authorized for and on behalf of the Company to:

(i) review,execute,submit and deliver the Special Purpose Transmission License Application (including any modification to the application for the Grant of Special Purpose Transmission License) and related documentation required by National Electric Power Regulatory Authority,including any contracts,documents,power of attorney, affidavits,statements,letters,forms,applications,deeds,guarantees,undertakings,approvals, memoranda,amendments,letters,communications,notices,certificates,requests,statements, and any other instruments of any nature whatsoever;

(ii) sign and execute necessary documentations, pay the necessary fees, appear before the Electric Power Regulatory Authority as needed, and do all acts necessary for completion and processing of the Special Purpose Transmission License Application(including any modification to the application for the Grant of Special Purpose Transmission License);

(iii)do all such acts, matters and things as may be necessary for carrying out the purposes aforesaid and giving full effect to the above resolutions/resolution.

AND FURTHER RESOLVED THAT Mr. Wang Bo as Chief Executive Officer be and is hereby authorized to delegate all or any of the above powers in respect of the foregoing to any other officials of the Company as deemed appropriate.

Board of Directors
Pak Matiari-Lahore Transmission Company (Pvt) Limited

Signature:

Wang Bo | Geng Jialing | Yang Wenyu

Company Registration Office
Securities and Exchange Commission of Pakistan

A009953

SECURITIES AND EXCHANGE COMMISSION OF PAKISTAN

COMPANY REGISTRATION OFFICE, LAHORE

CERTIFICATE OF INCORPORATION

[Under section 32 of the Companies Ordinance, 1984 (XLVII of 1984)]

Corporate Universal Identification No.0095286

I hereby certify that PAK MATIARI-LAHORE TRANSMISSION COMPANY (PRIVATE) LIMITED is this day incorporated under the Companies Ordinance, 1984 (XLVII of 1984) and that the company is Limited by Shares.

Given under my hand at Lahore this Sixteenth day of September, Two Thousand and Fifteen

Fee Rs.5,000/-

CERTIFIED TO BE TRUE COPY

31/3/17

(LIAQAT ALI DOLLA)
Additional Registrar

No.ARL/ [illegible] DATED: 16-09-2015

SCANNED 08 SEP 2015

817005
8/9/15

THE COMPANIES ORDINANCE, 1984

(COMPANY LIMITED BY SHARES)

MEMORANDUM OF ASSOCIATION OF

PAK MATIARI-LAHORE TRANSMISSION COMPANY (PVT.) LIMITED

Company Registration Office Lahore
Securities and Exchange Commission of Pakistan

I. The name of the Company is "PAK MATIARI-LAHORE TRANSMISSION COMPANY (PVT.) LIMITED" (the "Company").

II. The Registered Office of the Company will be situated in the Province of Punjab.

III. The objective for which the Company is established will be all or any of the followings:

1 To carry on in Pakistan or abroad the business of design, engineering, construction, commission, ownership, management, control, operation and maintenance of electricity facilities including transmission lines, electrical transmission facilities, electrical circuits, converter stations, transmission towers, transformers and sub-stations, the movement and delivery of electric power, distribution and transmission activities and business, interconnection services and facilities and the matters connected therewith and incidental thereto subject to permission from NEPRA/other regulatory authorities.

2 To carry on, manage, supervise and control the business of transmitting, manufacturing, supplying, distributing and dealing in electricity and all forms of energy and power generated by any source, including but not limited to coal, oil, gas, bagasse, biomass, hydel or tidal, water, wind, solar, hydrocarbon fuel or any other form, kind or description of renewable or non-renewable resources, subject to approval from NEPRA/other relevant authorities.

3 To carry on in Pakistan or abroad the business of designing, engineering, constructing, establishing, commissioning, setting up, operating and maintaining electric power transmission systems/networks, power systems for transmission, trading or supply of power through establishing or using stations, tie-lines, converter stations, sub-stations and transmission lines and any other electricity transmission facilities in any manner, including build, own and transfer (BOT), and/or build, own and operate (BOO) and/or build, own, lease and transfer (BOLT) and/or build, own, operate and transfer (BOOT) basis or otherwise and to acquire in any manner power transmission systems/networks, power systems, tie-lines, sub-stations converter stations, transmission systems and any other electricity transmission facilities from relevant regulator including NEPRA, distribution companies and transmission companies utilities, generating companies, Federal Government or Provincial Government Undertakings, other local authorities or statutory bodies, other captive power producers,

new- captive power producers, small power producers, isolated generating companies, independent distribution companies, and/or independent power producers and distributors and to do all the ancillary, related or connected activities as may be considered necessary or beneficial or desirable for or along with any or all of the aforesaid purposes which can be conveniently carried on these systems, networks or platforms subject to approval from relevant authorities.

4 To plan, develop, establish, erect, construct, acquire, operate, run, manage, hire, take on lease, buy, sell, maintain, enlarge, alter, renovate, modernize, work and use power system networks of all types including high voltage direct current (HVDC), ultra-high voltage (UHV), extra-high voltage (EHV), high voltage (HV), medium voltage (MV) and low voltage (LV) lines and associated stations, converter stations, sub- stations, transmission and distribution centers, systems and networks and to lay cables, wires, accumulators, plants, motors, meters, apparatus, computers, telecommunication and telemetering equipment and other materials connected with generation, transmission, distribution, supply and other ancillary activities relating to the electrical power and to undertake for and on behalf of others all these activities in any manner subject to approval from relevant authorities.

5 To carry on all or any of the businesses of purchasing, importing, transforming, converting, supplying, exporting and dealing in electricity and all other forms of energy and products or services associated therewith and of promoting the conservation and efficient use of electricity and to perform all other acts which are necessary or incidental to the business of electricity transmission and supply subject to approval from relevant authorities.

6 To locate, establish, construct, equip, operate, use, manage and maintain power grid station, transforming, switching, conversion, and transmission facilities, grid stations, converter stations, cables, overhead lines, sub- stations, switching stations, tunnels, cable bridges, link boxes, heat pumps, plant and equipment for combined heat and power schemes, offices, computer centers, shops, dispensing machines for pre-payment cards and other devices, showrooms, depots, factories, workshops, plants, printing facilities, warehouses and other storage facilities subject to approval from NEPRA/relevant authorities.

7 To carry on all or any of the businesses of wholesalers, retailers, traders, importers, exporters, suppliers, distributors, designers, developers, manufacturers, installer, filters, testers, repairers, maintainers, contractors, constructors, operators, users, inspectors, reconditioners, improvers, alterers, protectors, removers, hirers, replacers, importers and exporters of and dealers in, electrical appliances, systems, products and services used for energy conservation, equipment, machinery, materials and installations, including but not limited to cables, wires, meters, pylons, tracks, rails, pipelines and any other plant, apparatus equipment, systems and things incidental to the efficient generation, procurement, transformation, supply and distribution of electricity.

8 To ascertain the tariff for bulk supply that will secure recovery of operating costs, interest charges and depreciation of assets, redemption at due time of loans other than those covered by depreciation, expansion projects, payment of taxes, and reasonable return on investment, to quote the tariff to bulk purchasers of electrical power, and to prefer petition to the appropriate authority for approval of the schedule of tariff and of adjustments or increases in its bulk supply tariff, where desirable or necessary.

9 To carry on or undertake in Pakistan and/or elsewhere the business to market, import, export, buy, sell, resale, research and to act as agent, broker, supplier, contractor, consultant, engineer, collaborator or otherwise to deal in all types of plants, machineries, equipment, components, instruments, parts, fittings, accessories, implements systems, devices used in electrical and electronics industry.

10 For the purposes of achieving the above objectives, the Company is authorized:

(a) to purchase, import or otherwise deal with any raw materials, equipment, facilities, machinery and allied items required in connection thereto in any manner the Company may think fit from any market whether in Pakistan or any part of the world;

(b) to acquire or obtain for use, whether by purchase, take on lease, concession, grant, hire or otherwise, from a government department, a private owner or from any company, body corporate or other entity, properties, assets and undertakings, including but not limited to land and right of way;

(c) to prepare feasibilities and to conduct surveys and studies for transmission line projects or any other engineering, electrical, mechanical and allied project;

(d) to expand, upgrade or restore the transmission line projects or any other engineering, electrical, mechanical and allied project;

(e) to own, establish or have and maintain shops, branches and agencies all over Pakistan or elsewhere for sale and distribution of cables, wires, meters, pylons, tracks, rails, pipelines and any other plant, apparatus equipment, systems and things incidental to the efficient generation, procurement, transformation, supply and distribution of electricity;

(f) to make known and give publicity to the business and products of the Company by such means as the Company may think fit;

(g) to purchase, acquire, protect, renew, improve, use and sell, whether in Pakistan or elsewhere any patent, right, invention, license, protection or concession which may appear advantageous or useful to the Company for running the business;

(h) to pay all costs, charges and expenses, if any, incidental to the promotion, formation, registration and establishment of the Company;

(i) to purchase, hold and get redeemed shares, debentures, bonds of any business, company, financial institution or any Government institutions but not to act as an investment company;

(j) to apply for tender, offer, accept, purchase or otherwise acquire any contracts and concession for or in relation to the projection, execution, carrying out, improvements, management, administrations or control of works and conveniences and undertake, execute, carryout, dispose of or otherwise turn to account the same;

connection with or secured under entry of any certificate of trade- marks or otherwise, and to use, exercise, develop and grant licenses in respect of, or otherwise turn to account any such trade-marks, copyrights, patents, licenses, processes and the like or any such property or rights, necessary or incidental thereto.

13 To construct, erect and build structures and buildings including, but without prejudice to the generality of the foregoing, factories, warehouses, workshops, offices, sheds, dwellings, stores and any other works or convenience which may seem directly or indirectly conducive to any of the objects of the Company.

14 To buy, sell, manufacture, store, repair, alter, improve, exchange, hire, import, export and deal in all factories, works, plant, machinery, tools, utensils, aircraft, vehicles, appliances, apparatus, products, materials, substances, articles and things capable of being used in any business which the Company is competent to carry on or required by any customers of or persons dealing with the Company or commonly dealt with by persons engaged in any such business or which may seem capable of being profitably dealt with in connection therewith and to manufacture, experiment with, render marketable and deal in all products of residue and by-products incidental or obtained in any of the business carried on by the Company.

15 To sell, exchange or mortgage all or any of the property of the Company and to grant licenses, easements, options or other rights over the same and to accept such consideration as my be thought fit for the same.

16 To construct and provide or otherwise acquire, whether by purchase, take on lease or otherwise, residential accommodation for persons engaged in the business of the Company.

17 To purchase or otherwise acquire and undertake the whole or any part of the business, property, assets and liabilities of any person, firm, body or company carrying on any business which the Company is authorized to carry on, or possessed of property suitable for the purpose of the Company.

18 To support and subscribe to any charitable or public object, and any institution, society or club which may be for the benefit of the Company or its employees or may be connected with any town or place where the Company carries on business.

19 To enter into any arrangement and to take all necessary or proper steps with the Government of Pakistan, and, with the approval of the Government of Pakistan (if required), with any provincial government or foreign government or public authority, local, municipal or otherwise or with any corporation or private persons or all or any of these for the purposes of directly or indirectly carrying out the objects of the Company or effecting any modification in the constitution of the Company or furthering the interests of the Company and to oppose any such steps taken by any other authority, firm or person which the Company considers likely, directly or indirectly, to prejudice its interests, and to obtain from any such governmental or other public authority any charters, contracts, decrees, rights, grants, loans, subsidies, privileges, concessions, indemnities, sanctions or consents as the Company may think proper.

20 To enter into partnership or into any arrangement for sharing profits, union of interest, co-operation, joint venture, reciprocal concession or amalgamation with any person or Company carrying on or engaged in , or about to carry on or engaged in any business or transaction which this Company is authorized to carry on or engaged in . or any business or transaction capable of being conducted which may, directly or indirectly, benefit this Company, and to guarantee the contracts of, or otherwise assist, any such person or company, and to take or otherwise acquire shares and securities of any such Company, and to sell, hold, re-issue with or without guarantee, or otherwise deal with the same.

21 To sell or otherwise dispose of the whole or any part of the undertaking of the Company for such consideration as the Company may think fit, and in particular for shares, debentures or securities of any company purchasing the same.

22 To open bank accounts either in local or foreign currency with any local, foreign banks and financial institutions and deposit, withdraw money from such account or accounts and accept, discount, endorse, execute or negotiate and issue cheques, promissory notes, bills of exchange, bills of lading and other negotiable instruments as required by the bank(s) and financial institutions for the benefit of the Company's business.

23 To expend money in experimenting on and testing and in improving or seeking to improve any patents, rights, inventions, discoveries, processes or information of the Company or which the Company may acquire or propose to acquire.

24 To form, incorporate or promote any company or companies whether in Pakistan or in any foreign country, having amongst its or their objects the acquisition of all or any of the assets or control, management or development of the Company or any other objects or object which in the opinion of the Company could or might directly or indirectly assist the Company in the management of its business or the development of its properties or otherwise prove advantageous to the Company and to pay all or any of the costs and expenses incurred in connection with any such promotion or incorporation and to remunerate any person or company in any manner it shall think fit for services rendered or to be rendered in obtaining subscriptions for or placing or assisting to place or to obtain subscription for or for guaranteeing the subscription of or the placing of any share in the capital of the Company or any bonds, debentures, obligations or securities of any other company held or owned by the Company or in which the Company may have an interest or the promotion or formation of any other company in which the Company may have an interest subject to prior permission of the Federal Government.

25 To take or otherwise acquire and hold shares, stock, debentures, debenture-stock and other securities whether convertible into shares, to acquire and undertake the whole or any part of the shares, business, property or liabilities of any other company having objects altogether or in part similar to those of the Company or carrying on any business capable of being conducted so as directly or indirectly to benefit the Company.

26 To pay any premiums or salaries and to pay for any property rights or privilege acquired by the Company or for services rendered in connection with the promotion of the objects or the business of the Company or in connection with the acquisition of any property, rights

or privileges for the Company or otherwise howsoever, either wholly or partially in cash or in shares, bonds, debentures or other securities of the Company and to issue any shares, bonds, debentures or other securities, and to charge any such bonds, debentures or any part of the property of the Company.

27 To pay all costs, charges and expenses which the Company may lawfully pay with respect to the promotion, formation and registration of the Company.

28 To distribute any of the property of the Company among its members in specie or otherwise in the event of winding up.

29 To do all or any of the things herein in any part of the world either as principals, agents, trustees, contractors or otherwise, and either alone or in conjunction with others.

30 To do all and everything necessary, suitable or proper or incidental or conducive to the accomplishment of any of the purposes or the attainment of any of the objects or the furtherance of any of the powers hereinbefore set forth, either alone or in association with other corporate bodies, firms or individuals and to do every other act or thing incidental or appurtenant to or arising out of or connected with the business or powers of the Company or part thereof, provided the same be lawful.

31 It is hereby undertaken that the Company shall not engage in banking or the business of an investment company or payment sales receipt scheme, or leasing business or insurance business or in any unlawful business and that nothing in this object clause shall be construed to entitle the company to engage in such business. The Company shall not launch multi-level marketing, pyramid and ponzi schemes.

32 Notwithstanding anything stated in any object clause, the Company shall obtain such other approval or license from the competent authority, as may be required under any law for the time being in force, to undertake a particular business.

IV. The liability of the members is limited.

V. The authorized capital of the Company is Rs. 100,000/- (Rupees One Hundred Thousand only) divided into 10,000 (Ten Thousand) ordinary shares of Rs. 10/- (Rupees Ten only) each with power to enhance, increase, reduce or consolidate the share capital and to divide the shares of the Company into different classes and kinds subject to the provisions of the Companies Ordinance, 1984.

We, the several persons, whose names and address are subscribed below, are desirous of being formed into a Company in pursuance of this Memorandum of Association, and we respectively agree to take the number of shares into the capital of the Company set opposite our respective names.

Names & Surname In Full	Father's Name in Full	Nationality with any Former Nationality	Occupation	Residential Address in Full	No. of shares Taken by each Subscriber	Signature
Zhong Cheng Xin International Limited (represented by Mr. Yao Yousheng, holding Chinese passport PE0110835)	N/A	Hong Kong, China	Corporation	Suite 1304, Great Eagle Centre, 23 Harbour Road, Wanchai, Hong Kong	6,998 (six thousand, nine hundred and ninety-eight)	
Zhong Zhuo Yue International Limited (represented by Ms. Ning Yi, holding Chinese passport PE0638548)	N/A	Hong Kong, China	Corporation	Suite 1304, Great Eagle Centre, 23 Harbour Road, Wanchai, Hong Kong	3,000 (three thousand)	
Wang Bo (holding Chinese Passport P01292673)	Wang Deben	Chinese	Service	Room 1201, The Fourth Floor, 12 Building, Nanhuali Community, Xicheng District, Beijing City, P.R. China	1(one)	

Geng Jialing (holding Chinese passport P01465163)	Geng Chuande	Chinese	Service	7-1-702, Shahu Colony, No.315, Xudong Avenue, Wuhan, Hubei Province, P.R. China	1(one)	
				Total Number of Shares	10,000 (ten thousand)	

Dated: The14thday of August 2015.

Witness to above signatures:

CERTIFIED TO BE TRUE COPY

ADDITIONAL JOINT REGISTRAR OF COMPANIES
COMPANY REGISTRATION OFFICE
LAHORE

2/3/17

Signature: Herman

Full Name: So Hau Man Herman

NIC Number: Hong Kong SAR Passport No. K02863341

Father's Name: So Wai Keung

Occupation: Trainee Solicitor

Full Address: Flat 1C, Merlin Court , 6 Marigold Road, Yau Yat Chuen, Kowloon, Hong Kong

THE COMPANIES ORDINANCE 1984

(COMPANY LIMITED BY SHARES)

ARTICLES OF ASSOCIATION OF

PAK MATIARI-LAHORE TRANSMISSION COMPANY (PVT.) LIMITED

PRELIMINARY

1 **Table 'A' not to apply**

The regulations contained in Table 'A' in the First Schedule to the Companies Ordinance, 1984 shall not apply to the Company except in so far as these are adopted or contained in these Articles.

2 **Rule of Interpretation**

(1) The chapter headings shall not affect the construction hereof.

(2) "In Writing" and "Written" include printing, lithography and other modes of representing or reproducing words in a visible form.

(3) Words importing the singular number include the plural number and vice versa.

(4) Words importing persons include bodies corporate.

(5) Words importing the masculine gender include the feminine gender.

Company Registration Office Lahore Securities and Exchange Commission of Pakistan

3 **Definitions**

Words or expressions contained in these Articles shall, unless otherwise defined herein or unless inconsistent with the subject or context, have the same meanings as in the Companies Ordinance, 1984. In these Articles, unless there is something in the subject or context inconsistent therewith:

(1) "Articles" means these Articles of Association, as originally framed or as altered from time to time by Special Resolution.

(2) "Board" shall mean the Board of Directors from time to time of the Company.

(3) "Company" means the PAK MATIARI-LAHORE TRANSMISSION COMPANY (PVT.) LIMITED.

(4) "Chief Executive" means the Chief Executive of the Company appointed from time to time pursuant to Section 198 of the Ordinance and these Articles.

(5) "Debenture" shall include Term Finance Certificates.

(6) "Directors" means the Directors of the Company appointed from time to time pursuant to these Articles and shall include the alternate directors.

(7) "Dividend" means the distribution of profits of the Company to its Members.

(8) "Member" means a member of the Company within the meaning of Clause (21) of sub-section (1) of Section 2 of the Ordinance.

(9) "Memorandum" means the Memorandum of Association of the Company as originally framed or as altered from time to time in accordance with the provisions of the Ordinance.

(10) "Month" means a calendar month according to the Gregorian calendar.

(11) "Ordinance" means the Companies Ordinance, 1984 as amended and now in force in Pakistan and any amendment or re-enactment thereof for the time being in force.

(12) "Register" means the Register of Members to be kept pursuant to Section 147 of the Ordinance.

(13) "Registered Office" means the Registered Office of the Company.

(14) "Registrar" shall have the meaning assigned thereto in clause (31) of sub-section (1) of Section 2 of the Ordinance.

(15) "Section" means Section of the Ordinance.

(16) "Seal" means to common Seal of the Company.

(17) "Special Resolution" shall have the meaning assigned thereto in clause (36) of sub-section 1 of Section 2 of the Ordinance.

FORMATION OF COMPANY

4 Private Limited Company

The Company is a Private Company and accordingly the following provisions shall have effect:

(1) The number of the Members of the Company (exclusive of persons who are for the time being in the employment of the Company) shall not any time exceed fifty (50): Provided that where two or more persons hold one or more shares in the Company jointly, they shall, for the purpose of these Articles, be treated as a single Member.

(2) The Company shall not at any time offer any of its shares, Debentures or Debenture stock to the public for subscription.

(3) The right to transfer shares in the Company is restricted as provided in these Articles.

5 Registered Office

The Registered Office of the Company will be situated in the in the Province of Punjab.

SHARES

6 Issuance and Allotment of Shares

Subject to the provisions of the Ordinance and of these Articles, the shares shall be under the control of the Board. The Company shall not issue partly paid shares. In the case of an issue of shares for cash, the amount payable on application shall be the full nominal amount of the share, except where shares are issued at a premium or at a discount in accordance with the provisions of the Ordinance.

The Board shall, as regards any allotment of shares, duly comply with the direction of the General Meeting and such provisions of Sections 67 to 73 of the Ordinance as may be applicable.

Shares may be registered in the name of any limited company or other corporation body but not in the name of a minor or a person of unsound mind.

7 Further Issuance and Allotment of Shares

The Board may issue, allot or otherwise dispose of any shares of the Company to such persons, on such terms and conditions and at such times as the Board thinks fit, and at a premium or at par or (subject to the provisions of the Ordinance) at a discount and for such consideration as the Board thinks fit:

Provided that, where at any time the Board decides to increase the issued capital of the Company by issuing any further shares, such shares shall be offered to the Members in proportion to the existing shares held by each Member, and such an offer shall be made by a notice specifying the number of shares to which the Member is entitled, and limiting a time within which the offer, if not accepted, will be deemed to be declined; and on the expiration of such time, or on receipt of information from the Member to whom such notice is given that he declines to accept the shares offered, the Board may, subject to the provision of Section 86(7) of the Ordinance, dispose of the same in such manner as it may consider most beneficial to the Company.

8 Shares for Consideration Other Than Cash

Subject to the provisions of the Ordinance and these Articles, the Board may allot or issue shares in the capital of the Company as payment for any property, (tangible) sold or transferred, goods or machinery supplied, or for services rendered to the Company or expenses ~~incurred~~ on behalf of the Company or in the conduct of its business or affairs; any shares which may be so allotted shall be issued as fully paid up shares.

CERTIFICATES

9 Certificates

The certificates of title to shares shall be issued under the Seal of the Company.

10 Members' Right to Certificates

Every Member shall be entitled, after issuance, allotment or registration of transfer of shares, within the time period prescribed under Section 74 of the Ordinance unless the conditions of issue of the shares otherwise provide, without payment, to one (1) certificate for all of the shares registered in his name, or upon paying such fee as the Board may from time to time determine, to several certificates, each for one or more shares. Every certificate of shares shall specify and denote the number of shares in respect of which it is issued, and the amount paid thereon.

In respect of a share or shares held jointly by several persons, the Company shall not be bound to issue more than one certificate and delivery of the share certificate to anyone of the joint holders shall be sufficient delivery to all.

11 Issue of Duplicate Certificate

If any certificate is worn-out, defaced or rendered useless, then upon production thereof to the Board, the Board may order the same to be canceled and may issue a new certificate in lieu thereof, and if any certificate is lost or destroyed, then, on proof thereof to the satisfaction of the Board and on such indemnity as the Board deems adequate being given, a new certificate in lieu thereof may be issued on such terms and fee as may be prescribed by the Board including payment of expenses incurred by the Company in investigating title.

TRANSFER OF SHARES

12 Instrument of Transfer

A share may, subject to provisions of Section 76 of the Ordinance, be transferred, by a Member or other person entitled to transfer, provided it is approved by the Board in accordance with the Ordinance and these Articles.

The instrument of transfer of any share in the Company shall be duly stamped and executed both by the intended transferor and transferee. The transferor shall be deemed to remain holder of the shares until the name of the transferee is entered in the Register. After the name of the transferee is entered in the Register, the transferee of shares shall, if not already a Member become Member and shall be bound by the terms of these Articles in the same manner and to the same extent as the transferor of shares.

The instrument of transfer of any share shall be in writing in the form specified in regulation 9 of Table A of the First Schedule to the Ordinance or in any other form which the Directors shall approve and must be left at the Registered Office accompanied by the certificate or, if no certificate is in existence, such evidence as the Directors may require to prove the title of the transferor or his right to transfer the shares.

13 Restricted Right of Transfer of Shares

(1) No Member shall, except in accordance with the following provisions of these Articles: (a) pledge, mortgage (whether by way of fixed or floating charge) or otherwise encumber its legal or beneficial interest in its shares; (b) sell, transfer or otherwise dispose of any of such shares (or any legal or beneficial interest therein); or (c) enter into any agreement in respect of the votes attached to shares; or (d) agree, whether or not subject to any condition precedent or subsequent, to do any of the foregoing.

(2) Notwithstanding the above clause, a Member may: (a) pledge, mortgage (whether by way of fixed of floating charge) or otherwise encumber its legal or beneficial interest in its shares to the financier(s) for the purposes of banking finance; (b) sell, transfer or otherwise dispose of any of such shares (or any legal or beneficial interest therein): (i) with the approval of the Board; or (ii) as part of the enforcement of the pledge, mortgage (whether by way of fixed of floating charge) or other encumbrance granted to the financier(s) for the purpose of banking finance.

(3) The Directors may refuse to transfer any shares to a non-member of the Company after assigning sufficient reason. If any Member of the Company shall desire to sell his shares, he shall convey such desire to the Company by a written notice. The directors shall offer these shares to the existing Members. If any one or more of the existing Member(s) is / are willing to purchase those shares, then the transferor shall be bound to transfer such shares to the existing Member on receipt of sale price determined by the auditor of the Company. If the existing Members refuse to purchase these shares, the transferor shall be at liberty to sell these shares to non-Member(s) and Directors will not refuse such transfer of shares.

(4) The Directors may also refuse to transfer any shares if the transfer deed is for any reason defective or invalid: Provided that the Company shall, within thirty (30) days from the date on with the instrument of transfer was lodged with it, notify the transferor and transferee to the defect or invalidity, either of whom shall, after removal of such defect or invalidity, be entitled to re-lodge the transfer deed with the Company.

(5) If the Company refuses to register the transfer of any shares, the Company shall, within thirty (30) days after the instrument of transfer was lodged with it, send to the transferor and the transferee notice of the refusal indicating the reasons for such refusal.

Company Registration Office Lahore

TRANSMISSION OF SHARES

14 Transmission of Shares of Deceased Member

The executors, administrators, heirs or nominees (as specified in Section 80 of the Ordinance), as the case may be, of a deceased sole holder of a share shall be the only persons recognized by the Company as having any title to the share. In the case of a share registered in the names of two or more holders, the survivors or survivor, as the case may be, shall be the only person(s) recognized by the Company as having any title to the share.

15 Right of Successor to Become Member or Transfer Shares

Any person becoming entitled to a share in consequence of the death or insolvency of a Member shall, upon such evidence being produced as may from time to time be required by the Directors, have the right, either to be registered as a Member in respect of the share or, instead of being registered himself, to make such transfer of the share as the deceased or insolvent person could have made; but the Directors shall, in either case, have the same right to decline or suspend registration as they would have had in the case of transfer of the share by the deceased or insolvent person before the death or insolvency.

If the person so becoming entitled shall elect to be registered himself, he shall deliver or send to the Company a notice in writing signed by him stating that he so elects. If he shall elect to have another person registered he shall testify his election by executing to that person a transfer of the share. All the limitations, restrictions and provisions of these Articles relating to the right to transfer and the registration of transfers of shares shall be applicable to any such notice or transfer as aforesaid as if the death or insolvency of the Member had not occurred and the notice or transfer were a transfer signed by that Member.

16 Right of Successor to Receive Dividends and Other Advantages

Any person becoming entitled to a share by reason of the death or insolvency of the holder shall be entitled to the same Dividends and other advantages to which he would be entitled as if he were the registered holder of the share, except that he shall not, before being registered as a Member in respect of the share, be entitled in respect of it to exercise any rights in relation to meetings of the Company.

17 Company not to be Liable

The Company shall incur no liability or responsibility whatever in consequence of its registering or giving effect to a transfer of shares made or purporting to be made by any apparent legal owner thereof (as shown or appearing in the Register) to the persons having or claiming any equitable right, title or interest in the same shares notwithstanding that the Company may have had notice of such equitable right, title or interest or notice prohibiting registration of such transfer, and the Company shall not be bound or required to regard to or attend or give effect to any notice which may be given to it of any equitable right, title or interest, or be under any liability whatsoever for refusing or neglecting so to do.

ALTERATION OF CAPITAL

18 Power to Increase Authorized Capital

The Company may, from time to time by ordinary resolution of the General Meeting, increase its authorized share capital by such sum, to be divided into such number of shares, as the resolution shall prescribe.

Except so far as otherwise provided by the conditions of issue, or by these Articles, any capital raised by the creation of new shares shall be considered part of the original capital, and shall be subject to the provisions herein contained with reference to transfer, transmission, right to Dividend, bonus and otherwise.

19 Power to Reduce Share Capital

The Company may by Special Resolution reduce its share capital in any manner and with and subject to any incident authorized and consent required by law and the Ordinance.

20 Power to Sub-Divide or Consolidate Shares

Subject to the provision appearing after clause (d) of sub-section 1 of Section 92 of the Ordinance, the Company may in General Meeting by ordinary resolution of the Members alter the conditions of its Memorandum as follows:

(1) Consolidate and divide the whole or any part of its shares into shares of larger amount than its existing shares;

(2) Sub-divide its shares or any of them into shares of smaller amount than is fixed by the Memorandum; or

(3) Cancel any shares which, at the date of passing of the resolution in that behalf, have not been taken or agreed to be taken by any person, and diminish the amount of its share capital by the amount of shares so canceled.

MODIFICATION OF RIGHTS

21 If at any time the share capital is divided into different classes of shares, the rights attached to any class (unless otherwise provided by the terms of issue of the shares of that class) may, subject to the provisions of Section 108 of the Ordinance and whether or not the Company is being wound up, be varied extended or abrogated with the consent in writing of the holders of three-fourths of the issued shares of that class passed at a separate General Meeting of the holders of the shares of the class. To every such separate General Meeting the provisions of these Articles relating to General Meetings shall mutatis mutandis apply, and the necessary quorum shall be at least two (2) Members entitled to vote and representing not less than twenty-five percent (25%) of the total voting power of that class of shares either of their own account or as proxies, provided that if within half an hour from the time appointed for the General Meeting a quorum is not present, the General Meeting, if called upon the requisition of Members, shall be dissolved; in any other case, it shall stand adjourned to the same day in the next week at the same time and place, and, if at the adjourned meeting a quorum is not present within half an hour from the time appointed for the meeting, the Members present holding that class of shares, being not less than two, shall be a quorum..

GENERAL MEETINGS

22 Annual General Meetings

An Annual General Meeting of the Company shall be held in accordance with the provisions of Section 158 of the Ordinance within eighteen (18) Months form the date of incorporation of the Company and thereafter once at least in every calendar year within a period of four (4) months following the close of its financial year at such time and place as may be determined by the Board: Provided that no greater interval than fifteen (15) months shall be allowed to elapse between two consecutive Annual General Meetings. Subject as aforesaid each such Annual General Meeting shall be held at such place and at such time as may be determined by the Directors, provided that the Company may, for any special reason and with permission of the Registrar of Companies, extend the time within which such Annual General Meeting, not being the first such meeting, shall be held by a period not exceeding thirty days.

Such General Meetings shall be called "Annual General Meetings" and all other General Meetings shall be called "Extraordinary General Meetings".

23 Extraordinary General Meetings

Subject to the provisions of Section 159 of the Ordinance, the Directors may at any time call an Extraordinary General Meeting of the Company to consider any matter which requires the approval of the Company in a General Meeting and shall also, on the requisition of Members representing not less than one-tenth of the voting power on the date of the deposit of the requisition, forthwith proceed to call an Extraordinary General Meeting.

24 Notice of Meetings

Subject to the provisions of Section 158 and 159 of the Ordinance, twenty-one (21) days' notice at the least (exclusive of the day on which notice is served or deemed to be served, but inclusive of the day for which notice is given) specifying the place, the day and the hour of meeting and, in case of special business, the general nature of that business, shall be given in the manner provided by Section 160 of the Ordinance for the General Meeting, to such persons as are under the Ordinance or these Articles, entitled to receive such notices from the Company.

The notice of every General Meeting shall prominently specify that a proxy may be appointed who shall have the right to attend, demand and join in demanding a poll and vote on a poll and speak at the meeting in the place of the Member appointing him and shall be accompanied by a form of proxy acceptable to the Company.

25 Special Business

All business shall be deemed special that is transacted at an Extraordinary General Meeting, and also all business that is transacted at an Annual General Meeting, with the exception provided by clause (b) of subsection (1) of Section 160 of the Ordinance, of: (i) declaring a Dividend, (ii) the consideration of the accounts, balance sheet and reports of the Directors and auditors, (iii) the election and appointment of Directors and (iv) the appointment, and the fixing of the remuneration of, the auditors.

26 Shorter Notice

In the event of an emergency affecting the business of the Company, the Board may, in accordance with the provisions of Section 159(7) of the Ordinance, make application to the Registrar for a shorter notice period, and, if the Registrar authorizes a shorter notice period, then an Extraordinary General Meeting may be convened upon such shorter notice as authorized by the Registrar.

27 Omission to Give Notice

The accidental omission to give notice of a General Meeting to any Member of the Company or the accidental non-receipt of notice of a General Meeting by any Member shall not invalidate the proceedings at any such General Meeting.

PROVEEDINGS AT GENERAL MEETING

28 Quorum at General Meetings

At least two (2) Members present in person or by proxy entitled to vote and representing not less than twenty-Five percent (25%) of the total voting power either in their own account or as proxies shall be quorum for a General Meeting, and no business shall be transacted at any general Meeting unless the quorum requisite is present at the commencement of the business.

29 Who to Preside General Meetings

The Chairman of the Board of Directors shall preside as the Chairman of the General Meetings, and if at any General Meeting the Chief Executive is not present within fifteen minutes after the time appointed for the meeting or is unwilling to take the Chair, then any one of the Directors present may be elected to be Chairman and if none of the Directors is present, or willing to act as Chairman. the Members present shall choose one of their number to be Chairman .

30 Adjournment of Meeting for Lack of Quorum

If within thirty (30) minutes after the time appointed for the holding of General Meeting a quorum is not present, the meeting, if convened on the requisition of the Members, shall be dissolved, and in every other case it shall stand adjourned to the same day in the next following week at the same time and place as was appointed for holding the General Meeting, and if at such adjourned meeting a quorum is not present within half an hour, those Members who are present and entitled to vote not being less than two (2) shall be a quorum and they may transact the business for which the meeting was called.

31 Adjournment by Chairman

The Chairman of General Meeting may, with the consent of the General Meeting at which a quorum is present (and shall, if so directed by the General Meeting), adjourn any General Meeting from time to time, but no business shall be transacted at any adjourned General Meeting other than business left unfinished at the General Meeting from which the adjournment took place. When a General Meeting is adjourned for ten (10) days or more, notice of adjourned meeting shall be given as in the case of original meeting. Save as aforesaid, it shall not be necessary to give any notice of an adjournment or of the business to be transacted at an adjourned meeting.

32 Voting on Resolution and When Poll Demanded

At any General Meeting a resolution put to the vote of the General Meeting shall be decided by a show of hands, unless a poll is demanded (before or on the declaration of the results of the show of hands) in accordance with the provisions of Section 167 of the Ordinance:

(1) by the Chairman of the Meeting;

(2) by one Member having the right to vote on the resolution and present in person or by proxy if not more than seven (7) such Members are personally present, and by two (2) such members present in person or by proxy if more than seven (7) such Members are personally present;

(3) by any Member or Members present in person or by proxy and holding not less than one-tenth of the total voting power in respect of the resolution; or

(4) by any Member of Members present in person or by proxy and holding shares in the Company conferring a right to vote on the resolution, being shares on which an aggregate sum has been paid up which is not less than one-tenth of the total sum paid up on all the shares conferring that right.

Unless a poll is so demanded, a declaration by the Chairman that on a show of hands, a resolution has or has not been carried, or lost, and an entry to that effect in the books containing the minutes of the proceedings of the Company, shall, until the contrary is proved, be evidence of the fact, without further proof of the number or proportion of the votes recorded in favor of or against such resolution.

33 When Poll Taken

Any poll demanded on the election of a Chairman of a Meeting or on any question of adjournment shall be taken at the General Meeting and without adjournment.

A poll demanded on any other questions shall be taken (subject to Section 168 of the Ordinance) in such manner and at such time and place as the Chairman of the General Meeting directs, and either at once or after an interval or adjournment of not more than fourteen (14) days from the day on which the poll is demanded, and the results of the poll shall be deemed to be the resolution of the General Meeting at which the poll was demanded.

34 Effect of Demand for Poll

The demand for a poll shall not prevent the continuation of a General Meeting for the transaction of any business, other than the question on which the poll was demanded. The demand for a poll may be withdrawn at any time by the person or persons who made the demand.

35 Minutes

Minutes shall be made in books provided by the Board pursuant to Section 173 of the Ordinance for the purposes of all resolutions and proceedings at General meetings, and any such Minutes if signed by the Chairman of the General Meeting or of the next following General Meeting shall be receivable as evidence of the facts therein stated without further proof.

VOTES OF MEMBERS

36 Votes of Members

Except as to voting for the election of Directors as provided in Section 178 of the Ordinance, every Member, either present in person or by proxy, shall have votes proportionate to the paid-up value of the shares or other securities carrying voting rights held by him according to the entitlement of the class of such shares or securities, as the case maybe, provided that, at the time of voting, fractional votes shall not be taken into account.

37 Voting by Joint Holders

In the case of joint holders, the vote of the senior who tenders a vote, whether in person or by proxy, shall be accepted to the exclusion of the votes of other joint holders; and for this purpose seniority shall be determined by the order in which their names stand in the Register.

38 Representative of Corporate Members

Subject to Section 162 of the Ordinance, a company being a Member may by a resolution of its Directors authorize any of its officers or any other person to act as its representative at any General Meeting and the person so authorized shall be entitled to exercise the same powers on behalf of the Company which he represents as if he were an individual Member.

39 Instrument of Proxy

The instrument appointing a proxy shall be in writing under the hand of the appointer or of his attorney dully authorized in writing, or if the appointer is a corporate, under its common seal or the hand of the attorney so authorized and in default of the instrument of proxy shall not be fully aruthorized. A proxy may be a non-Member of the Company.

The instrument appointing a proxy shall be lodged with the Company not later than forty-eight (48) hours before the time of holding the General Meeting at which the person named in the instrument proposes to vote, and in default the instrument of proxy shall not be treated as valid.

An instrument of proxy shall be in the form specified in Regulation 39 of Table A in the First Schedule to the Ordinance, or in any other form which the Board may approve.

The instrument appointing a proxy shall be deemed to confer authority to demand or join in demanding a poll on any question.

40 Validity of Proxy

A vote given in accordance with the terms of an instrument of proxy shall be valid notwithstanding the previous death of the principal or revocation (where permissible) of the proxy or of any power of attorney or other authority under which such proxy was singed: Provided that no intimation in writing of the death or revocation shall have been received at the Registered Office before the General Meeting or the adjourned General Meeting at which the proxy is used.

41 Validity of Vote

Subject to Section 160A of the Ordinance, no objection shall be made to the validity of any vote except at the General Meeting or at the poll at which such vote shall be tendered except the General Meeting or adjourned General Meeting at which the vote objected to is given or tendered, and every vote whether given personally or by proxy not disallowed at such General Meeting or poll shall be deemed valid for all purposes of such General Meeting or poll. Any such objection made in due time shall be referred to the Chairman of the General Meeting.

42 Chairman to Decide

If any question or objection is raised, the Chairman of the General Meeting shall decide the validity of every vote tendered at such General Meeting in accordance with the Ordinance and these Articles, whose decision shall be final and conclusive.

In the case of an equality of votes, whether on a show of hands or on a poll, the Chairman of the General Meeting at which the show of hands takes place, or at which the poll is demanded, shall have a second or casting vote.

43 Special Resolution

Except for the matters specially required for Special Resolution at General Meeting under the Ordinance, all other matters and business that is decided and transacted at a General Meeting shall be resolved by ordinary resolution, i.e. simple majority, by the Members at the General Meeting.

DIRECTORS

44 First Directors

Subject to the provisions of these Articles and the Ordinance the Directors shall all be elected by the Members in General Meeting. The following shall be the first Directors of the Company who shall hold office until the election of Directors at the first Annual General Meeting:

(1) Mr. Wang Bo

(2) Mr. Geng Jialing

45 Appointment of Chairman

The Directors may elect one of their members as the Chairman of the Board and vest in him such powers and functions as they may deem fit in relation to the management and administration of the affairs of the Company subject to their general supervision and control.

46 Number of Directors

The number of Directors to be elected shall be fixed, according to the provisions of Section 178 of the Ordinance, from time to time by the Board, subject to the condition that the number of Directors shall not be less than two (2). The Board shall fix the number of Directors of the Company to be elected not later than thirty-five (35) days before the convening of the General Meeting at which Directors are to be elected, and the number so fixed shall not be changed except with the prior approval of the Company in General Meeting.

47 Election of Directors

The provisions of these Articles shall apply for the election of Directors by election of the Members in General Meeting from amongst the candidates eligible, namely:

(1) After the expiry of term of the former Directors, the number of Directors to be elected shall be fixed by the Board not later than thirty five (35) days before convening of the General Meeting at which Directors are to be elected (and such number shall not be less than two (2)) and Directors shall be elected by the Members in the General Meeting unless the number of candidates is not more than the number of Directors to be elected, in the following manner. Retiring Directors shall continue to perform their function until their successors are elected.

(a) A Member shall have such number of votes as is equal to the product of the voting shares held by him and the number of Directors to be elected;

(b) A Member may give all his votes to a single candidate, or divide them between more than one of the candidates in such manner as he may choose; and

(c) The candidate who gets the highest number of votes shall be declared elected as Director and then the candidate who gets the next highest number of votes shall be so declared, and so on until the total number of Directors to be elected has been so selected.

(2) No person, whether a retiring director or otherwise, shall be eligible for election as a Director unless notice of his candidature for election has been lodged in writing at the Registered Office not less than fourteen (14) days before the date of the Meeting at which the election of Directors is to take place.

(3) Where the number of candidates is equal to or less than the number of Directors to be elected, it will not be necessary to hold an election as laid down in paragraph (1) above of these Articles and all candidates shall be deemed to have been elected under these Articles.

48 Qualification for Election as Directors

Members in General Meeting shall elect the Directors from amongst persons who, not being ineligible in accordance with Section 187 of the Ordinance, offer themselves for election as Directors in accordance with these Articles. Any person claiming to be eligible who desires to offer himself for election shall, whether he is a retiring Director or not, file with the Company not later than fourteen (14) days before the date of the General Meeting at which Directors are to be elected, a notice that he, being eligible, intends to offer himself for election as a Director at that meeting. A person offering himself for election as a Director may withdraw his candidature at any time before the holding of the election and may do so by withdrawing the notice in which he offered himself for election. Not later than seven (7) days before the date of the meeting the Company will notify the Members of the persons offering themselves for election as Directors at such meeting and shall so notify the Members.

49 Term of Office

he is a partner or any private company of which he is a director without the sanction of the Company in General Meeting accepts or holds any office of profit under the Company; (5) he absents himself from three consecutive meetings of the Directors or from all meetings of the Directors for a continuous period of three months whichever is the longer without leave of absence from the Board of Directors; (6) he acts in contravention of Section 195 of the Ordinance; (7) he resigns his office by notice in writing to the Company; (8) he suffers from any of the disabilities or disqualifications mentioned in Section 187 of the Ordinance; or (9) he has betrayed lack of fiduciary behavior and a declaration to this made by the Court under Section 217 of the Ordinance.

POWERS AND DUTIES OF DIRECTORS

56 General Powers of Company vested in Directors

The control of the Company shall be vested in the Board and the business of the Company shall be managed by the Board, which may pay all expenses incurred in forming and registering the Company, and may exercise all such powers of the Company as are not by Ordinance or any statutory modification thereof, for the time being in force, or by these Articles, required to be exercised by the Company in General Meeting, subject nevertheless to the regulations of these Articles, to the provisions of the Ordinance and such regulations, (not being inconsistent with the aforesaid regulations or provisions) as may be prescribed by the Company in General Meeting; but no regulation made by the Company in General Meeting shall invalidate any prior act of the Board which would have been valid if the regulation had not been made.

A resolution at a meeting of the Directors duly convened and held shall be necessary for excising the powers of the Company specified in Section 196(2) of the Ordinance. A decision shall be made by a majority vote of the Directors present at the meeting of the Directors duly convened (in person, or through alternative director).

57 Power to Obtain Finances and Giving of Securities

(1) For the purposes of the Company only, the Board may obtain finance or borrow moneys and secure payment of such sum or sums of money in such manner and upon such terms and conditions as it may think fit, and in particular by the issue of bonds, perpetual or redeemable Debentures, or by mortgage or charge or other security on the whole or any part of the property, assets and rights of the Company (both present and future), and the undertaking of the Company: Provided, however, that the above power of the Board shall not entitle the Company to carry on the business of banking / finance / investment company.

(2) Any bonds, Debentures or other securities issued or to be issued by the Company shall be under the control of the Board which may issue them upon such terms and conditions and in such manner and for such consideration as shall be considered by the Board to be for the benefit of the Company.

58 Power of Attorney

The Directors may from time to time and at any time by power of attorney appoint any company, firm or person or body of persons, whether nominated directly or indirectly by the Directors, to be the attorney or attorneys of the Company for such purposes and with such powers, authorities and discretion (not exceeding those vested in or exercisable by the Directors under these Articles) for such period subject to such conditions, if any, as they may think fit, and any such powers of attorney may contain such provisions for the protection and convenience of persons dealing with any such attorney to delegate all or any of the powers, authorities, and discretion vested in him; and without prejudice to the generality of the foregoing any such power of attorney may authorize the attorney to institute, conduct, defend, compound or abandon any legal proceedings by or against the Company whether generally or in any particular case.

59 Compliance with Laws

The Directors shall duly comply with the provisions of the Ordinance or any statutory modification thereof for the time being in force, and in particular with the provisions in regard to the registration of the particulars of mortgages and charges affecting the property of the Company or created by it, and to keep a Register of the Directors and Members and to send to the Registrar an annual list of Members and a summary of particulars relating thereto and notice of any consolidation or increase of share capital and copies of the resolutions and a copy of the Register of Directors and notification of any changes.

60 Minute Books

(1) The Board shall cause minutes to be made in books provided for the purposes:

(a) Of the names of Directors present in person, at each meeting of the Board or any committee of the Directors;

(b) Of all resolutions and proceedings at all meetings of the Company, and the Board, and of the committees of Directors; and

(c) Of appointments of officers made by the Directors.

(2) Any such minutes of any meeting of the Directors or of a committee of Directors or of the Company, if signed by the Chairman of such meeting or of the next succeeding meeting, shall be receivable as evidence of the matters stated in such minutes.

(3) Every Director present in person at any meeting of the Directors shall sign his name in a book to be kept for that purpose and a list of the Directors present in person shall be listed as such in the book by the Chairman of the meeting.

PROCEEDINGS OF DIRECTORS

61 Meetings of Directors

The Directors may meet together at least twice a year for the dispatch of business, adjourn and otherwise regulate meetings of the Board as they think fit. The Chairman may at any time, and shall on the written requisition of any two (2) Directors, summon a meeting of the Directors.

At least seven (7) days' notice will be given to all Directors for a meeting of the Board, and such notice shall set forth the purpose or purposes for which such meeting is summoned, and such notice shall be sent by registered air mail or telexed or e-mailed to any Director residing outside Pakistan. With the consent in writing of the majority of Directors entitled to receive notice of a meeting, or to attend or vote at any such meeting, a meeting of the Board may be convened by shorter notice than specified in these Articles. Any Director may waive notice in writing for the time, place and purpose of any meeting either before, at or after such meeting.

The Chairman of the Board shall preside the meeting of the Directors. If at any meeting of the Directors the Chairman is absent, the Directors may elect any Director to act as the Chairman for the meeting.

62 Quorum of Directors' Meeting

A meeting of the Board, at which a quorum is present, shall be competent to exercise all or any of the authorities, powers and discretion by or under the Articles or by or under any law vested in or exercisable by the Board generally. Except as hereinafter provided, two (2) Directors shall constitute a quorum. If there is no quorum at a meeting properly called, the meeting of the Board will be adjourned for seven (7) days. Questions arising at any meeting shall be decided by a majority of votes.

63 When acts of Meetings of the Board or a Committee Valid Notwithstanding Defective Appointment

All acts done by any meeting of the Board or of a Committee of Directors, or by any person acting as Director or Alternate Director shall, notwithstanding that it be afterwards discovered that there was some defect in the appointment of any such Directors or persons acting as aforesaid, or that they or any of them were disqualified, be as valid as if every such Director or person had been duly appointed and was qualified to act: Provided that as soon as any such defect has come to notice, the Director or other person concerned shall not exercise the right of his office till the defect has been rectified.

64 Resolution By Circulation

Questions arising at any meeting of the Directors shall be decided by a majority vote. In case of an equality of votes, the Chairman shall have a second or casting vote.

Except as otherwise provided in the Ordinance, a resolution in writing which is circulated together with the necessary papers, if any, to all Directors and signed by all of the Directors (or in their absence their alternate directors) entitled to vote thereon shall be as valid and effectual (if approved by majority Directors) as if it had been passed at a meeting of the Directors duly called and constituted. Transmission of documents and signature of resolutions by facsimile or other electronic transmission shall be effective for purposes of circulating and executing documents and resolutions.

ALTERNATE DIRECTORS

65 Power to Appoint Alternate Directors.

Any Director not permanently resident in Pakistan or any Director so resident but intending to be absent from Pakistan for a period of not less than three (3) Months may appoint any person being eligible in accordance with the provision of Section 187 of the Ordinance acceptable to the Board to be his alternate director to act for him. Every such appointment shall be in writing under the hand of the Director making the appointment. The alternative director shall not be deemed to be an agent of the Director appointing him but shall be reckoned as one with his appointer. An alternative director need not to be a Member of the Company.

An alternate director so appointed shall not be entitled to appoint another Director nor receive remuneration from the Company, but shall otherwise be subject to the provisions of the Articles with regard to Directors. An alternate director shall be entitled to receive notice of all meetings of the Directors, and to attend and vote as a Director at any such meeting at which the Director appointing him is not personally present, and generally to perform all the functions of his appointer as a Director in the absence of such appointer.

An alternate director shall ipso facto cease to be an alternate director if his appointer for any reason ceases to be a Director or if and when his appointer returns to Pakistan, or if the appointee is removed from office by notice in writing under the hand of the appointer. An alternative director may resign as such upon giving thirty (30) days prior notice to the Board to this effect.

CHIEF EXECUTIVE

66 Appointment of the Chief Executive

(1) The Board shall, within fifteen (15) days of the incorporation of the Company, appoint, subject to the provisions of Section 198 of the Ordinance, any person including a Director as the Chief Executive of the Company. The first Chief Executive shall hold office until the first Annual General Meeting of the Company (unless he earlier resigns or otherwise ceases to hold office). If the Chief Executive ceases to hold office before the first Annual General Meeting, the Board shall fill the vacancy within fourteen (14) days, but the person so appointed to fill the vacancy shall hold office only until the first Annual General Meeting.

(2) Within fourteen (14) days from the date of an election of Directors or the date the office of Chief Executive becomes vacant, as the case may be, the Board shall appoint, subject to the provisions of Section 198 of the Ordinance, the Chief Executive of the Company, but such appointment shall not be for a period exceeding three (3) years from the date of such appointment.

(3) Upon the expiry of the terms of appointment under (a) or (b) above, the Chief Executive shall be eligible for reappointment.

(4) The Chief Executive shall be appointed on such terms and conditions including remuneration (whether by way of salary, commission, participation in profits, allowances, perquisites, etc.; or partly in one way and partly in another) as the Board shall fix.

67 Powers of Chief Executive

The Board may delegate to the Chief Executive such of its powers, authorities and discretion as are necessary for and consistent with the effective management of the Company, and as are not required to be exercised by the Directors at their meetings, subject to the supervision of the Board and upon such terms and conditions and with such restrictions as they may think fit, and either collaterally with or to the exclusion of their own powers.

68 Without prejudice to the general powers conferred above and to any other powers or authorities conferred by these Articles on the Chief Executive, and subject to the provisions of Section 196 of the Ordinance, subject to the limit fixed by the Directors, the Chief Executive may from time to time raise or borrow any sums for and on behalf of the Company from other companies, banks or financial institutions on such terms as may be approved by the Directors from time to time.

69 Remuneration of Chief Executive

Chief Executive shall receive such remuneration as the Directors may determine and it may be made a term of his appointment that he be paid a pension and/or gratuity and/or other benefits on retirement from his office.

OFFICIAL SEAL

70 Official Seal

The Board shall provide a Seal for the purposes of the Company and shall provide for the safe custody of the Seal. The Seal shall never be used except by the authority of the Board or a committee of Directors previously given, and two Directors at least shall sign every instrument to which the Seal is affixed: provided, nevertheless, that any instrument bearing the Seal of the Company and issued for valuable consideration shall be binding on the Company notwithstanding any irregularity.

DIVIDENDS AND RESERVES

71 Declaration of Dividends

The Company in General Meeting may declare Dividends, but no Dividend declared shall exceed the amount recommended by the Board.

72 Interim Dividends

The Board may from time to time pay to the Members such interim Dividends as appear to be justified by the profits of the Company.

73 Dividends Payable out of Profits

No Dividend shall be paid otherwise than out of profits of the year or any other undistributed profits and in the determination of the profits available for Dividends the Boards shall have regard to the provisions of the Ordinance and in particular to the provisions of Section 83, 235, and 248 of the Ordinance.

74 Distribution of Dividends

The profits distributed as Dividends shall be declared and paid according to amounts paid on the shares and the number of shares themselves.

75 Right to Dividends and Apportionment

76 Subject to the rights of persons (if any) entitled to shares with special rights as to Dividends, all Dividends shall be declared and paid according to the amounts paid on the shares, but if and so long as nothing is paid upon any of the shares in the Company, Dividends may be declared and paid accordingly to the amounts of the shares. No amount paid on a share in advance of calls shall be treated for the purposes of this provision as paid on the share. **Time for Payment of Dividend**

All Dividends shall be paid within thirty days of the declaration in accordance with the Section 251 of the Ordinance.

77 Receipts for Dividends by Joint Holders

If several persons are registered as joint holders of any share, any one of them may give effectual receipts for any Dividends payable on the shares.

78 No Interest on Dividends

No Dividend shall bear interest or mark-up against the Company. The Dividends shall be paid within the period laid down in the Ordinance.

79 Reserves

The Directors may, before recommending any Dividends, set aside out of the profits of the Company, such sums as they think proper as a reserve or reserves, which shall, at the discretion of the Directors, be applicable for meeting contingencies, or for equalizing Dividends, or for any other purpose to which the profits of the Company may be properly applied, and pending such application may, at the like discretion, either be employed in the business of the Company or be invested in such investments (other than shares of the Company) as the Directors, subject to the provisions of the Ordinance, may from time to time think fit.

80 Carrying Forward of Profits

The Directors may carry forward any profits, which they may think prudent not to distribute, without setting them aside as a reserve.

81 Unclaimed Dividends

Subject to compliance with Section 251 of the Ordinance, unclaimed Dividends may be invested or otherwise used by the Board for the benefit of the Company until claimed.

CAPITALIZATION OF PROFITS

82 Power to Capitalize

The Company in General Meeting may upon the recommendation of the Boards resolve that it is desirable to capitalize any part of the amount for the time being standing to the credit of any of the Company's reserve accounts or to the credit of the profit and loss account or otherwise available for distribution, and accordingly that such sum be set free for distribution amongst the Members who would be entitled thereto if distributed by way of Dividend and in the same proportions on condition that the same be not paid in cash but be applied either in or towards paying up any amounts for the time being unpaid on any shares held by such Members respectively or paying in full un-issued shares or Debentures of the Company to be allotted and distributed / credited as fully paid up to and amongst such Members in the proportion aforesaid, or partly in the one way and partly in the other and the Boards shall give effect to such resolution; provided that a share premium account may, for the purposes of these Articles, only be applied in paying up of unissued shares to be allotted to Members as fully paid bonus shares.

83 Effect of Resolution to Capitalize

Whenever such a resolution as aforesaid shall have been passed, the Boards shall make all appropriations and applications of the undivided profits resolved to be capitalized thereby, and all allotments and issues of fully paid shares or Debentures, if any, and generally shall do all acts and things required to give effect thereto, with full power to the Boards to make such provision by payment in cash or otherwise as they think fit for the case of share or Debentures becoming distributable in fractions and also to authorize any person to enter on behalf of all the Members entitled thereto into an agreement with the Company providing for the allotment to them respectively, credited as fully paid up, of any further shares or Debentures to which they may be entitled upon such capitalization, or (as the case may require) for the payment up by the Company on their behalf by the application thereto of their respective proportions of the profits resolved to be capitalized of the amounts or any part of the amounts remaining unpaid on their existing shares and any agreement made under such authority shall be effective and binding on all such Members.

ACCOUNTS

84 Books of Account to be Kept

The Board shall cause to be kept proper books of account as required under Section 230 of the Ordinance.

85 Where to be Kept

The books of account shall be kept at the Registered Office or at such other place as the Board think fit and shall be open to inspection by the Directors during business hours.

86 Profit and Loss Account and Balance Sheet

As required by Section 233 and 236 of the Ordinance, within eighteen (18) Months of the incorporation of the Company, and subsequently once at least in every year, the Directors shall cause to be prepared and laid before the Company in Annual General Meeting a balance sheet and profit and loss account, both made up in accordance with the Ordinance and to a date not more than four (4) months before the date of the General Meeting. Every such balance sheet and profit and loss account shall be accompanied by an auditor's certificate and the Directors' report, in accordance with the provisions of the Ordinance in that behalf.

87 Copies of Directors' Report and Balance Sheet to be Sent to the Members

A copy of the report of the Directors and of the balance sheet (including a report of the Auditors and every document required by law to be annexed thereto), and of the profit and loss account shall be sent to all Members along with the notice convening the General Meeting before which the same are required to be laid at least twenty-one (21) days preceding the General Meeting.

88 Directors to Comply with the Ordinance

The Directors shall in all respect comply with the provisions of Section 230 to 247 of the Ordinance.

Company Registration Office Lahore * Securities and *

AUDIT

89 Appointment of Auditors and Their Duties

Auditors shall be appointed and their duties regulated in accordance with Section 252 to 255 of the Ordinance.

NOTICE

90 How Notices to be Served

A notice may be given by the Company to any Member or Director either personally or by sending it to him by mail, postage prepaid, or by facsimile, at his registered address, or if he has no registered address in Pakistan, to the address supplied to the Company for the giving of notices to him. Notwithstanding the foregoing, notices to Members and Directors that are located outside Pakistan may be sent by facsimile.

91 Personal Delivery of Notice

Where a notice is delivered personally, the recipient shall sign a receipt in such form as the Board shall determine.

92 Service by Post

Where a notice is sent by post, service of the notice shall be deemed to be effected by properly addressing prepaying and posting a letter containing the notice and, unless the contrary is proved, to have been effected at the time at which the letter would be delivered in the ordinary course of post.

93 Notice to Joint Holders

A notice may be given by the Company to the joint holders of a share by giving the notice to the joint holder named first in the register in respect of the share, and a notice so given shall be sufficient notice in the ordinary course of post.

94 Notice of General Meetings

Notice of every General Meeting shall be given in the same manner herein authorized to (a) every Member and also to (b) every person entitled to a share in consequence of the death or insolvency of a Member, who but for his death or insolvency would be entitled to receive notice of the General Meeting, and (c) to the auditors of the Company for the time being.

SECRECY

95 Secrecy

Every Director, Chairman, Chief Executive, general manager, auditor, trustee, officer, servant, agent, accountant or other person employed in the business of the Company shall, if so required by the Board before entering upon his duties, sign a declaration in the form approved by the Board pledging himself to observe strict secrecy representing all transactions of the Company with the customers and the state of accounts with individuals and in matters relating thereto, and shall by declaration pledge himself not to reveal an of the matters which may come to his knowledge in the discharge of his duties except when required so to do by any law for the time being in force, the Board, or by any General Meeting, or by a court of law, and except so far as may be necessary in order to comply with any provisions in these presents contained.

96 Restrictions on Inspection of Books of Account of Company or on Entering Into Property of Company

Save as otherwise provided by the Ordinance, no Member or other person (not being a Director) shall be entitled to enter the premises or property of the Company, or inspect any account or books of account or document of the Company or properties of the Company, without permission of the Chief Executive or the Board, and to require disclosure of any information respecting any detail of the Company's trading, or any matter which is or may be in the nature of a trade secret, mystery of trade, or secret to the conduct of the business of the Company and which in the opinion of the Board will be in expedient in the interest of the Company to communicate.

WINDING UP

97 Distribution of Assets on Winding Up

We, the several persons, whose names and address are subscribed below, are desirous of being formed into a Company in pursuance of this Articles of Association, and we respectively agree to take the number of shares into the capital of the Company set opposite our respective names.

Names & Surname In Full	**Father's Name in Full**	**Nationality with any Former Nationality**	**Occupation**	**Residential Address in Full**	**No. of shares Taken by each Subscriber**	**Signature**
Zhong Cheng Xin International Limited (represented by Mr. Yao Yousheng, holding Chinese passport PE0110835)	N/A	Hong Kong, China	Corporation	Suite 1304, Great Eagle Centre, 23 Harbour Road, Wanchai, Hong Kong	6,998 (six thousand, nine hundred and ninety-eight)	
Zhong Zhuo Yue International Limited (represented by Ms. Ning Yi, holding Chinese passport PE0638548)	N/A	Hong Kong, China	Corporation	Suite 1304, Great Eagle Centre, 23 Harbour Road, Wanchai, Hong Kong	3,000 (three thousand)	
Wang Bo (Chinese Passport P01292673)	Wang Deben	Chinese	Services	Room 1201, The Fourth Floor, 12 Building, Nanhuali Community, Xicheng District, Beijing City, P.R. China	1(one)	

Geng Jialing (Chinese passport P01465163)	Geng Chuande	Chinese	Services	7-1-702, Shahu Colony, No.315, Xudong Avenue, Wuhan, Hubei Province, P.R. China	1(one)	
				Total Number of Shares	10,000 (ten thousand)	

Company Registration Office Lahore ★ Securities and Exchange Commission of Pakistan ★

Dated: The 14th day of August 2015.

Witness to above signatures:

Signature:

Herman

Full Name: So Hau Man Herman

NIC Number: Hong Kong SAR Passport No. K02863341

Father's Name: So Wai Keung

Occupation: Trainee Solicitor

Full Address: Flat 1C, Merlin Court , 6 Marigold Road, Yau Yat Chuen, Kowloon, Hong Kong

CERTIFIED TO BE TRUE COPY

REGISTRAR OF COMPANIES

31/3/17

Part B-Financial Proposals

Matiari-Lahore ±660kV HVDC Transmission Line project is a ±660 kV HVDC Bipole Transmission Line, which is approximately 878 km in length, with Design Transmission Capability of 4,000 MW from Matiari to Lahore on Built Own Operate and Transfer (BOOT) basis.

This project intends to adopt project financing mode and the IRR of 17% is guaranteed under CPEC Cooperation agreement. As per Pakistan transmission policy, capital investment of project financing mode shall be no less than 20%. Therefore, the proposed project investment a total of USD1.658 billion is consist of a debt to equity structure of 80 : 20.

Overseas investment company of State Grid of China, State Grid International Engineering Limited, will provide about USD332 million as the equity through 2 Special Purpose Vehicles.

Project Financing	Percentage	USD in million
Equity	20%	332
Debt	80%	1326
Total	100%	1658

China Development Bank has been appointed to provide financing of USD1.326 billion as the debt on the provision of Sinosure insurance coverage, accounting for 80% of the total investment. CDB has offered preliminary financing conditions as follow, interest rate at 6 months LIBOR+4.5%(whereas in case of local financing,interest rate is 6 month KIBOR with a spread of 3%) which was approved by determination dated November 24th 2016 read with determination dated August 18th 2016 in Case# NEPRA/TRF-351/PPIB-2016 and may be adjusted according to the Financing Agreements,the lender up-front fee at 1%, commitment fee not higher than 0.2% and repayment period of 10 years plus 36 months grace period.In case, the spread on LIBOR/KIBOR is negotiated by ITC at lower than 450/300 basis points respectively, the benefit of such reduction in rate will be adjusted in proportion of 40% to ITC and 60% to the consumer through necessary adjustment in tariff at COD.

As per Determination by NEPRA dated Nov. 24, 2016, total financial charges including the cost related to the debt financing of the project will be adjusted at COD on the basis of actual, up to a maximum of 3% of the total debt allowed (excluding the impact of interest during construction, Sinosure fees and financial charges).Also, the Interest during Construction (IDC) will be adjusted at COD on the basis of actual debt composition, variation in PKR/USD, debt drawdown (not exceeding the amount allowed by NEPRA) and applicable 6-months LIBOR/KIBOR during the project construction period allowed by the NEPRA.

Exhibit-XIV -The type, technology, model, technical details and design of the facilities proposed to be acquired, constructed, developed or installed

Please refer to Exhibit- X III,Part A

Exhibit-XV - Territorial map of the service area proposed to be covered

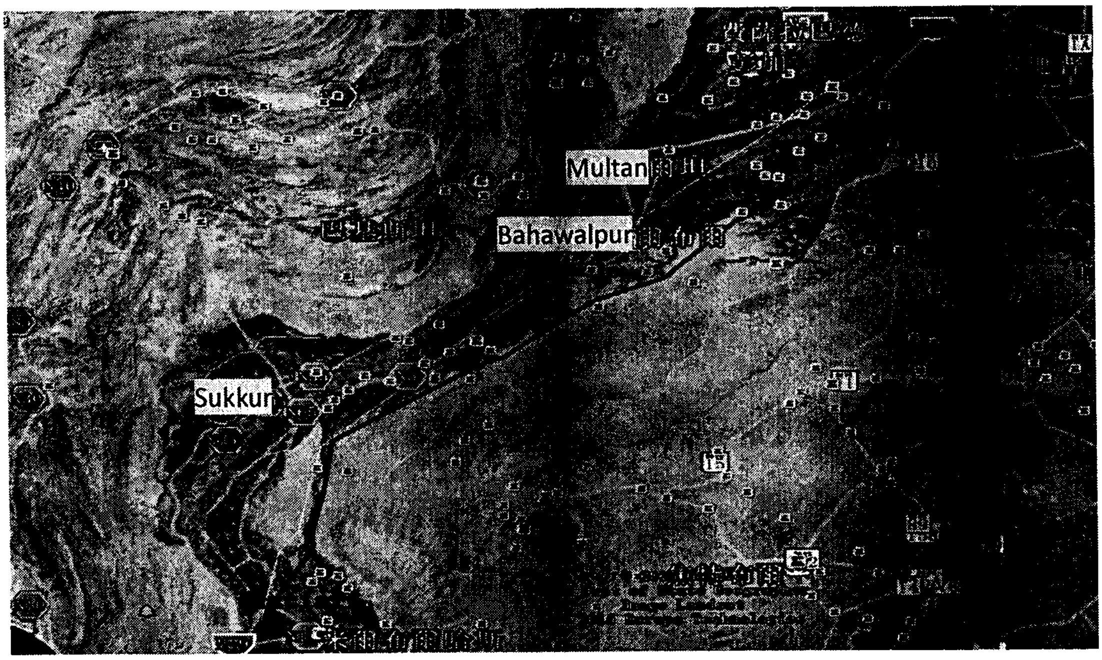


Exhibit-X VI - Particulars in respect of the availability, sources, rates and evidence of commitments from the sources of electric power

TO BE PROVIDED BY NTDC

Exhibit-X VII - Feasibility report in respect of the project

ATTCHED

Exhibit-X VIII - Prospectus

To promote development of coal and electricity base at the south of Pakistan and meet increasing need for electricity in Lahore, it is planned to construct the ±660kV HVDC Project from Matiari to Lahore.

The ±660kV HVDC Project from Matiari to Lahore is planned to be completed and put into operation around 2019 with a capacity of 4000MW. The line extends about 878km from Matiari of Sindh Province to Lahore of Punjab Province.

The project is the first HVDC transmission project in Pakistan. It will be constructed by State Grid Corporation of China with the BOOT mode and have a commercial operation period of 25 years.

Exhibit-X IX - Schedule III

Please Note: The following information is based on the Feasibility report in respect of the project and may be revised and adjusted according to the change of actual condition from time to time.

1.Purpose

In order to promote the development coal power base in the south of Pakistan, and satisfy the increase of electrical load in Lahore area, the Matiari~Lahore ±660kV DC power transmission line is planned to be constructed. The beginning point of the line is Matiari in Sindh province and the terminal point is Lahore in Punjab province, the length of the power transmission line is about 878km.

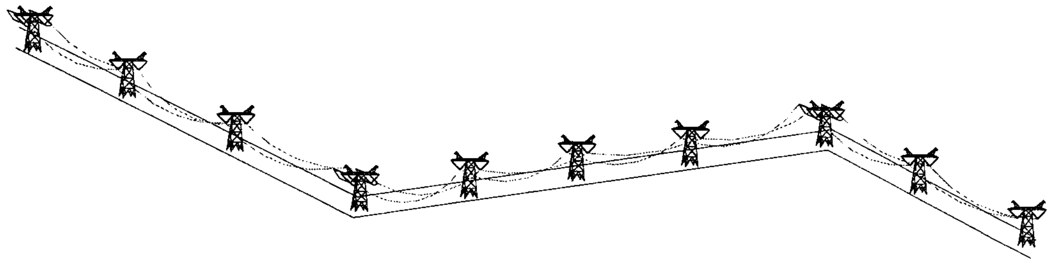
2.Line route and territory maps

The Matiari-Lahore ±660kV HVDC transmission line starts at Matiari converter station about 38km northeast to Hyderabad and ends at Lahore converter station about 40 km southwest of Lahore City. The line goes from southwest to northeast and crosses Sindh and Punjab, measuring 810km in aviation line. The length determined at feasibility study stage (the recommended route) is 878km, with a buckling factor of 1.08. The altitude ranges from 20 to 200m along the line.

The Land Route of the transmission line is as follows:

The line corridor width is controlled by the electromagnetic environment, the demolition line and the wind deflection distance. The corridor is shown below.

Schematic diagram of the transmission line corridor



3.Line lengths, starting point, termination point, year of completion

Line lengths： 878 kilometers
Starting point: Matiari converter station about 38km northeast to Hyderabad
Termination point: Lahore converter station about 40 km southwest of Lahore City
Year of completion:27 months after Construction Start Date

4.System studies

1- Power Flow Contingency Analysis of the Year 2018
2- Security and Stability Study
3- Access System Design of Matiari Converter Station
4- Access System Design of Lahore Converter Station
5- Study of System Short Circuit Characteristics
6- Study of Reactive Power Compensation of Converter

5.ESSA

The proposed T/L and Converter Stations will not cause potentially significant environmental and social adverse impacts on the local environment after the implementation of mitigation measures. Considering the current electricity situation and the efforts being made by the Government to generate electricity in Thar, T/L to dispatch the generated Power to the upcountry is a prerequisite. It is suggested that the proposed T/L should be implemented as soon as possible after all necessary approvals, design provisions and the implementation of EMMP and LARP.

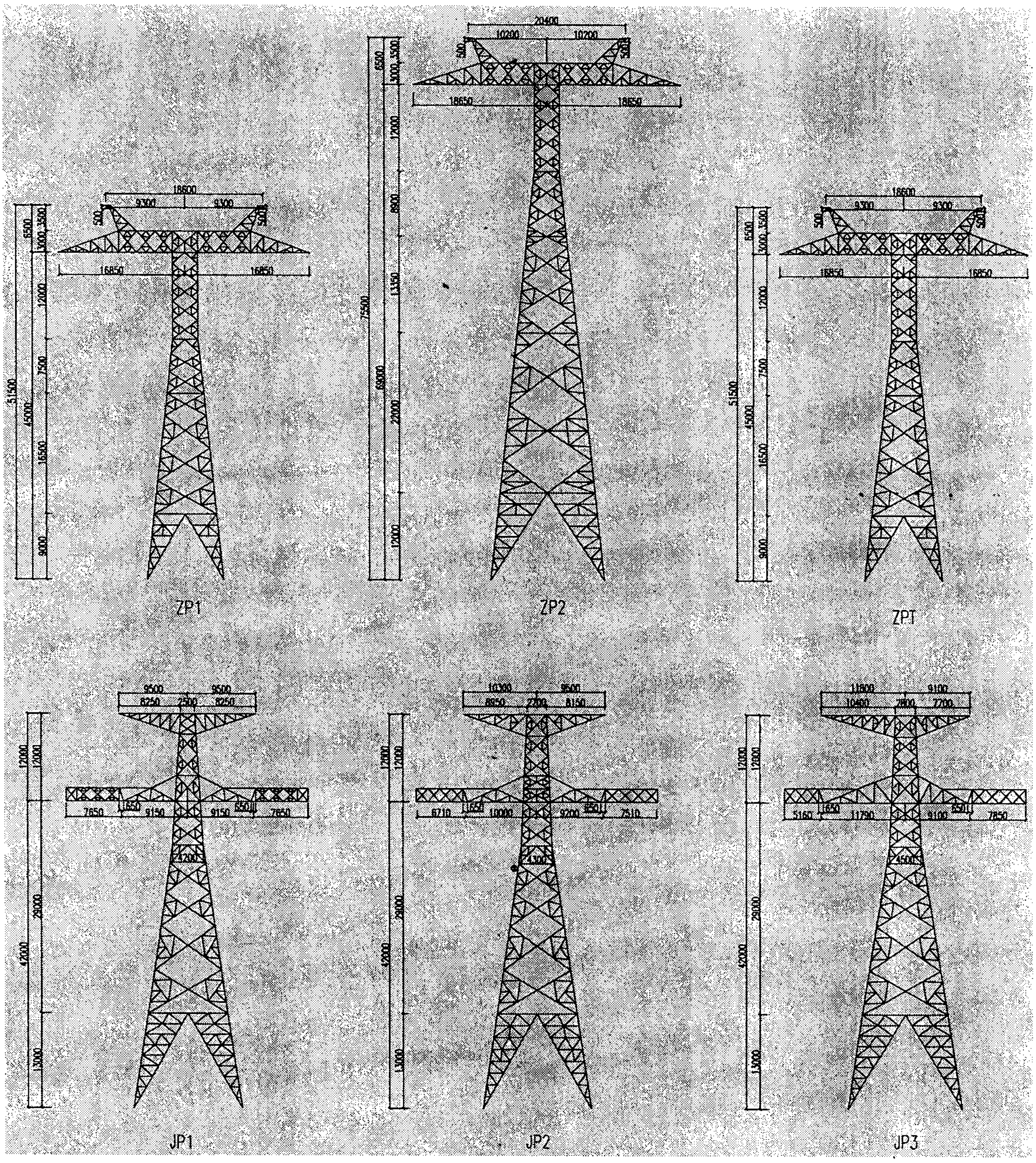
Please refer to HVDC ± 660 KV TRANSMISSION LINE FROM MATIARI TO LAHORE Environmental Impact Assessment (EIA) Report for more details.

6.Structures: type, number/km

Tower family

Tower pattern	Angle	Wind span (m)	Weight span (m)	Range of Nominal height (m)	Basic Nominal height (m)

ZP1	0-2°	480	600	33-51	42
ZP2	0°	580	750	54-75	69
ZPT	0-2°	480	600	33-51	42
JP1	0-20°	450	650	27-42	42
JP2	20-40°	450	650	27-42	42
JP3	40-60°	450	650	27-42	42



Outlines of tower

7.Line characteristics

The Matiari-Lahore ± 660kV HVDC transmission line starts at Matiari converter station about 38km northeast to Hyderabad and ends at Lahore converter station approximately 40km southwest of Lahore. The line goes from southwest to northeast and crosses Sindh and Punjab, measuring 810km in aviation line. The length determined at feasibility study stage (the recommended route) is 878km, with a buckling factor of 1.08. The altitude ranges from 20 to 200m along the line.

The line corridor is mainly flat terrain, including flat ground of 342km (38.9%), and desert of 496km (56.5%), swamp of 40km(4.6%). The highest temperature is 52.5°C, the lowest temperature -5°C, the 3-sec gust wind speed at 10m above ground is 160km/h(44.44m/s), the corresponding 10-minute average wind speed at 10 meters above ground is 31.1m/s.The corridor goes through ice-free areas.

According to the feasibility study, the following are recommended: conductor uses 4×JL1/G3A-1250/70 and 4×JL1/LHA1-800/550;both2 shield wires use 24-fiber OPGW-120;towers use lattice steel self-supported type (1977 towers, 2.25 towers/km), including 257 tension towers (13%), 1720 suspension towers (87 %).

8.Conductor, type, current carrying capacity, circuit power transfer

The conductor type is: 4×JL1/G3A-1250/70 and 4×JL1/LHA1-800/550-54/37
Current carrying capability is :3030A.
Circuit power transfer: 4000MW.

9.Insulators

Conductor suspension string:
300kN composite insulator single string V type suspension string
420kN composite insulator single string V type suspension string
300kN composite insulator double string V type suspension string
Conductor tension string ：
Triple string 420kN disc type insulator string
Double string 210kN disc type insulator string
Jumper string
Double string 160kN V-type string cage type hard jumper insulator
Ground wire string
Single string 120kN hardware string

10.Shield-wire: number, size

Size：24 core OPGW-15-120-2
Number：2

11.Compensation employed: series, Shunt, SVC

Matiari CS:
According to calculations, the total capacity of capacitive reactive power compensation of Matiari converter station is taken as 2610 Mvar provisionally. The reactive power compensation capacitors are divided into 4 banks and subdivided into 16 sub-banks. Each sub-bank has a capacity of 150 Mvar to 180 Mvar (there are two sub-bank sizes: the low capacity size is 150 Mvar, and the high capacity size is not greater than 180 Mvar).

It is recommended that at least one 500kV power source in the vicinity be started

when the DC system is put into operation.
The final division of sub-banks should be determined by further studies according to the actual conditions including switching level, system harmonics, and the arrangement of converter station.
As for inductive reactive power compensation, in this phase, 4 banks of low-voltage reactors are provided on the 35 kV low-voltage side of Matiari converter station preliminarily, each bank with a capacity of 60 Mvar. These reactors should be of outdoor dry-type air-core design. In the actual engineering design, the configuration of low-voltage reactors should be further optimized according to the actual condition of the low-voltage bus of converter station.

Lahore CS:
According to calculations, the total capacity of capacitive reactive power compensation of Lahore converter station is taken as 2480 Mvar provisionally. The reactive power compensation capacitors are divided into 4 banks and subdivided into 16 sub-banks. Each sub-bank has a capacity of 150 Mvar to 160 Mvar (there are two sub-bank sizes: the low capacity size is 150 Mvar, and the high capacity size is not greater than 160 Mvar).
The final division of sub-banks should be determined by further studies according to the actual conditions including switching level, system harmonics, and the arrangement of converter station.
As for inductive reactive power compensation, in this phase, 3 banks of low-voltage reactors are provided on the 35 kV low-voltage side of Lahore converter station preliminarily, each bank with a capacity of 60 Mvar and each phase with a capacity of 20 Mvar. These reactors should be of outdoor dry-type air-core design. In the actual engineering design, the configuration of low-voltage reactors should be further optimized according to the actual condition of the low-voltage bus of converter station.

12.Communication system: PLC, fibre optics, microwave

The system communication design of this project mainly includes DC fiber-optic communication, DC power line carrier communication, relevant channel organization, communication equipment configuration in converter stations, etc.

13.Grid station(s) involved: number, existing/new and details of the following:

- Scope, size, number of transmission circuits, in and out

Matiari CS:
The long-term targets for Matiari converter station include 12 AC 500 kV outgoing lines, 4 banks of AC filters (hereinafter referred to as "ACF"), and 2 banks of converter transformers, i.e., totally 18 elements, which constitute 8 complete strings and 2 incomplete strings. Either of the two buses will be connected with one 500/35 kV step-down transformer. All of the long-termed planned 12 outgoing lines will be provided with high-voltage reactors, except the Jamshoro double lines and Moro line. The converter transformers are provided with AC PLC at their line incoming points

provisionally.
In the current phase, 8 outgoing lines (1 to Dadu New,2 to Jamshoro, 1 to Moro, 2 to Hubco New power station, 2 to Qasim power station, and 2 to Thar power station), 4 banks of ACFs, and 2 banks of converter transformers will be built. A total of 16 elements will be incorporated into the strings, constituting 7 complete strings and 2 incomplete strings. Each of the two buses will be connected with one 500/35 kV step-down transformer. All the outgoing lines will be provided with outgoing disconnectors. All of the outgoing lines will be provided with high-voltage reactors, except the Jamshoro double lines and Moro line.

Lahore CS:
The long-term targets for Lahore converter station are the same as the current target.
In the current phase, 6 outgoing lines (2 to Lahore North Substation, 2 to Lahore South Substation, and 2 to Lahore Substation), 4 banks of ACFs, and 2 banks of converter transformers will be built. A total of 12 elements will be incorporated into the strings, constituting 6 complete strings. Each of the two buses will be connected with one 500/35 kV step-down transformer. All the incoming and outgoing lines will be provided with outgoing disconnectors. The converter transformers are provided with AC PLC at their line incoming points provisionally.

- Type:

outdoor, transformation/switching

- Arrangement scheme:

breaker and a half, double bus

- Basic insulation level: kV

AC:500kV
DC:660kV

- Control and protection system

(1)HVDC control system

In addition to basic control of various operation modes, the HVDC control system includes various basic controllers and limiters, and is capable of maintaining the controlled signals such as DC power, DC current, DC voltage and converter firing angle within the steady state limits of primary DC equipment. The control system also has the ability to suppress transient overcurrent and overvoltage, and to recover steadily within the specified response time after AC or DC system failures.
The HVDC control system will be of a hierarchical distributed architecture. With the purpose of assigning control functions to the lowest possible layer, the HVDC control system is divided into the following by function: double-pole control layer, pole control layer and converter valve control layer.

The sampling units, data bus, master device to control port, should be fully in duplicated configuration.

(2) HVDC protection system

The HVDC protection system is arranged based on protection zones. The protection system of the converter station is divided into the following seven protection zones: AC filter/shunt capacitor protection zone, converter transformer protection zone, converter protection zone, DC line protection zone, DC filter protection zone, DC switchyard protection zone, and DC earth electrode line protection zone. Each protection zone and adjacent protection zone are overlapped to ensure that there is no dead zone. Triple redundant protection will be used for the HVDC system.
Among them, the DC filter protection and converter transformer protection will be provided by the pole protection; three sets of electrical quantity protection and non electrical quantity protection will be provided for each pole; duplicated protection will be provided for the AC filters based.
DC protection of the two poles are completely separate. HVDC protection and DC control systems will be relatively independent, both in redundancy.

- Specification of equipment:

breakers-type,re-closing mechanism,duty cycle,isolators,transformers-type, size, cooling system,tap-change,protection

- Lightening arresters, shunt reactors, metering and instrumentation

The details for above two items as follows:
Matiari CS:
The main AC equipment used in this project is summarized as follows:
Table 1: Selection of main AC equipment

No.	Equipment Description	Main Parameters and Type Selection
I	500 kV AC switchgear	
1	Circuit breaker	550kV 4000A 63kA(3s) 160kA, with closing resistor[1] Circuit breaker failure protection, automatic reclosing
2	Current transformer	500kV 2×2000/1A
3	500kV vertical break disconnector with single earth switch	550kV 3150A 63kA(3s) 160kA
4	500kV disconnector, with single stationary contact and single earth switch	550kV 3150A 63kA(3s) 160kA , dual-column, horizontal type
5	500kV disconnector, with double stationary contacts and triple earth switches	550kV 3150A 63kA(3s) 160kA , three-column, horizontal type

No.	Equipment Description	Main Parameters and Type Selection
6	Maintenance earth switch	550kV 63kA(3s) 160kA
7	500kV capacitive voltage transformer (three-phase, used on the incoming line, bus, and outgoing line of converter transformer)	500kV/√3/0.1/√3/0.1/√3/0.1/√3/0.1kV
8	500kV metal-oxide surge arrester	Y20W
9	500kV shunt reactor	550/√3kV, 50Mvar 550/√3kV, 40Mvar 550/√3kV, 34Mvar,over current protection,restricted earth fault protection
10	Neutral-point reactor of 500kV shunt reactor	66kV, ~500 (+10% to 10%)Ω
II	AC filter switchgear	
1	500kV AC filter/capacitor bank	Rated capacity: 150Mvar Rated capacity: 180Mvar
2	Porcelain knob type circuit breaker for the incoming line of capacitor bank	Dual-break, 550kV, 3150A, 63kA/3s, 160kA
3	Current transformer for the incoming line of capacitor bank	500kV, 1000/1A
4	Vertical break disconnector for the incoming line of capacitor bank	550kV, 3150A, 63kA/3s, 160kA, with single earth switch
5	Earth switch for the incoming line of capacitor bank	550kV, 63kA/3s 160kA
6	500kV metal oxide surge arrester	Y20W
7	500kV capacitive voltage transformer	500/√3/0.1/√3/0.1/√3/0.1/√3/0.1kV
8	Earth switch for 500kV bus	550kV, 63kA/3s 160kA
III	Station service system	
1	500kV three-phase oil-immersed transformer	SFP-130000/500, 525±2x2.5%/35kV, non-exciting regulation, differential protection,over current protection
2	132kV three-phase oil-immersed transformer	8MVA, 132±2x2.5%/11.5kV, ONAN, YN,d11, non-exciting regulation
3	132kV SF6 circuit breaker	145kV 1600A 40kA 100kA
4	500kV circuit breaker	550kV 4000A, 63kA(3s), 160kA

No.	Equipment Description	Main Parameters and Type Selection
5	500kV horizontal break disconnector with single earth switch	550kV 3150A 63kA/3s 160kA
6	132kV disconnector	145kV 1600A 40kA 100kA, dual-column, horizontally opening, single earth switch
7	500kV earth switch	500kV, 63kA (3s) 160kA
8	132kV disconnector	145kV 1600A 40kA 100kA, dual-column, horizontally opening, double earth switches
9	500kV current transformer	500kV 2×2000/1A
10	132kV current transformer	132kV
11	500kV metal oxide surge arrester	Y20W
12	132kV surge arrester	132kV
13	500kV capacitive voltage transformer	500kV
14	132kV capacitive voltage transformer	132kV
15	35kV three-phase two-winding non-exiting regulation transformer	8MVA, 35/11.5kV
16	40.5kV circuit breaker	40.5kV, 2500A; 40kA; 100kA
17	40.5kV circuit breaker	40.5kV, 2000A; 40kA; 100kA
18	35kV current transformer	35kV, routine outdoor type
19	35kV voltage transformer	35kV, 35/√3: 0.1/√3: 0.1/√3:0.1/3kV
20	Dual-column horizontally-rotation disconnector	(1) 40.5kV, 2500A; 40kA; 100kA; with double earth switches (2) 40.5kV, 2000A; 40kA; 100kA; with single earth switch (3) 40.5kV, 2000A,: 40kA; 100kA; with double earth switches

The main DC equipment used in this project is summarized as follows:

Table 2: Selection of main DC equipment

No.	Equipment Description	Main Parameters and Type Selection
1	Dry-type smoothing reactor for pole line	680kV, 3030A, 75mH
2	Dry-type smoothing reactor for neutral line	150kV,3030A, 75mH
3	680kV DC disconnector	3030A
4	DC high-speed switch NBGS	3030A, including circuit breaker, capacitor bank, reactor, and arrester

No.	Equipment Description	Main Parameters and Type Selection
5	DC high-speed switch NBS	3030A, including circuit breaker, capacitor bank, reactor, and arrester
6	Metallic return transfer breaker (MRTB).	3030A, including circuit breaker, capacitor bank, reactor, arrester, disconnector, and earth switch
7	Ground return transfer switch (GRTS)	3030A, including circuit breaker, capacitor bank, reactor, arrester, disconnector, and earth switch
8	DC current measuring devices	680kV, optical current transformer, with optical connectors and photoelectron equipment
9	DC voltage measuring devices	680kV
10	DC pole bus arrester	680kV
11	Smoothing reactor arrester	680kV
12	12th/24th DC filter	Including C1-high-voltage capacitor, high-voltage capacitor imbalance CT, L1-high-voltage reactor, L2-neutral point reactor, T3-reactor L2 branch CT, T4-CT on the neutral point side, F3-arresters on both ends of L1, F1-arrester on the high-voltage end of L1, C2 low-voltage capacitor, F2-arresters on both ends of L2, etc.
13	6th/42th DC filter	Including C1-high-voltage capacitor, high-voltage capacitor imbalance CT, L1-high-voltage reactor, L2-neutral point reactor, T3-reactor L2 branch CT, T4-CT on the neutral point side, F3-arresters on both ends of L1, F1-arrester on the high-voltage end of L1, C2 low-voltage capacitor, F2-arresters on both ends of L2, etc.
14	Other equipment on DC side	Including high-voltage and low-voltage post insulators, low-voltage disconnector/earth switch, DC neutral bus impulse capacitor, PLC reactor, capacitor, etc.

Lahore CS:

The main AC equipment used in this project is summarized as follows:

Table 3: Selection of main AC equipment

No.	Equipment Description	Main Parameters and Type Selection
I	500 kV AC switchgear	
1	Circuit breaker	550kV 4000A 63kA(3s) 160kA, with closing resistor[1]
2	Current transformer	500kV 2x2000/1A

No.	Equipment Description	Main Parameters and Type Selection
3	500kV vertical break disconnector with single earth switch	550kV 3150A 63kA(3s) 160kA
4	500kV disconnector, with single stationary contact and single earth switch	550kV 3150A 63kA(3s) 160kA, dual-column, horizontal type
5	500kV disconnector, with double stationary contacts and triple earth switches	550kV 3150A 63kA(3s) 160kA , three-column, horizontal type
6	Maintenance earth switch	550kV 63kA(3s) 160kA
7	500kV capacitive voltage transformer	500/√3/0.1/√3/0.1/√3/0.1/√3/0.1kV
8	500kV metal-oxide surge arrester	Y20W
II	AC filter switchgear	
1	500kV AC filter/capacitor bank	Rated capacity: 150Mvar Rated capacity: 160Mvar
2	Porcelain knob type circuit breaker for the incoming line of capacitor bank	550kV 3150A 63kA/3s 160kA , Dual-break
3	Current transformer for the incoming line of capacitor bank	500kV 1000/1A
4	Vertical break disconnector for the incoming line of capacitor bank	550kV 3150A 63kA/3s 160kA, with single earth switch
5	Earth switch for the incoming line of capacitor bank	550kV 63kA/3s 160kA
6	500kV metal oxide surge arrester	Y20W
7	500kV capacitive voltage transformer	500/√3/0.1/√3/0.1/√3/0.1/√3/0.1kV
8	Earth switch for 500kV bus	550kV 63kA/3s 160kA
III	Station service system	
1	500kV three-phase oil-immersed transformer	SFP-130000/500 510±2×2.5%/35kV, non-exciting regulation
2	132kV three-phase oil-immersed transformer	8MVA 132±2×2.5%/11.5kV ONAN , non-exciting regulation
3	132kV SF6 circuit breaker	145kV 1600A 40kA 100kA
4	500kV circuit breaker	550kV 4000A 63kA/3s 160kA

No.	Equipment Description	Main Parameters and Type Selection
5	500kV horizontal break disconnector with single earth switch	550kV 3150A 63kA/3s 160kA
6	132kV disconnector	145kV 3150A 40kA 100kA, dual-column, horizontally opening, single earth switch
7	500kV earth switch	500kV 63kA/3s 160kA
8	132kV disconnector	145kV 1600A 40kA 100kA,dual-column, horizontally opening, double earth switches
9	500kV current transformer	500kV 2x2000/1A
10	132kV current transformer	132kV 800/1A
11	500kV metal oxide surge arrester	Y20W
12	132kV surge arrester	132kV
13	132kV capacitive voltage transformer	132/√3/0.1/√3/0.1/√3/0.1/√3/0.1kV
14	35kV three-phase two-winding non-exiting regulation transformer	8MVA 35/11.5kV
15	40.5kV circuit breaker	40.5kV 2000A 40kA 100kA
16	35kV current transformer	35kV, routine outdoor type
17	35kV voltage transformer	35/√3/0.1/√3/0.1/√3/0.1/√3/0.1kV
18	Dual-column horizontally-rotation disconnector	(1) 40.5kV, 2000A; 40kA; 100kA;with double earth switches; (2) 40.5kV, 2000A; 40kA; 100kA; with single earth switch

The main DC equipment used in this project is summarized as follows:

Table 4: Selection of main DC equipment

No.	Equipment Description	Main Parameters and Type Selection
1	Dry-type smoothing reactor for pole line	680kV, 3030A, 75mH
2	Dry-type smoothing reactor for neutral line	150kV,3030A, 75mH
3	680kV DC disconnector	3030A
4	DC high-speed switch NBGS	3030A, including circuit breaker, capacitor bank, reactor, and arrester
5	DC high-speed switch NBS	3030A, including circuit breaker, capacitor bank, reactor, and arrester
6	DC current measuring devices	680kV ,Optical current transformer, with optical connectors and photoelectron equipment
7	DC voltage measuring devices	680kV

No.	Equipment Description	Main Parameters and Type Selection
8	DC pole bus arrester	680kV
9	Smoothing reactor arrester	680kV
10	12th/24th DC filter	Including C1-high-voltage capacitor, high-voltage capacitor imbalance CT, L1-high-voltage reactor, L2-neutral point reactor, T3-reactor L2 branch CT, T4-CT on the neutral point side, F3-arresters on both ends of L1, F1-arrester on the high-voltage end of L1, C2 low-voltage capacitor, F2-arresters on both ends of L2, etc.
11	6th/42th DC filter	Including C1-high-voltage capacitor, high-voltage capacitor imbalance CT, L1-high-voltage reactor, L2-neutral point reactor, T3-reactor L2 branch CT, T4-CT on the neutral point side, F3-arresters on both ends of L1, F1-arrester on the high-voltage end of L1, C2 low-voltage capacitor, F2-arresters on both ends of L2, etc.
12	Other equipment on DC side	Including high-voltage and low-voltage post insulators, low-voltage disconnector/earth switch, low-voltage current/voltage measure device, DC neutral bus impulse capacitor, PLC reactor, capacitor, power line carrier equipment,etc.

- SCADA and communication

The SCADA information shall satisfy the following principles:
(1) Complete telecontrol information should be collected in a timely manner to fully reflect the operating conditions of the power grid.
(2) Information collection shall meet the needs of all levels of dispatch centers for hierarchical management and independent accounting.
(3) Information collection shall meet the requirements of power grid security monitoring and advanced application functions.
(4) The SCADA information shall be directly collected and transmitted to NPCC in real-time.
The converter station will be designed on a manned basis. The computer monitoring and control system will be of object-oriented design. Through full use of computer technology, modern control technology, network communications technology and graphics technology, an integrated automation system of control, measurement, telecontrol and modern comprehensive management. The computer monitoring and control system will be of modular, hierarchical distributed network architecture. The operators may use the HMI in the control room to monitor, control and record all the equipment in the converter station, and send related information to control centers through remote communications devices.

Communication system

System Dispatch Exchange

One system dispatch and station administrative exchange will be provided for Matiari Converter Station and Lahore Converter Station respectively. The exchange can be connected to the private power dispatch exchange network via 2Mbit/s and E&M digital interface, thereby realizing communication with the dispatch center(NPCC).

Communication Power Supply

Two sets of communication power supply will be provided in duplicate configuration for both Matiari and Lahore Converter Stations, each including two sets of high frequency switching communication DC power supply equipment, two DC distribution panels, and two maintenance-free battery banks.

NATIONAL TRANSMISSION & DESPATCH COMPANY (NTDC) LIMITED PAKISTAN

FEASIBILITY STUDY

FOR

±660kV HVDC PROJECT

FROM MATIARI TO LAHORE IN PAKISTAN

VOLUME I

GENERAL REPORT

Pak Matiari-Lahore Transmission Company (Private) Limited

January 2017, Beijing, P.R. China

±660kV HVDC PROJECT
FROM MATIARI TO LAHORE IN PAKISTAN
GENERAL LIST OF CONTENTS

TECHNICAL DEFINITIONS

The following technical definitions apply to this Specification:

Purchaser	National Transmission And Dispatch Company Limited (NTDC)
Company	The project company for development, investment, construction, operation and maintenance of the ±660kV HVDC project from Matiari to Lahore in Pakistan.
HVDC System	All of the relevant equipments and systems in bipolar operation, including converter transformers, converter valves, DC yard equipment, AC filter, control& protection system, DC transmission line, electrode and electrode line, etc.
HVDC Project	HVDC System and the relevant construction works in this project. the relevant construction works including outlet and inlet line of converter station, buildings and structures, related auxiliary production facilities and living facilities.
M-L T/L	Matiari-Lahore Transmission Line
AC yard	AC switchgear area in converter station
DC yard	DC switchgear area in converter station
Life yard	Living facilities and part of auxiliary production facilities area in converter station
T area	Transformer area
M-E T/L	Matiari Electrode Grounding Transmission Line
M E/G	Matiari Electrode Grounding
L-E T/L	Lahore Electrode Grounding Transmission Line
L E/G	Lahore Electrode Grounding
M C/S	Matiari Converter Station
L C/S	Lahore Converter Station
M AC busbar	Matiari AC busbar
L AC busbar	Lahore AC busbar
M AC system	Matiari AC system
L AC system	Lahore AC system

P I	Pole I
P II	Pole II

The following abbreviations apply to this Specification:

AC	Alternating Current
ACI	American Concrete Institute
A/D	Analog to Digital
AN	Audible Noise
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing Material
BIL	Basic Impulse Insulation Level
BS	British Standard
BSL	Basic Switching Impulse Insulation Level
CB	Control Building
CCITT	International Consultative Committee on Telephone and Telegraph Systems
CT	Current Transformer
CTV	Capacitive Voltage Transformer
D/A	Digital to Analog
DC	Direct Current
DIN	Deutsches Institute fur Normung
EEI	Edison Electric Institute
EIA	Environmental Impact Assessment
ESCR	Effective Short Circuit Ratio
ESDD	Equivalent Salt Deposit Density
FAT	Factory Acceptance Tests
HF	High Frequency
HVDC	High Voltage Direct Current
IEC	International Electrotechnical Commission

IEEE	Institute of Electrical and Electronics Engineers
I/O	Input/Output
ISO	International Standards Organization
LED	Light Emitting Diode
MMI	Man Machine Interface
MVU	Multiple Valve Unit
NFPA	National Fire Protection Association
OPGW	Optical Fiber Composite Overhead Ground Wire
P&C	Protection and Control
PLC	Power-line Carrier
PT	Potential Transformer
RF	Radio Frequency
RI	Radio Interference
RIV	Radio Interference Voltage
RTU	Remote Terminal Unit
RPC	Reactive Power Controls
SCADA	Supervisory Control and Data Acquisition
SER	Sequence of Events Recorder
SLG	Single Line to Ground Fault
SMC	Station Master Clock
SPC	Software Production Control
SWC	Surge Withstand Capability
TFR	Transient Fault Recorder
UPS	Uninterruptible Power Supply
VDT	Video Display Terminal
VDU	Video Display Unit
VF	Voice Frequency
VT	Voltage Transformer

VOLUME Ⅰ CONTENTS

1. General

1.1 Project Overview

To promote development of coal and electricity base at the south of Pakistan and meet increasing need for electricity in Lahore, it is planned to construct the ±660kV HVDC Project from Matiari to Lahore.

The ±660kV HVDC Project from Matiari to Lahore is planned to be completed and put into operation around 2019 with a capacity of 4000MW. The line extends about 878km from Matiari of Sindh Province to Lahore of Punjab Province.

The project is the first HVDC transmission project in Pakistan. It will be constructed by State Grid Corporation of China with the BOOT mode and have a commercial operation period of 25 years.

1.2 Design Basis

1.2.1 National Power System Expansion Plan 2011-2030, Main Report, Canada SNC-Lavalin International Corporation, Pakistan National Technology Service Company, 2011

1.2.2 State of Industry Report 2013, Pakistan National Electric Power Regulatory Authority (NEPRA)

1.2.3 The Feasibility Study Report of HVDC/HVAC 1300km Long Transmission Line from Karachi to Up-country for Dispersal of 2500-3000MW Power from Imported Coal Based Power Project, Canada SNC-Lavalin International Corporation, Pakistan National Technology Service Company, 2013

1.2.4 NEPRA Grid Code

1.2.5 Transmission Services Agreement

1.2.6 Minutes of meeting signed between China and Pakistan

1.2.7 ±660kV HVDC Transmission Line From Matiari to Lahore Environment Impact Assessment (EIA) Report.

1.2.8 ±660kV HVDC Transmission Line From Matiari to Lahore Initial Poverty and Social Analysis (IPSA) Report.

1.2.9 Laws, regulations, specifications and codes of Pakistan

1.3 Technical Standard

The engineering, construction, operation and maintenance of the HVDC Transmission Project will be performed according to: (i) IEC and/or IEEE for the AC portion of the HVDC Transmission Project; and(ii) the IEC, IEEE, or the Chinese

Standards for the DC portion of the HVDC Transmission Project.

1.4 Design condition

1.4.1 Environmental Conditions

1.4.1.1 Climatic Data

Table 1.4-1 Environmental Climatic Data

	Matiari		Lahore	
	Data	Remark	Data	Remark
a) Temperature (˚C)				
max. dry bulb temperature	52.5	201506MOM 150701Cheema	52.5	201506MOM 150701Cheema
min. dry bulb temperature	-5		-5	
average year temperature	27.7	Hyderabad weather station	25	
average month temperature of the hottest month	34	Hyderabad weather station	33.6	Lahore weather station
10% wet bulb temperature	29.6	Hyderabad weather station	28.2	Lahore weather station
b) Air pressure (Hpa)				
average year air pressure	1001.2	Hyderabad weather station	983.1	Lahore weather station
c) Relative humidity				
average relative humidity (%)	58.8	Hyderabad weather station	63	Lahore weather station
min. relative humidity (%)	23.3	Hyderabad weather station	24.5	Lahore weather station
d) Wind direction and velocity				
average wind velocity (m/s)	5.6 (3s) 3.9 (10min)	Hyderabad weather station	1.6 (3s) 1.1 (10min)	Lahore weather station

	Matiari		Lahore	
	Data	Remark	Data	Remark
average maximun wind speed (within 50 years 10 minute measured at 10m height maximum wind speed, m/s)	31.1	20150303MOM	31.1	20150303MOM
prevailing direction	S	Hyderabad weather station	NW	Lahore weather station
e) Precipitation (mm)				
normal for year	171.8	Hyderabad weather station	679.7	Lahore weather station
max. monthly				
max. 24 hours	153.0	Hyderabad weather station	274	Lahore weather station
f)others				
icing	0	20150303MOM	0	20150303MOM
percentage of sunshine(%)	70		66	
Sunshine intensity（kW/m^2）	0.7	NASA data	0.7	NASA data

1.4.1.2 Thunderstorm Days

Table 1.4-2 Thunderstorm Days at Converter Station

	Matiari	Lahore
average thunderstorm days/year	8	32
maximum thunderstorm days/year	18	

1.4.1.3 Seismic Conditions

Table 1.4-3 Seismic Conditions at Converter Station

	Matiari	Lahore
Seismic intensity	7 degree（0.14g）	7 degree（0.14g）

1.4.1.4 Altitude

Table 1.4-4 Altitude of Converter Station

	Matiari	Lahore
approximate elevation above sea level (m)	25	195

1.4.1.5 Recommended values for air pollution and external insulation

N.A.

1.4.2 Data of AC System

Currently, the highest voltage of Pakistan's transmission network is 500 kV, and it has formed a main frame structure covering main regions in Pakistan, which consists of 2-4 south-north 500 kV lines used to transmit power to load centers of Punjab and Islamabad and a ring network in load centers. Pakistan's national grid is divided into two parts by power transmission region: one is operated by NTDC and the other by KESC Industrial Park.

The main grid of NTDC operates at 500 kV and 220 kV while the grid of local distribution company operates at 132kV and 66kV which is transferring to 132kV preliminarily. Up to the end of 2014, Pakistan's grid has 12 500 kV substations with a total capacity of 15,750 MVA, 29 220 kV substations with a total capacity of 18,231 MVA, 5144 km 500 kV lines, and 8358 km 220 kV lines.

According to geographical locations, local distribution companies of Pakistan include IESCO, LESCO, GEPCO, FESCO, and MEPCO in Punjab and Islamabad, SEPCO, HESCO and KESC Industrial Park in Sindh and Karachi, QESCO in Balochistan, PESCO and TESCO in the north.

1.4.2.1 Connection of Matiari Converter Station

AC side of the Matiari converter station is at 500 kV voltage, and is π-connected to Jamshoro-Moro and Jamshoro-Dadu New 500 kV power line. The associated thermal power projects are collected to the converter station at 500 kV. There will be ten incoming lines leading to the converter station at the first stage, with two from Jamshoro, one from Moro, one from Dadu New, and six from the associated power sources.

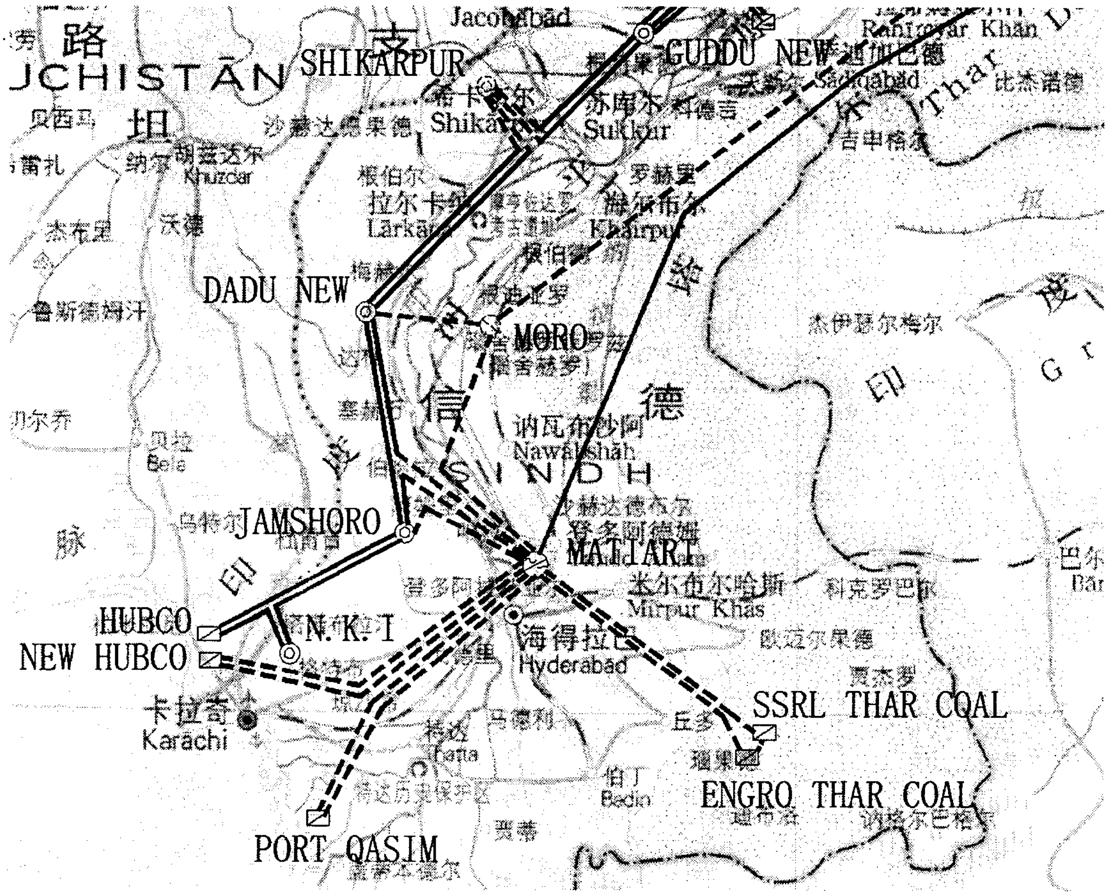


Figure 1.4-1 Grid Connection of M C/S

1.4.2.2 Connection of Lahore Converter Station

AC side of the Lahore converter station is at 500 kV voltage, and is π-connected to the Lahore-Lahore South 500 kV double-circuit line. Also, a 500 kV Lahore North substation, and Lahore-Lahore North-Gakkhar 500 kV double-circuit line need to be built. There will be six outgoing lines led from the converter station, two to Lahore, Lahore South, and Lahore North each.

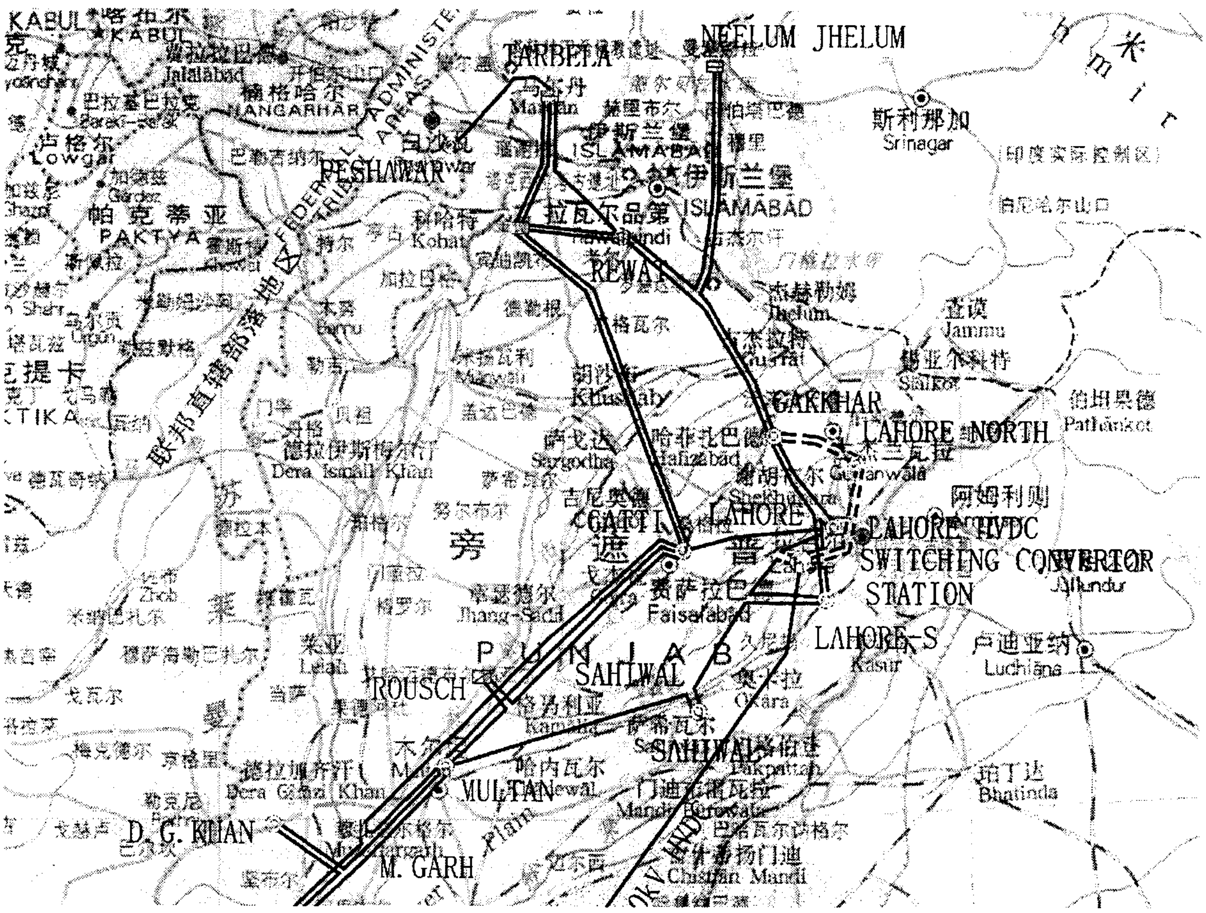


Figure 1.4-2 Grid Connection of L C/S

1.4.2.3 Normal and Extreme Voltage Range of Converter Station AC Buses

The normal operating voltage of the Matiari converter station AC bus is recommended to be 500kV, the normal continuous operating voltage range will be from 475 to 540kV, the voltage variation generally remains 505~525kV and the extreme continuous operating voltage range is from 450 to 550kV.

The normal operating voltage of the Lahore converter station AC bus is recommended to be 500kV, the normal continuous operating voltage range will be from 475 to 530kV, the voltage variation generally remains 490~510kV and the extreme continuous operating voltage range is from 450 to 550kV.

1.4.2.4 Normal and Post-Disturbed Frequency Variation

The normal frequency variation of the Matiari converter station AC bus is within the range of 50± 0.1Hz, the post distribution frequency variation is within the range of 49.4~50.5Hz, and the frequency after fault clearance is within the range of 50±0.2Hz.

The normal frequency variation of the Lahore converter station AC bus is within the range of 50±0.1Hz, the post distribution frequency variation is within the range of 49.5~50.5Hz, and the frequency after fault clearance is within the range of 50±0.2Hz.

1.4.3 DC Transmission Line

Location: from Matiari Converter Station, Hyderabad to Lahore Converter Station, Lahore.

Rated voltage:	±660 kV
Number of transmission line:	Single Circuit
Rated current:	3030A
Transmission line length:	878km

1.5 Conclusions

1.5.1 Primary System

1.5.1.1 Project Necessity

(1) Accommodate power demands of load centers in Pakistan;

(2) Optimize resource allocation across the country;

(3) Enable power evacuation from southern Pakistan.

1.5.1.2 Transmission Scheme

It is recommended to adopt ±660kV/4000MW HVDC transmission scheme characterized by: (1) Satisfying the requirement on transmitting capacity of this Project, requirements of medium- and long-term grid planning of Pakistan, and south-north power transmission requirements; (2) Isolating disturbance between sending- and receiving-end systems, and facilitating control of short-circuit current level of Pakistan's grid; (3) Controlling project cost, and achieving good project and economic benefits by using construction contractor's rich design, construction, and O&M experience.

1.5.1.3 Connection of Converter Station to System

(1) Connection of Sending-End Convertor Station

AC side of the sending-end converter station is at 500 kV voltage, and is π-connected to Jamshoro-Moro 500 kV power line. 2×10 km new lines are required. Thermal power units are connected to the convertor station at the voltage of 500 kV. There are 10 outgoing lines led from the sending-end convertor station, 1 to Dadu New, 2 to Jamshoro, 1 to Moro and 6 to power stations.

(2) Connection of Receiving-end Converter Station

AC side of the receiving-end converter station is at 500 kV voltage, and is π-connected to the Lahore-Lahore South 500 kV double-circuit line, for which 2×1 km and 2×10 km new lines are required. Also, a 500 kV Lahore North substation, and receiving-end-Lahore North-Gakkhar 500 kV double-circuit line (around 2×110 km) need to be built. There are six outgoing lines led from the receiving-end converter station, two to Lahore, two to Lahore South, and two to Lahore North.

1.5.2 Secondary System

See Volume II-2 for details.

1.5.3 Converter Station

1.5.3.1 Overview of Site Selection of Sending-end Converter Station

(1) Siting Process

In August 2014, China Electric Power Equipment and Technology Co., Ltd. (CET) carried out site survey for the convertor station site and selected three sites for preliminary feasibility study.

In March 2015, personnel from Pakistan and CET carried out investigation and survey for three sites, among which one was suggested by personnel from Pakistan and the other two were proposed sites for preliminary feasibility study. Finally, the site suggested by personnel from Pakistan was determined as the candidate for feasibility study, and the two parties carried out on-the-spot investigation.

(2) Main Technical Schemes

The converter adopts bipolar wiring scheme with one 12-pulse valve group per pole and 6-pulse midpoint grounded via arrester. The converted power, rated DC voltage, and rated DC current is 4000 MW, ±660 kV, and 3030 A respectively. The converter valves are air-insulated, forced water-cooled 5-inch thyristor valves which are implemented in suspended double-valve structure.

There are 12 single-phase dual-winding converter transformers in service and two standby converter transformers (one YNy0-connected transformer and one YNd11-connected transformer) at the Matiari converter station. The line-side bushings of single-phase dual-winding converter transformers are YN-connected on the line side and then directly connected to the AC system, the valve-side bushings are Y- or d-connected in the valve hall and then connected to the valve tower. The three-phase wiring groups of converter transformer are YNy0 and YNd11 respectively. The converter transformers are oil-immersed single-phase dual-winding OLTC transformers.

The long-term targets for Matiari converter station include 12 AC 500 kV outgoing lines, 4 banks of AC filters (hereinafter referred to as "ACF"), and 2 banks of converter transformers, i.e., totally 18 elements, which constitute 8 complete strings and 2 incomplete strings. Either of the two buss will be connected with one 500/35 kV step-down transformer. All of the long-termed planned 12 outgoing circuits will be provided with high-voltage reactors, except the Jamshoro double lines and Moro line. The converter transformers are provided with AC PLC at their line incoming points provisionally.

In this phase, 10 outgoing circuits (1 to Dadu New, 2 to Jamshoro, 1 to Moro, 2 to Hubco New power station, 2 to Port Qasim power station, and 2 to Thar power station), 4 banks of ACFs, and 2 banks of converter transformers will be built. A total of 16 elements will be incorporated into the strings, constituting 7 complete strings and 2 incomplete strings. Either of the two buses will be connected with one 500/35 kV step-down transformer. All the outgoing lines will be provided with outgoing disconnectors. All of the 10 outgoing lines will be provided with high-voltage reactors, except the Jamshoro double lines and Moro line.

500 kV AC filter yard employs single-bus connection mode. There are four banks of 500 kV AC filters and parallel capacitors, which are subdivided into 16 sub-banks consisting of eight 150 Mvar sub-banks and eight 180 Mvar sub-banks. In this phase, 16 sub-bank circuit breakers are installed. The AC filters are of outdoor open type and arranged in a line. SF_6 live tank circuit breakers with the ability to break/make capacitive current are recommended.

The 35 kV AC switchyard employs single-bus connection mode. The switchgear is arranged outdoors. The Matiari converter station has two 35 kV buses, 4 banks of 60 Mvar low-voltage reactors, and two 35/11.5 kV auxiliary transformers.

Three circuits of auxiliary power supply are proposed for Matiari converter station; two circuits will be led through 35/11.5 kV auxiliary transformers on two 35 kV AC buses; the other circuit will be led from the from 132 kV transmission line near converter station. The specific power supply lines will be determined by Pakistan.

1.5.3.2 Overview of Site Selection of Receiving-end Converter Station

(1) Siting Process

In August 2014, CET carried out site survey for the convertor station site and selected three sites for preliminary feasibility study.

In March 2015, personnel from Pakistan and CET carried out investigation and survey for three sites, among which one was suggested by personnel from Pakistan and the other two were proposed sites for preliminary feasibility study. Finally, the site suggested by personnel from Pakistan was determined as the candidate for feasibility study, and the two parties carried out on-the-spot investigation.

In May 2015, CET indicated that the site suggested by NTDC is located at a low-lying place requiring high backfilling workloads. Therefore, CET hopes that an alternate site shall be proposed. After measuring the elevation of the other site suggested by NTDC and the alternate site proposed by CET, it is found that the elevation of the original site is relatively high. Therefore, it is still recommended to select the original site since NTDC insists on selection of the original site.

(2) Main Technical Schemes

The converter adopts bipolar connection scheme with one 12-pulse valve group per pole and 6-pulse midpoint grounded via arrester. The converted power, rated DC voltage, and rated DC current is 4000 MW, ±660 kV, and 3030 A respectively. The converter valves are air-insulated, forced water-cooled 5-inch thyristor valves which are implemented in suspended double-valve structure.

There are 12 single-phase dual-winding converter transformers in service and two standby converter transformers (one YNy0-connected transformer and one YNd11-connected transformer) at the Lahore converter station. The line-side bushings of single-phase dual-winding converter transformers are YN-connected on the line side and then directly connected to the AC system, the valve-side bushings are Y- or d-connected in the valve hall and then connected to the valve tower. The three-phase connection groups of converter transformer are YNy0 and YNd11 respectively. The converter transformers are oil-immersed single-phase dual-winding OLTC transformers.

3/2 circuit breaker connection method is used for 500kV AC side. The long-term targets of this converter station are the same as this phase. In this phase, there are 6 AC 500 kV outgoing lines (two to Lahore North, two to Lahore South, and two to Lahore), 4 AC filter banks and 2 converter transformer banks. There are 12 elements, which form 6 complete strings. Either of the two buses will be connected with one 500/35 kV step-down transformer. All outgoing lines will be provided with outgoing disconnectors. The converter transformers are provided with AC PLC at their line incoming points provisionally.

500 kV AC filter yard employs single-bus connection mode. There are four

banks of 500 kV AC filters and parallel capacitors, which are subdivided into 16 sub-banks consisting of eight 150 Mvar sub-banks and eight 160 Mvar sub-banks. In this phase, 16 sub-bank circuit breakers are installed. The AC filters are of outdoor open type and arranged in a line. SF_6 live tank circuit breakers with the ability to break/make capacitive current are recommended.

The 35 kV AC switchyard employs single-bus connection mode. The switchyard is arranged outdoors. The Lahore converter station has 2 35 kV buses, 3 banks of 60 Mvar low-voltage reactors, and two 35/11.5 kV auxiliary transformers.

Three circuits of auxiliary power supply are proposed for Lahore converter station; two circuits will be led through 35/11.5 kV auxiliary transformers on two 35 kV AC buses; the other circuit will be led from the 132kV transmission line nearby or the 132 kV bay within the SARFRAZ NAGAR 220 kV substation.

1.5.4 DC Transmission Line

The Matiari-Lahore ± 660kV HVDC transmission line starts at Matiari converter station about 38km northeast to Hyderabad and ends at Lahore converter station approximately 40km southwest of Lahore. The line goes from southwest to northeast and crosses Sindh and Punjab, measuring 810km in aviation line. The length determined at feasibility study stage (the recommended route) is 878km, with a buckling factor of 1.08. The altitude ranges from 20 to 200m along the line.

The line corridor is mainly flat terrain, including flat ground of 342km (38.9%), and desert of 496km (56.5%), swamp of 40km(4.6%). The highest temperature is 52.5°C, the lowest temperature -5°C, the 3-sec gust wind speed at 10m above ground is 160km/h(44.44m/s), the corresponding 10-minute average wind speed at 10 meters above ground is 31.1m/s.The corridor goes through ice-free areas.

According to the feasibility study, the following are recommended: conductor uses 4×JL1/G3A-1250/70 and 4×JL1X1/LHA1-800/550;both2 shield wires use 24-fiber OPGW-120;towers use lattice steel self-supported type (1977 towers, 2.25 towers/km), including 257 tension towers (13%), 1703 suspension towers (87%).

1.6 The HVAC system interconnection requirement

a) Interconnection with a total of 16 No. 500 kV circuits at both ends (10 circuits at Matiari and 6 circuits at Lahore) will be up and become operational no later than the COD time of Matiari - Lahore HVDC project.

b) If each of the Interconnection with a total of 16 No. 500 kV circuits at both ends hasn't become operational with the COD time of Matiari - Lahore HVDC project, it may cause significant impacts on the power grid.

c) In/Out of 3rd Jamshoro – Moro T/L and Jamshoro – Dadu New T/L at Matiari end provides essential condition for start-up of converter station, it should be completed and become operational no later than the COD time of Matiari - Lahore HVDC project.

d) If Lahore Switching/Converter station – Lahore (North)/ Gakkhar 500 kV D/C T/L is delayed by the Purchaser and the HVDC Transmission Project is not operated at full load (i.e. Design Transmission Capability 4000MW) due to this grid constraint. In that case, Section 5.4 of TSA will prevail.

e) Following the No. GMPP/CEMP/TRP-304/4996-5000 Sub: Looping In/out of Existing Jamshoro-Dadu New 500kV Circuit at Matiari dated Nov.25, 2015, the change of interconnection at Matiari end will affect the grouping variation of the reactive power compensation at Matiari converter station and the specific configurations of filter, so the configuration scheme of filter will be confirmed after the calculations.

f) In accordance with your letter on China Experts Group Report (F.No.2(24)/2015-IC dated Nov. 18, 2015), NTDC recommended the HVDC 4000MW ±660kV transmission line project with proposed HVAC reinforcement as the most viable option, THE COMPANY will be responsible to complete the Matiari - Lahore HVDC Project by BOOT model, however, the HVAC reinforcement project shall be established and completed by NTDC no later than the COD time of Matiari - Lahore HVDC project.

2. Power System Study

2.1 Overview of Power System

At present, Pakistan has transmission grids with the ceiling voltage of 500kV, and its main grid structure covers the main areas of the country with 2-4 circuit 500kV transmission channels from the south and north to the load centers with loop networks in Islamabad and Punjab. The State Grid of Pakistan is divided into NTDC and KESC Industrial Park in Karachi according to transmission areas.

NTDC has main grid structure with voltages of 500kV and 220kV, and local power distribution companies have grids of 132kV and 66kV, of which the 66kV is being transited to 132kV. At present, Pakistan has twelve 500kV substations with transformation capacity of 15750 MVA, twenty-nine 220kV substations with transformation capacity of 18230 MVA, and has 5,144km of 500kV line and 8,358km of 220kV line.

On the basis of geographical location, the local distribution companies of Pakistan include IESCO, LESCO, GEPCO, FESCO and MEPCO in Punjab and Islamabad, SEPCO and HESCO in Sindh and Karachi, KESC Industrial Park in Karachi, QESCO in Balochistan, PESCO and TESCO in the north of Pakistan.

As for the power consumption structure, residential electricity accounts for a largest proportion of about 45%; the proportion of industrial electricity takes second place with about 29%; and power consumption proportions for agriculture, business and other large users are about 11%, 8% and 7% respectively. Punjab and Islamabad consume most of the power, accounting for about 60% of the whole country while Sindh and Karachi for about 20%, and Balochistan and Khyber Pakhtunkhwa and its surrounding northern area for about 6% and 14% respectively. There forms the pattern that the hydropower in the north and the thermal power in the south are supplied to the middle area. The maximum load demand of power grid in Pakistan in 2014 is 23040 MW with actual maximum load of 18830 MW and installed capacity of 24110 MW, and the power utilization capacity is about 67%.

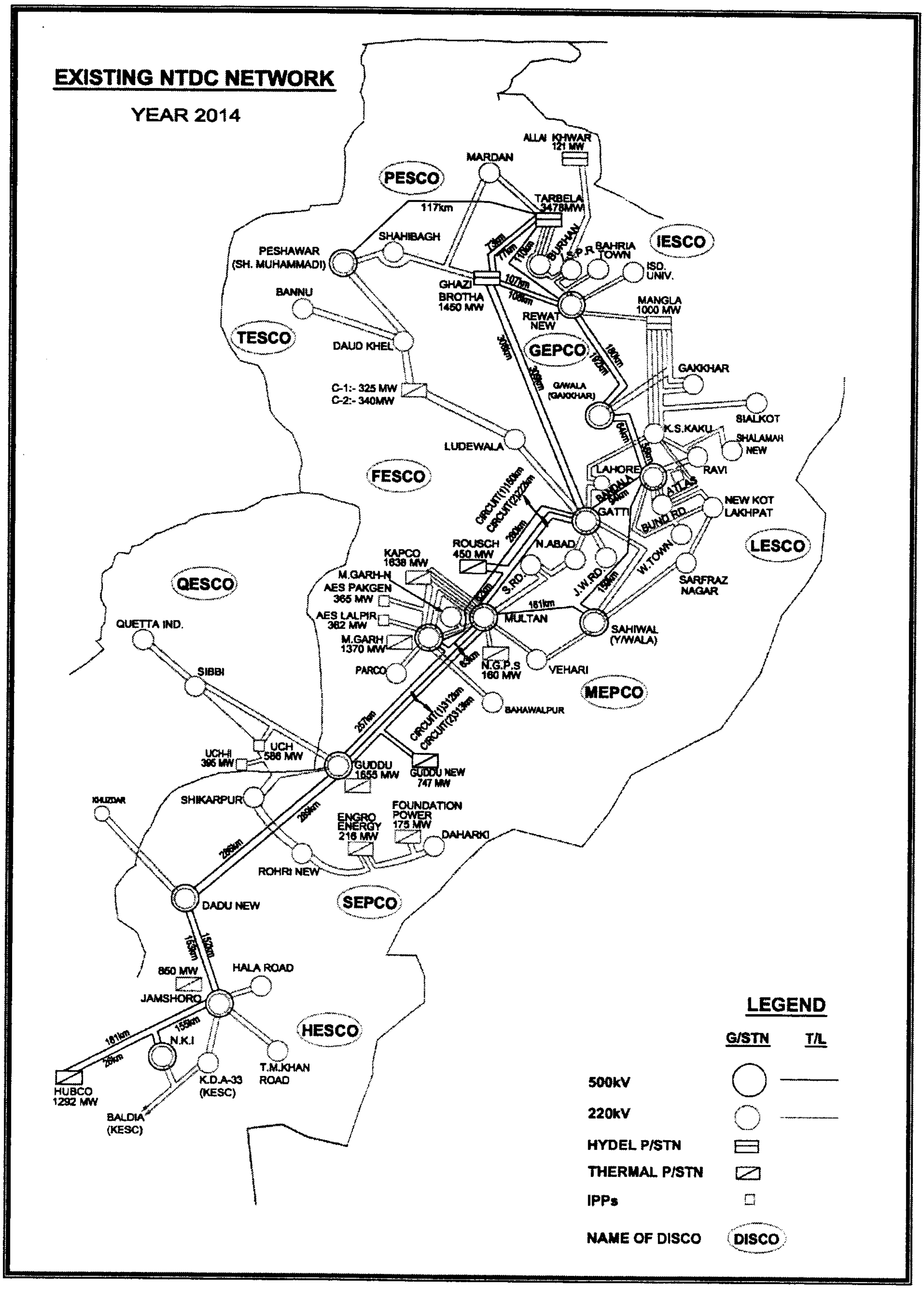


Figure 2.1-1: Geographic connection diagram of Pakistan's 220 kV and above power grids in 2014

2.2 Plan of Power System Development

Pakistan's national grid is divided into two load areas by power transmission region, one operated by NTDC and the other by KESC Industrial Park. According to the latest load prediction data provided by Pakistan, the maximum load of Pakistan's grid in 2017 and 2020 will be 26680 MW and 30820 MW respectively, and the average annual growth rate in 2015-2020 will be 4.9%.

The Project Team and China Communication Planning and Design Institute for Waterway implemented technical exchange on June 19, 2015, defined the power project scale and production sequence of CPEC, and considered the connection of production power plants and strengthening of supporting grid during the study of system scheme.

To promote the construction of CPEC and facilitate the social and economic development of Pakistan, the National Energy Administration implemented energy planning for CPEC in 2014, and the bilateral governments signed "Cooperation Agreement for the Energy Project of CPEC" in November 2014. 21 planned power projects will be put into operation before 2023 as per the agreement with total scale of 17705 MW, of which the thermal power for 13665 MW, hydraulic power for 2690 MW and new energy for 1350 MW; it includes priority project and promotion project.

The total installed capacity of priority projects is 10400 MW. The thermal power projects of 7560 MW are mainly located in Punjab and Sindh. The hydraulic power projects of 1590 MW are located in the north area. New energy projects of 1250 MW are mainly located in Punjab. The total installed capacity of promotion project is 7305 MW. Of which, the thermal power for 6105 MW, hydraulic power for 1100 MW and the new energy for 100MW.

A balancing study on Pakistan power shows that from 2017 to 2020, the power shortage of Pakistan will be 10100MW, 6000MW, 6620MW and 6890MW respectively and the shortage of Punjab and Islamabad will be 10490MW, 9810MW, 10760MW and 11160MW respectively.

According to the Pakistan's latest power grid planning, from 2015 to 2018, Matiari-Lahore Transmission Project is planned to meet load development and grid strengthening demands and to satisfy power gaps in load center in the middle and power delivery demands in the South; 3-circuit power transmission from South to the North 500kV transmission line is constructed (Jamshoro-Moro-R.Y.Khan);500kV power transmission and transformation projects such as South Lahore have been constructed; cooperate with CPEC power project and construct Shahiwal Power Plant and thermal power 500kV sending project in the South.

By 2023, as the operation of K-2 and K-3 nuclear power projects and planned thermal power projects, Matiari-Faisalabad 2-circuit power transmission project from South to North is planned to meet power delivery and load demands. Tajikistan-Peshawar DC and 500kV auxiliary project shall be constructed; 500kV substation such as Chakwal, Isd West and Ludewala will be constructed in load center of Punjab and Islamabad, receiving-end 500kV ring network structure power supply capacity will be improved. K2 and K3 nuclear power stations, Muzaffargarh, R.Y.Khan, Gaddani, Oracle and hydropower 500kV delivery project in the North will be constructed to cooperate with the CPEC power project.

60% load demands of Pakistan concentrates in Punjab and Islamabad in the middle part and energy resources are mainly in Sindh and Karachi in the South and power supply pattern of power transmission from South to North will be kept for a long time in Pakistan. According to the National Power System Expansion Plan 2011-2030 (2011), during 2020-2030, large-scale thermal power/nuclear power supply will be planned for southern part of Pakistan and installed capacity scale will be over 37000 MW. With continuous operation of large-scale power supply, the power delivery demands in the southern part of Pakistan will increase year by year. It is suggested to construct power transmission from 8-circuit 4000 MW DC to load center in the middle part by 2030 to meet long-term Pakistan load center power demands and power delivery demands in the South.

2.3 Project Necessity

It is necessary to construct the project for reasons below.

(1) accommodate power demands of load centers in Pakistan;

Power loads in Punjab and Islamabad account for about 60% of the national total; therefore, Punjab and Islamabad are the load centers and receiving-end system of the entire grid. Based on power balance and considering definite power sources, the power shortage of Punjab and Islamabad will be 10490 MW and 11160 MW respectively in 2017 and 2020. This Project will make it possible to transmit bulk power from southern Pakistan to load centers of Pakistan, satisfy load demands of Pakistan, especially Punjab and Islamabad, and provide guarantee for continuous and fast economic development.

(2) optimize resource allocation across the country;

The development of Pakistan's power industry at this stage focuses on satisfying the power demands of national economic and social development. As the energies and loads are distributed unevenly, to solve the power shortage problem of Pakistan, it is necessary to optimize the allocation of energy resources to the maximum extent possible by using platforms such as grid and transportation system, build multiple energy supply channels, and improve power safety and reliability. Therefore, the construction of this Project is the need of optimized allocation of energy resources and power supply for places lack of energies.

(3) enable power evacuation from south Pakistan.

Currently, the prominent problem of power shortage has significantly restricted the continuous and fast economic development of Pakistan. Since oil-fired and gas-fired power has been dominant in power mix for a long time, power generation cost is high, output is insufficient, and energy is highly dependent on foreign trade, greatly affecting the power generation efficiency and further deteriorating power shortage situations. Therefore, the power mix needs to be optimized. To mitigate this problem, Pakistan will build large fossil-fired power plants based on Thar coalfield in the south of Pakistan and large nuclear power plants in the south. The power projects are far away from the load centers; therefore, the construction of this Project is the need of long-distance transmission of power from southern Pakistan.

2.4 Study on Power Transmission Scheme

This section analyzes the transmission scheme of this Project based on medium- and long-term grid planning of Pakistan, distribution characteristics of power sources and loads, construction and operation of this Project, and grid operation situations.

Currently, the prominent problem of power shortage has significantly restricted the continuous and fast economic development of Pakistan. Since oil-fired and gas-fired power has been dominant in power mix for a long time, power generation cost is high, output is insufficient, and energy is highly dependent on foreign trade, greatly affecting the power generation efficiency and further deteriorating power shortage situations. Therefore, the power mix needs to be optimized. To guarantee medium- and long-term power supply, *2011-2030 Power Development Plan of Pakistan* (the Plan) makes an in-depth planning and research on medium- and long-term power development of Pakistan. According the Plan, during 2017-2030, Pakistan will build large fossil-fired power plants in the south based on large energy bases such as Thar coalfield and nuclear power plants with an expected installed capacity of more than 30000 MW. Pakistan plans to transmit bulk power from the south to load centers of Punjab and Islamabad in the north through six 4000 MW DC transmission lines. From the medium- and long-term grid planning of Pakistan, we can see that adopting DC transmission mode in this Project complies with relevant requirements and this Project is one of the important projects in grid planning.

Based on the load distribution of Pakistan and the latest load prediction data issued by Pakistan, the maximum load in Pakistan will be about 30820 MW, 44000 MW, and 65000 MW respectively in 2020, 2025, and 2030, and about 70% of the loads concentrate in Punjab and Islamabad in the north. The load in central Pakistan along Matiari-Lahore transmission line increases slowly, and therefore, there is no need to build power supply stations in the middle of Matiari-Lahore line. For this reason, from the view of distribution characteristics of loads and power sources in Pakistan, it is suitable to employ DC transmission mode in this Project.

From the view of safe and reliable operation of system, DC transmission mode can isolate disturbance between sending- and receiving-end systems because Pakistan's grid is weak and this Project is a long-distance transmission project with a large capacity. Besides, DC transmission mode is beneficial for control of short-circuit current level of Pakistan's grid because the DC system usually doesn't supply short-circuit current to the AC system. What's more, DC transmission mode allows for simply and clear interface between this Project and Pakistan's main grid, facilitating energy metering and definition of O&M responsibilities and creating good preconditions for international cooperation.

From the view of design, construction, and O&M of this Project, if DC transmission mode is used to transmit 4000 MW power over 1000 km, China's Ningdong-Shandong DC transmission project (660kV/4000MW/1300km) which has rich design, construction, and O&M experience and satisfactory technical and economic indicators can be used as a reference. Therefore, with reference to the successful experience in Ningdong-Shandong DC transmission project, ±660 kV DC voltage and 4000 MW transmitting capacity will contribute to smooth construction and operation of the Project.

In summary, it is recommended to adopt ±660kV/4000MW DC transmission scheme. It has the following advantages: (1) Satisfying the requirement on transmitting capacity of this Project, requirements of medium- and long-term grid planning of Pakistan, and south-north power transmission requirements; (2) Isolating disturbance between sending- and receiving-end systems, and facilitating control of short-circuit current level of Pakistan's grid; (3) Controlling project cost, and achieving good project and economic benefits by using construction contractor's rich design, construction, and O&M experience.

2.5 System Connection Scheme Study

2.5.1 Study on System Connection Scheme of Sending-end Converter Station

(1). Scheme of Sending-end Power Sources

The power grid in Sindh has two voltage classes, 500 kV and 220kV. Given that it is not suitable to connect 660 MW and above power plants to 220 kV grid, the power sources will be combined together at 500 kV voltage. In particular, two 500 kV outgoing lines are led from one power plant or two series-connected power plants.

Sending-end power source scheme: Hubco New is connected to the converter station via a 200 km long 500 kV double-circuit line, Port Qasim via a 180 km long 500 kV double-circuit line, and Engro and SSRL respectively via one 270 km long 500 kV one-circuit line. The latter two power sources are connected together via one 500 kV one-circuit line.

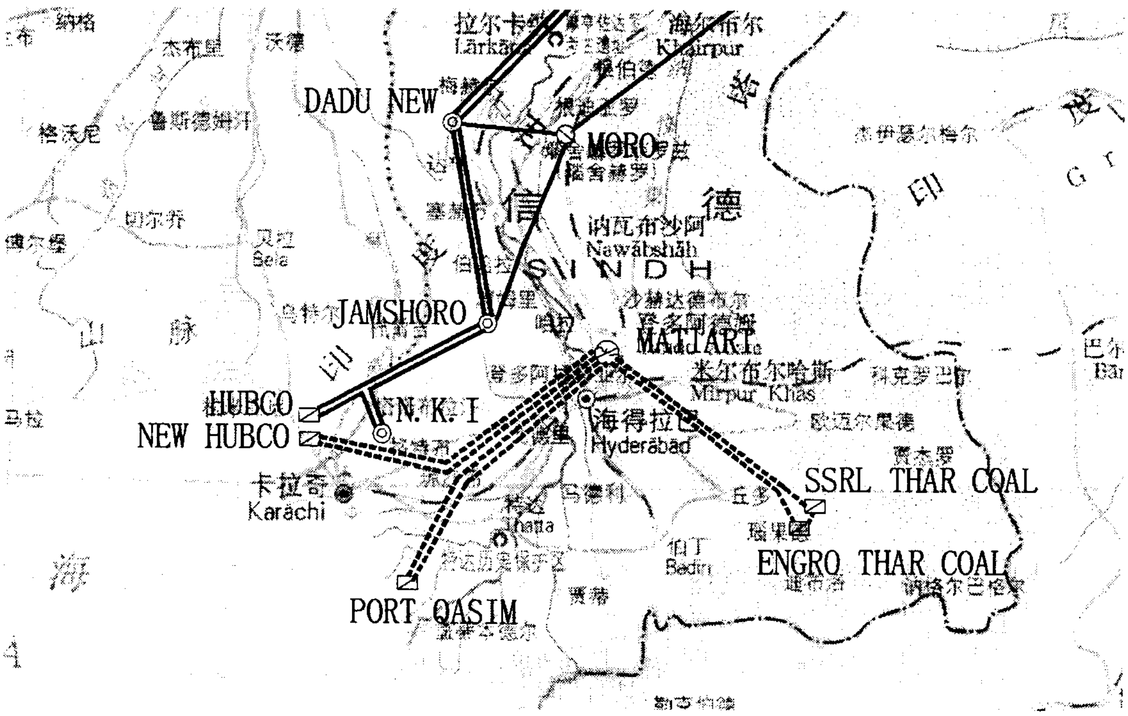


Figure 2.5-1: Sending-end power sources scheme

(2). System Connection Scheme of Sending-end Converter Station

With Matiari and its surrounding area as the sending end of the DC power link, the following connection scheme is proposed:

AC side of the sending-end converter station is at 500 kV voltage, and is π -connected to Jamshoro-Moro 500 kV power line. 2×10 km new lines are required. DC matching thermal power generating units with the voltage class of 500kV are connected into the convertor station. There will be ten incoming lines leading to the converter station, with two from Jamshoro, one from Moro, one from Dadu New, and six from the associated power sources.

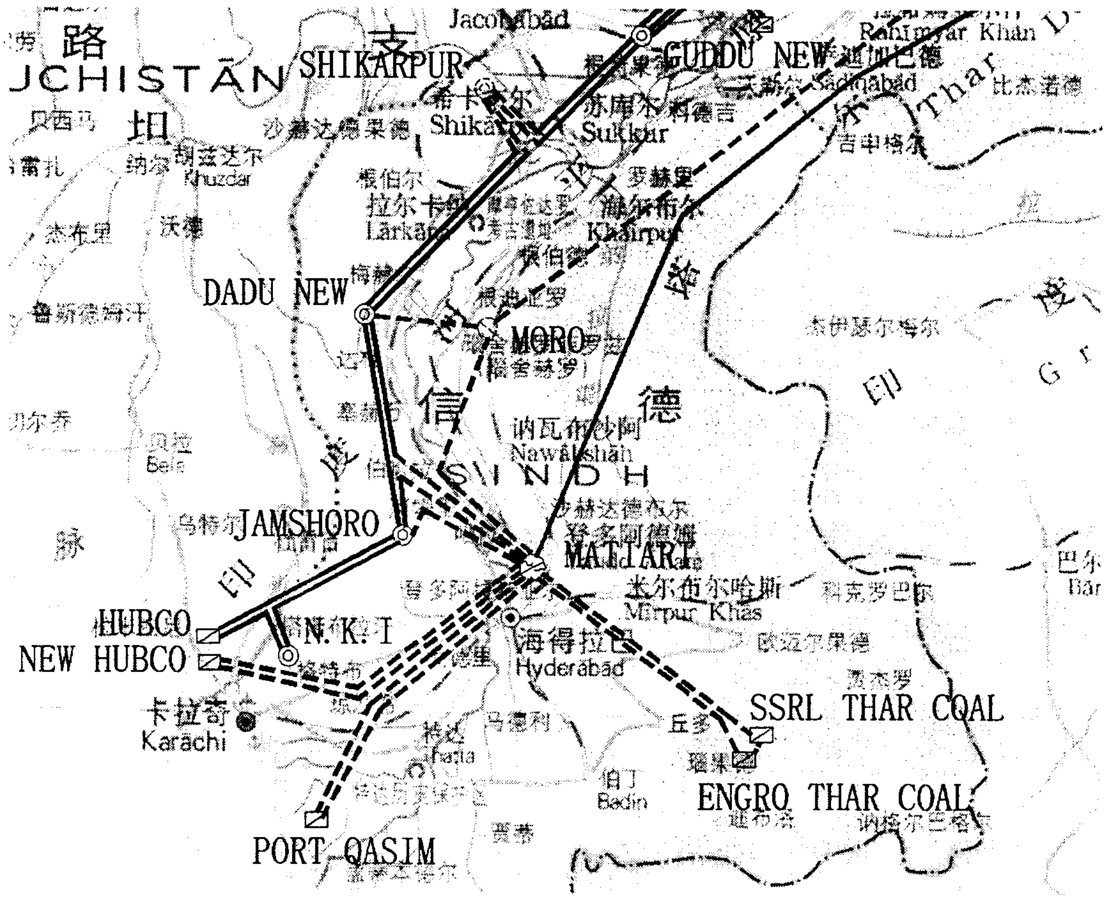


Figure 2.5-2: Connection of sending-end converter station (M C/S)

2.5.2 Study on System Connection of Receiving-end Converter Station

With south Lahore as the receiving end of the DC power link, the following connection scheme is proposed:

AC side of the receiving-end converter station is at 500 kV voltage, and connected to the Lahore-Lahore South 500 kV double-circuit line, for which 2×1 km and 2×10 km new lines are required. Also, a 500 kV Lahore North substation, and receiving-end-Lahore North-Gakkhar 500 kV double-circuit line (around 2×110 km) need to be built. There will be six outgoing lines led from the receiving-end converter station, two to Lahore, Lahore South, and Lahore North respectively.

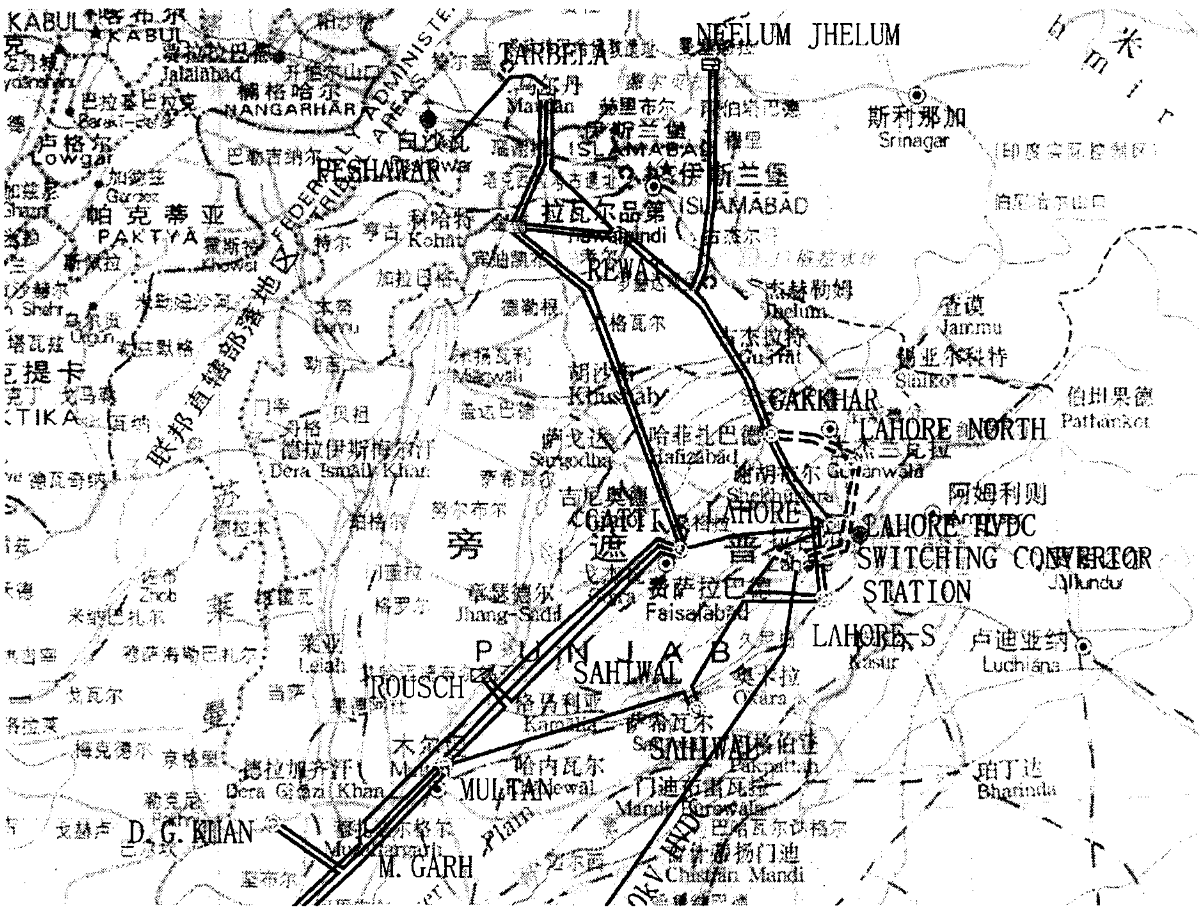


Figure 2.5-3: Connection of receiving-end converter station (L C/S)

2.6 Project Scale

The project is about one-circuit 660 kV DC transmission, and has a transmission capacity of 4000 MW.

2.7 System Requirements on DC Operating Mode and Main Technical Parameters

2.7.1 Requirements on DC Operating Mode

This project is a typical bipolar DC transmission line with both neutral points earthed. Conventionally, its basic operating modes shall include: bipolar mode, monopole ground-return mode, and monopole metallic-return mode.

According to the previous Ningdong-Shandong ±660 kV HVDC transmission line project, this project adopts one 12-pulse converter valve bank for either pole. The operating modes of Matiari-Lahore ±660kV DC transmission line mainly include:

(1) Bipolar full-voltage mode;

(2) Monopole metallic-return mode;

(3) Monopole ground-return mode;

(4) Reverse power transfer mode;

(5) Reduced voltage mode.

2.7.2 Requirements on Main Technical Parameters of Converter Station

(1) Ratings of DC System

When DC system continuously operates at its ratings and power is transmitted from Matiari converter station to Lahore converter station, the continuous operation ratings of the DC line side of DC smoothing reactor used at converter station are as follows:

Rated Power: 4000 MW in bipole, and 2000 MW for either pole;

Rated voltage : ±660 kV

Rated current : 3030 A

(2) Minimum Transmission Power of DC System

To prevent interrupted DC current when the average DC current is too low, a minimum DC current of DC system should be specified, which generally is taken as 5% to 10% of the DC current rating. According to the previous engineering experience, the minimum DC current of this project is taken as 10% tentatively, i.e., the minimum power transmitted by DC system is 10% of its power rating.

(3) Reduced-voltage Operation Capability of DC system

According to the previous engineering experience and the performance of related equipment, the maximum permissible reduction of operating voltage of Matiari-Lahore ±660kV DC transmission line is taken as 70% tentatively, that is, at 100% to 70% of normal voltage, the DC system is capable of transmitting 100% to 70% of rated power.

(4) Reverse Power Transfer Capability of DC System

There is no special requirement on reverse power transfer, i.e., the reverse power transfer only relies on the DC equipment, and additional equipment investment is not required.

2.7.3 Operating Voltage and Frequency of AC System

According to the related conclusions of power flow and stability calculations, the operating voltage and frequency ranges of AC busbar of Matiari converter station are tentatively determined as follows:

(1) System Operating Voltage

The normal voltage of 500 kV busbar of sending-end converter station is taken as 475kV to 540 kV, the rated voltage and post-emergency voltage of 500 kV busbar on the AC side of the converter station are taken as 500 kV and 450–550 kV respectively.

(2) System Frequency

The normal frequency of busbar of sending-end converter station is 50±0.1Hz, the post-emergency frequency is 49.4–50.5Hz, and the steady frequency after faults are eliminated is 50±0.2Hz.

According to the related conclusions of power flow and stability calculations, the operating voltage and frequency ranges of AC busbar of Lahore converter station are tentatively determined as follows:

(1) System Operating Voltage

The normal voltage of 500 kV busbar of receiving-end converter station is taken as 475 kV to 530 kV, the rated voltage and post-emergency voltage of 500 kV busbar on the AC side of the converter station are taken as 500 kV and 450–550 kV respectively.

(2) System Frequency

The normal frequency of busbar of receiving-end converter station is 50±0.1Hz, the post-emergency frequency is 49.4–50.5Hz, and the steady frequency after faults are eliminated is 50±0.2Hz.

2.7.4 Requirements on Overload Withstand Capability of DC System

DC transmission system generally operates at a continuous rated power. But considering equipment design margin, ambient temperature variation, and other related factors, DC system must some overload withstand capability. The overload withstand capability of DC system can be classified into transient and short-term overload withstand capabilities according to the duration of overloading.

The higher the DC transient overload withstand level, the higher the transient stability level of system. The main function of DC short-term overload withstand capability is to supply more power by using the overload withstand capability of operating DC equipment and reduce the effect on grid operation after the AC and DC equipment stops operating due to faults.

This project has no specific requirement on DC overload withstand capability. According to the related DC project at home and abroad, the 2-hour overload withstand capability of DC system is taken as 1.1 times the rated transmission capacity without increasing additional commutation equipment, the 3-second overload withstand capability of DC system is taken as 1.2 times the rated transmission capacity without increasing additional commutation equipment.

The exact overload withstand capabilities of Matiari-Lahore ±660kV DC transmission line shall be determined in combination with the development of related equipment at the next stage. The determination of the overload withstand capabilities should not increase investment and the degree of implementation difficulty.

2.7.5 Requirements on Additional Control Functions of DC System

To improve the operational performance of AC system, according to the previous construction experience, DC system shall have the following control and auxiliary control functions:

1. Power swing damping in case of major incident of AC grid;
2. Reactive power control over the converter station transmitting power;
3. Emergency active support or power flow reversal;
4. Control of AC system frequency;
5. Control of voltage of AC busbar of converter station;
6. Suppression of subsynchronous oscillation of AC system.

2.7.6 Requirements on the Electrical Connection of Converter Station

It is recommended that the either pole of converter station be wired in one 12-pulse valve bank mode. The converter station is provided with one 500 kV busbar, which is wired in one-and-a-half circuit breaker arrangement. The sending-end converter station plans to have 18 500 kV bays. In this phase, 16 500 kV bays will be constructed, among which, 6 are for the incoming lines of power sources; 4 are for the grid connection line; 2 is connected to Jamshoro substation; 1 is connected to Moro substation; 1 is connected to Dadu New substation;capacitors and filters are connected into 4 banks; and the remaining 2 are for the incoming lines of converter transformer. The receiving-end converter station will be provided with 12 500 kV bays, among which, 6 are for grid connection lines; 2 are connected to the Lahore substation; 2 are connected to Lahore North substation; 2 are connected to Lahore South substation; capacitors and filters are connected into 4 banks; and the remaining 2 are for the incoming lines of converter transformer.

2.7.7 Requirements on Determination of Converter Transformer Parameters

(1) Determination of Parameters of Sending-End Converter Transformer

Percentage of short-circuit impedance: U_k is taken as 18% tentatively. It will be further optimized at the next stage according to equipment manufacturing capability and transportation condition.

Type of converter transformer: single-phase dual-winding transformer, which uses two connection modes: Y_0/Δ and Y_0/Y.

Capacity of converter transformer:	12+2.
Capacity of single-phase dual-winding transformer:	U_k=18%, capacity: 401 MVA.
Tapping range on the high-voltage side of converter transformer:	U_k=18%, -7–+23

(2) Determination of Parameters of Receiving-End Converter Transformer

Percentage of short-circuit impedance: U_k is taken as 18% tentatively. It will be further optimized at the next stage according to equipment manufacturing capability and transportation condition.

Type of converter transformer: single-phase dual-winding transformer, which uses two connection modes: Y_0/Δ and Y_0/Y.

Capacity of converter transformer:	12+2.
Capacity of single-phase dual-winding transformer:	U_k=18%, capacity: 401 MVA.
Tapping range on the high-voltage side of converter transformer:	U_k=18%, -7–+23.

2.7.8 Requirements on Grouping of Capacitors

(1) Matiari Converter Station

Configuration of AC filters and capacitor banks: The total capacitive reactive power compensation capacity in this phase is tentatively taken as 2610 Mvar, composed of 4 banks and 16 sub-banks (9 sub-banks of 150 Mvar and 7 sub-banks of 180 Mvar capacitors).

Configuration of low voltage reactors: 4 banks of 60 Mvar low voltage reactor will be configured at the low voltage side of Matiari converter station.

(2) Lahore Converter Station

Configuration of AC filters and capacitor banks: The total capacitive reactive power compensation capacity in this phase is tentatively taken as 2480Mvar, composed of 4 banks and 16 sub-banks (8 sub-banks of 150 Mvar and 8 sub-banks of 160 Mvar capacitors).

Configuration of low voltage reactors: 3 banks of 60 Mvar low voltage reactor will be configured at the low voltage side of Lahore converter station.

The final division of sub-banks should be determined by further studies according to the actual conditions including switching level, system harmonics, and the arrangement of converter station.

3. Secondary System

3.1 500kV Protection

Refer to Volume II-1

3.2 Dispatch Automation

Refer to Volume II-1

3.3 System Communication

Refer to Volume II-2

4. Converter Station

4.1 M C/S Site Selection and Project Planning

4.1.1 Site Selection

Site 1 (center coordinates: 25°38'25"N, 68°30'32"E) is located at about 30 km northeast of Hyderabad and at the east side of national trunk highway N5. The site with flat terrain has the natural ground level of about 21 to 24 m (MSL altitude datum, the same below). Wheat and banana are planted on most of the site and there is some wasteland with shrubs. Some simple houses (single adobe houses) at the sides of the country road at the north of the site need to be removed. The access road will be led from the country road which connects with the N5 highway. The flood level of 100-year return period is 24.96m, and flood prevention measures are required.

Site 2 (center coordinates 25°29'34"N, 68°24'49" E) is located north of national trunk highway N5 (National Highway No. 5). The site has an open topography and a flat terrain. There is mostly shrub wasteland and partially crops planted on the site. There are about 10 simple houses (single floor adobe houses) to be removed from the site. The access road can be led from the N5 highway. The site is low-lying, located on the east bank of the Indus River, and flood should be considered.

The site 3 (center coordinates 25°28'35"N, 68°25'20"E) is located at the east side of national trunk highway N5 (National Highway No. 5). The site has an open topography and a flat terrain. There is lush land vegetation and wheat and other crops planted. There is no house and other buildings and structures to be removed with the range of the site. The access road can be led from the N5 highway. The site is located on the east bank of Indus River, so the influence of flood may need to be considered.

The site 4, with center coordinates of 25°42'51"N and 68°31'12"E, is located at about 38 km northeast of Hyderabad and on the east side of national trunk highway N5. The station site is featured with flat terrain with a natural ground level of about 21–24 m (MSL altitude datum, the same below). Farmland spreads across the site area and dense irrigation ditches along with more than ten water wells are scattered therein. There are two neighboring brickyards to the west of the station site and one circuit of south-north 132 kV transmission line runs at a distance of about 350 m. All the residential areas around the station site are more than 200 m away from the latter. The access road is connected to the country road diverged from the national trunk highway N5. The 100-year flood level at the site is 23.8 m and, therefore, flood protection measures are required for the site.

4.1.2 Technical and Economical Comparison of the Sites and Recommendation

According to the comments of NTDC, site 1 is recommended for Matiari Converter Station and feasibility study was made, and the feasibility study report was completed in December 2015.

Because of the difficulty in land acquisition for site 1, NTDC proposes to change the station site in August 2016. From August 14–20, 2016, under the organization of CET, CSEPDI professionals and Pakistan personnel jointly carried out supplemental site survey for the station site in Pakistan and proposed a new station site (i.e., site 4) which is about 8 km away from site 1 and is to north by east of site 1. This feasibility study is completed based on site 4.

4.1.3 Construction Scale

According to system data, the construction scale of the sending-end converter station is as follows:

Table 4.1.3-1: Construction scale of M C/S

No.	Item	Scheme
1	Conversion power	Rated 4000MW
2	Converter valve	Double pole, each in a 12-pulse valve group connection. Rated ±660kV, DC 3030A, 7.2kV/3030A 5-inch thyristor valve
3	Transformer	Single-phase two-winding converter transformer, each 401MVA, 12+2
4	500kV AC yard	Open outdoor arrangement Future: 8 complete string , 2 incomplete strings and 2 bus bays, 12 500kV outgoing lines, 4 banks of ACF, 2 converter transformers; This phase: 7 complete strings, 2 incomplete strings, 2 bus bays, 10 500kV outgoing lines, 4 banks of ACF, 2 converter transformers
5	500kV AC filter	Open outdoor equipment, 4 banks, 16 sub-banks (9 rated 150Mvar and 7 rated 180Mvar)
6	500kV AC PLC	One will be installed at incoming line of converter transformers of P I and P II
7	35kV AC section	The converter station has two 35 kV buses, 4 banks of 60 Mvar low-voltage reactors, and two 35/11.5 kV auxiliary transformers.
8	Smoothing reactor	8+1 (dry type, each 75mH)
9	Auxiliary power supply	Three auxiliary power supplies, two of which are led from two 35kV AC buses through two 35/11.5kV auxiliary transformers, the other is led from the 132kV transmission line near the station

4.1.4 Technical Proposal

4.1.4.1 Main Electrical Connection

Each pole of the converter transformer will be of a 12-pulse group connection, with a conversion power of 4000MW, rated ±660kV, DC 3030A. The 6-pulse midpoint will be connected to the ground through lightning arrester. The converter valves feature 5-inch thyristor valve disc, forced water circulation, and air insulation, in suspended double valve arrangement.

Typical bipolar DC connection is used for DC yard and smoothing reactors, DC passive filters, DC voltage measuring devices, DC current measuring devices, DC disconnectors, high-speed transfer switches, neutral equipment and overvoltage protection devices are symmetrically provided according to the polarities.

The station will be provided with 12 operating single-phase two-winding converter transformers, along with two transformers standby. The line side bushings of the converter transformers will be connected to the AC system through YN connection, and the valve side bushings will be respectively connected to the valve tower through Y or d type connection. YNy0 and YNd11 connection will be used for the three phases of converter transformers. Single-phase two-winding, oil immersed, on-load tap changing converter transformers will be used.

The AC side of the 500kV system will be connected in the form of 3/2 circuit breaker. In future there will be 12 500kV AC outgoing lines, 4 banks of AC filters

(ACF) and 2 groups of converter transformers. There are 18 elements in total, which form 8 complete strings and 2 incomplete strings. Each of the two buses will be connected with one 500/35 kV step-down transformer. All the 12 outgoing lines will be equipped with HV reactors on the lines (except Jamshoro double lines and Moro line). For now AC PLC is considered for incoming lines of converter transformers. In the current phase, 10 outgoing lines (1 to Dadu New, 2 to Jamshoro, 1 to Moro, 2 to Hubco New power station, 2 to Qasim power station, and 2 to Thar power station), 4 banks of ACFs, and 2 banks of converter transformers will be built. A total of 16 elements will be incorporated, constituting 7 complete strings and 2 incomplete strings. Each of the two buses will be connected with one 500/35 kV step-down transformer. All of the 10 outgoing lines will be provided with high-voltage reactors, except the Jamshoro double lines and Moro line.

The string configuration is as shown in the following table:

Table 4.1.4-1: String configuration of 500 kV AC switchyard of M C/S

String No.	Line on 1M Side	Line on 2M Side
Bus connection	No. 1 500/35 kV step-down transformer	No. 2 500/35 kV step-down transformer
#1 string	#1 bank of AC filters	Converter transformer for P II
#2 string	#2 bank of AC filters	Thar power station 2
#3 string	Converter transformer for P I	Thar power station 1
#4 string	NA	Reserved
#5 string	Qasim power station 2	Reserved
#6 string	#3 bank of AC filters	Qasim power station 1
#7 string	#4 bank of AC filters	Hubco New power station 2
#8 string	Hubco New power station 1	Jamshoro2
#9 string	NA	Jamshoro1
#10 string	Moro	Dadu New

500kV AC filter yard will be connected in the form of single bus. 500kV AC filters and shunt capacitors will be in 4 banks, 16 sub-banks, with 8 rated 150Mvar and 8 rated 180Mvar. In this phase, 16 sub-bank circuit breakers will be installed. AC filters will be of open outdoor type, arranged in a line. SF_6 live tank circuit breakers are recommended, with capability of switching capacitance current.

The 35 kV AC switchyard employs single-bus connection mode. The switchgear is arranged outdoors. The station has 2 35 kV buses, 4 banks of 60 Mvar low-voltage reactors, and two 35/11.5 kV auxiliary transformers.

Three station power supply lines will be used for the station. Two of them are connected from two groups of 35kV AC buses by using two 35/11.5kV high voltage station transformers respectively and one of them is connected from 132kV transmission line nearby this station. The specific power supply lines will be determined by Pakistan.

4.1.4.2 Selection of Main Equipment in Converter Station

The following equipment will be used for the converter station:

Table 4.1.4-2: Selection of main equipment in M C/S

Number	Name	Specifications
1	Converter transformer	Single-phase, two-winding, each 401MVA, short-circuit impedance 18%
2	Converter valve	±660kV, 3030A, 5-inch thyristor disc, double valve tower, suspended.
3	Smoothing reactor	660kV, 3030A, 75mH, dry type
4	500kV AC yard	Outdoor, open type This phase: 7 complete strings, 2 incomplete strings, and 2 bus bars Future: 8 complete strings, 2 incomplete strings and 2 bus bars
5	Equipment outside 500kV AC filter fence	16 sub-bank bays, outdoor open equipment, including circuit breakers, disconnectors, CT and earth switches
6	Equipment inside 500kV AC filter fence	16 sub-banks, 9 rated 150Mvar and 7 180Mvar
7	35kV AC part	4 banks of 60Mvar LV reactors, two 35/11.5kV auxiliary transformers

4.1.4.3 Electrical Equipment Layout Plan

The electrical equipment layout plan of the Matiari converter station is as follows: control building, valve hall, converter transformer and 35kV switchgear will be arranged in the center, the DC switchyard in the east, and the ±660kV DC lines leave the station towards east. The 500kV AC switchgear will be arranged in the south. Except the lines to Moro, which are led to north, all other 500kV AC lines will go south. The AC filters will be arranged in north of the site. Spaces will be reserved for expansion of main transformers and 500kV and 220kV outgoing lines.

4.1.4.4 Secondary Electrical Systems

(1) The converter station will be manned. The AC and DC systems will share a unified computer monitoring and control system.

(2) The monitoring, measurement and control of all station equipment will be realized by the computer system, which will be of modular, layered and distributed, and open structure.

(3) High voltage DC control system is of layered and distributed structure. Configuration is made from sampling unit, data transmission bus and primary device to control outlet based on the principle of full duplication.

(4) The HVDC protection offers protection for pole/two poles, DC switchyard, DC lines and earth electrode lines, which are divided into multiple overlapped protection zones. The protection zones and configuration shall ensure all devices are under comprehensive protection. Triple redundant protection will be used for the HVDC system.

(5) High voltage DC protection and control systems are separated and independent and the protection systems of two poles on functions and group panels are completely independent.

(6) The HVDC control and protection system is suitable for rectification and converter operation.

(7) In the 500kV AC switchyard, a relay bay will be provided, and control and protection devices will be provided corresponding to the AC equipment bays. HVDC control and protection cabinets, converter transformer control and protection cabinets will be arranged in the respective rooms in the control building; the control and protection cabinets of AC filters, capacitors and reactor banks, and AC lines will be arranged in the local AC relay room.

(8) Based on the characteristics of HVDC systems, auxiliary DC power supplies will be provided respectively to DC P I, P II, common equipment of the station and AC local relay room.

4.1.4.5 Civil Works

4.1.4.5.1 Buildings

Buildings in the station include a valve hall for P I, a valve hall for P II, a control building, a 11 kV switchgear room, a 400V common power distribution room, three 500 kV relay and battery rooms (respectively the first 500 kV relay room and battery room, the second 500 kV relay room and battery room, the third 500 kV relay room and battery room), a spare parts warehouse, an integrated pump house, a deep well pump house, an administrative building, a security guard room and a gate. The total construction area is about 25781 m^2.

4.1.4.5.2 Structures

(1) Structural Type

Buildings will be constructed to be cast-in-situ R.C. frame structure or steel structure.

The gantry and equipment support will be latticed steel structure with cast-in-situ R.C. stepped footing. .Connections of members will be bolted. Gantry will be mounted on the foundations by means of anchor bolts embedded in the foundation concrete.

(2) Soil and Foundation

. Foundation dimensions and buried depth are calculated based on the data available from the geological report. Gantry foundation will be buried to 2.0m~3.5m deep. Equipment support foundation will be buried to 1.5m~2.5m. Foundation shall be placed on undisturbed soil layer, otherwise pile foundation should be adopted。

(3) Standard for structural design

A) RC structure

Deflection of members shall be no greater than L/240 (9.5.2.6 of ACI 318, the latest version)

B) Steel structure

Deflection of framework beams shall be no greater than L/300, and deflection of framework columns shall be no greater than H/150.

C) Slenderness Ratio

Table4.1.4-3 Limiting Slenderness Ratio (refer to ASCE 10 part 3.4, the latest version)

Main compression member	150
Secondary members carrying calculated stresses	200
Redundant members without calculated stresses	250
All tension-only members	350

D) Connection of steel structure

Connection method: Factory fabrication -- Bolt connection & welding; On-site-- Bolt connection.

Bolt: Grade 4.8 6.8 and 8.8 galvanized bolts will be used, with minimum diameter 12mm. All bolts will be completed with galvanized washers. Each bolt will be provided with one flat washer and one spring washer.

Welding: Q235B and Q345B steel electrodes shall use E43 type and E50 type. The welding operation shall be avoided as far as possible for the Q420B high-strength steel. Weld metal shall match the metal material of members to be connected. When steels of different strength are to be connected, the weld material matching the low strength steel way be used.

Table4.1.4-4 Summary of bolt Strength

Material origin	Grade	Yield strength (N/mm^2)	Tensile strength (N/mm^2)
China	4.8	320	400
	6.8	480	600
	8.8	640	800

(4) Materials

A) Steel

Steel Q235B and Q345B will be used as steel for gantry and equipment support. Calculation shall be carried out as per ASCE or ACI standard.

a) Main member angle steel : Q345B

b) Web member angle steel: Q235B

c) Walkway, ladder: Q235B

d) Anchor bolt: Q345B

Table 4.1.4-5 Summary of Steel Strength

Material origin	Brand	Thickness (mm)	Yield strength (N/mm^2)	Tensile strength (N/mm^2)
China	Q235B	$t \le 16$	235	375
		$16 < t \le 40$	225	
	Q345B	$t \le 16$	345	470
		$16 < t \le 35$	325	
		$35 < t \le 50$	295	

B) Concrete

Table4.1.4-6 Summary of Concrete Strength

Item	THE SPECIFIED COMPRESSIVE STRENGTH OF CONCRETE, CYLINDRICAL MODEL ON 28-DAY TESTS: fc'
Foundation	28 N/mm^2
Beam, column, slab	28 N/mm^2
Cable trench	28 N/mm^2
Pre-fabricated member	28 N/mm^2
bedding course	14 N/mm^2
Others	28 N/mm^2

C) Steel bar

Table 4.1.4-7 Summary of Steel Bar Strength

Category	(N/mm^2) Yield strength	Remark
Grade 40	280	
Grade 60	420	
Grade 75	520	

(5) Anti-corrosion of steel structure

The steel for gantry and equipment support will be hot-galvanized for corrosion resistance. The steel buildings will be painted for corrosion resistance. And zinc-rich painting will be used at site for local anti-corrosion treatment where the zinc coat is damaged.

(6) Noise

The noise at the boundary of the converter station is in accordance with Chinese standard (Emission Standard for Industrial Enterprise Noise at Boundary GB12348-2008) 2 level: the daytime noise level is less than 60dB(A) and night noise level is less than 50dB(A). And for residential area around the converter station, the noise should be less than 45dB(A) in night time.

4.1.4.6 Water, Heating, Ventilation and Fire Protection

(1) Water supply

Water for the converter station mainly includes comprehensive domestic water, production water and fire water. Production water is mainly used to supply water for external cooling system of the converter valve and water consumption varies based on different external cooling schemes of the valve. Water consumption of the only water cooling scheme is about 600 m^3/d and water consumption of air cooling + water cooling scheme is about 300 m^3/d. Comprehensive domestic water and fire water is 180 m^3/d, so total water consumption is about 780 m^3/d when only water cooling is used for external cooling of the valve and it is about 480 m^3/d when air cooling + water cooling method is used for external cooling of the valve.

According to site survey, ground water can meet water requirements of converter station.

(2) Valve cooling system

Each valve hall will be provided with one valve cooling system. The cooling system will be designed to cool the heat generated by thyristor valves and capable to operate and guarantee the design temperature range of cooling water for two hours and three seconds overload conditions, up to max specified design dry bulb ambient temperature.

Thyristor valve will be cooled by water, the hot water from the valves will be cooled down by closed evaporative cooling towers and spray water for cooling towers will be treated by reverse osmosis installation and chemical dosing unit.

(3) Heating and ventilation

Each valve hall and control building will be provided with a separate ventilation system, which is consisted of air cooled water chillers, modular air handling units and supply/return air ducts, to maintain temperature and relative humidity required for normal operation of equipment and personal comfort. Other buildings will be provided with air cooled split air conditioning unitsc. Each valve hall will be provided with a mechanical smoke exhausting system after the fire is extinguished.

Mechanical ventilation systems are provided for battery room, power distribution room, 11kV switchgear room, valve cooling equipment room and comprehensive pump room etc.

(4) Fire protection

The main objects of the fire protection system are the control building, valve halls, administrative building, spare parts warehouse, as well as converter transformers and other oil-containing equipment.

Each converter transformer will be provided with a water spray system, including deluge valve, signal butterfly valve, nozzle and pipe.

4.2 L C/S Site Selection and Project Planning

4.2.1 Site Selection

Site 1 (center coordinates: 31°15'35"N, 73°49'54"E) is located about 50km southwest of Lahore and east of Bhai Pheru-Mor Khunda highway. The site has a flat terrain, the natural ground level is about 191-191.4m. Wheat is mostly grown on the site. On and around the site some houses need to be removed, so does some 11. kV lines. The access road will be led from the Bhar Pheru-Mor Khunda road. The prevention measures are required.

Site 2 (center coordinates: 25°29'56"N, 68°24'13"E) is located south of national trunk highway N5 (National Highway No. 5). With an open and flat terrain, the site is covered by lush vegetation, mostly wheat. On the site there is an abandoned house and reinforced concrete shed which need to be demolished. A 220kV line crosses the site, and there is a natural gas pipe about 200 west of the site. The access road can be led from the N5 highway. The site is located on the east bank of the Indus River, and flood should be considered.

Site 3 (center coordinates: 25°29'56"N, 73°59'06"E) is located south of Bhai Pheru-Kot Radha Kishan road. With an open and flat terrain, the site is covered by lush vegetation and wheat and other crops. There is no house and other buildings and structures to be removed from site. The access road can be led from Bhai Pheru-Kot Radha Kishan road. The site is low-lying, located on the east bank of the Indus River, and flood should be considered.

4.2.2 Technical and Economical Comparison of the Sites and Recommendation

Based on NTDC's opinion, feasibility study is conducted for Lahore Converter Station that uses site 1 as the recommended site and surveys are not made for other sites in this phase. It is planned to carry out the converter station project on the basis of site 1.

4.2.3 Construction Scale

According to system data, the construction scale of the receiving-end converter station is as follows:

Table 4.2.3-1: Construction scale of L C/S

No.	Item	Scheme
1	Conversion power	Rated 4000MW
2	Converter valve	Double pole, each in a 12-pulse valve group connection. Rated ±660kV, DC 3030A, 7.2kV/3030A 5-inch thyristor valve
3	Transformer	Single-phase two-winding converter transformer, each 401MVA, 12+2
4	500kV AC yard	Open outdoor arrangement The same for this phase and future: 6 complete strings and 2 bus bays, 6 500 kV outgoing lines, 4 banks of ACF, 2 converter transformers
5	500kV AC filter	Open outdoor equipment, 4 banks, 16 sub-banks (8 rated 150Mvar and 8 rated 160Mvar)
6	500kV AC PLC	One will be installed at incoming line of converter transformers of P I and P II
7	35kV AC section	The station has two 35 kV buses, 3 banks of 60 Mvar low-voltage reactors, and two 35/11.5kV auxiliary transformers.
7	Smoothing reactor	8+1, (dry type, 75mH)
8	Auxiliary power supply	Three auxiliary power supplies, two of which are led from two 35kV AC buses through two 35/11.5kV auxiliary transformers, the other is led from 132kV transmission line nearby or the 132 kV bay within the SARFRAZ NAGAR 220kV substation.

4.2.4 Technical Proposal

4.2.4.1 Main Electrical Connection

Each pole of the converter transformer will be of a 12-pulse group connection, with a conversion power of 4000MW, rated ±660kV, DC 3030A. The 6-pulse midpoint will be connected to the ground through lightning arrester. The converter valves feature 5-inch thyristor valve disc, forced water circulation, and air insulation, in suspended double valve arrangement.

Typical bipolar DC connection is used for DC yard and smoothing reactors, DC passive filters, DC voltage measuring devices, DC current measuring devices, DC disconnectors, high-speed transfer switches, neutral equipment and overvoltage protection devices are symmetrically provided according to the polarities.

The station will be provided with 12 operating single-phase two-winding converter transformers, along with two transformers standby. The line side bushings of the converter transformers will be connected to the AC system through YN connection, and the valve side bushings will be respectively connected to the valve tower through Y or d type connection. YNy0 and YNd11 connection will be used for the three phases of converter transformers. Single-phase two-winding, oil immersed, on-load tap changing converter transformers will be used.

The AC side of the 500kV system will be connected in the form of 3/2 circuit breaker. The scale will remain the same for the current phase and future. The current phase will have 6 500kV AC outgoing lines (2 to north Lahore, 2 to south Lahore, and 2 to Lahore), 4 banks of ACF, and 2 converter transformers, with 12 elements forming 6 complete strings. Each of the two buses will be connected with one 500/35 kV step-down transformer. All outgoing lines will be provided with outgoing disconnectors. AC PLC is considered at incoming line of converter transformer.

The string configuration is as shown in the following table:

Table 4.2.4-1: String configuration of 500kV AC switchyard

String No.	Line on 1M Side	Line on 2M Side
Bus connection	No. 1 500/35 kV step-down transformer	No. 2 500/35 kV step-down transformer
#1 string	Lahore South 1	#1 bank of AC filters
#2 string	Converter transformer of P I	Lahore 1
#3 string	Lahore 2	Converter transformer for P II
#4 string	Lahore North 1	#2 bank of AC filters
#5 string	#3 bank of AC filters	Lahore North 2
#6 string	#4 bank of AC filters	Lahore South 2

500kV AC filter yard will be connected in the form of single bus. 500kV AC filters and shunt capacitors will be in 4 banks, 16 sub-banks, with 8 rated 150Mvar and 8 rated 180Mvar. In this phase 16 sub-bank circuit breakers will be installed. AC filters will be of open outdoor type, arranged in a line. SF_6 live tank circuit breakers are recommended, with capability of switching capacitance current.

The 35 kV AC switchgear yard employs single-bus connection mode. The distribution equipment is arranged outdoors. The Lahore Converter Station has two 35 kV buses, 3 banks of 60 Mvar low-voltage reactors, and two 35/11.5kV auxiliary transformers.

Three auxiliary power supplies will be used, two of which are led from two 35kV AC buses through two 35/11.5kV auxiliary transformers, the other is led from 132kV transmission line nearby or the 132 kV bay within the SARFRAZ NAGAR 220kV substation.

4.2.4.2 Selection of Main Equipment in Converter Station

Table 4.2.4-2: Selection of main equipment in L C/S

Number	Name	Specifications
1	Converter transformer	Single-phase, two-winding, each 401MVA, short-circuit impedance 18%
2	Converter valve	±660kV, 3030A, 5-inch thyristor disc, double valve tower, suspended.
3	Smoothing reactor	660kV, 3030A, 75mH, dry type
4	500kV AC yard	Outdoor, open type The same for the current phase and future: 6 complete strings, and 2 bus bays
5	Equipment outside 500kV AC filter fence	16 sub-bank bays, outdoor open equipment, including circuit breakers, disconnectors, CT and earth switches
6	Equipment inside 500kV AC filter fence	16 sub-banks, 8 rated 150Mvar and 8 160Mvar
7	35kV AC part	3 banks of 60Mvar LV reactors, two 35/11.5kV auxiliary transformers

4.2.4.3 Electrical Equipment Layout Plan

The electrical equipment layout plan of the Lahore converter station is as follows:

The control building, valve hall, converter transformer and 35kV switchgear will be arranged in the center, the DC yard in the west, and the ±660kV DC lines leave the station towards west. The 500kV switchgear will be arranged in the east. The six 500kV AC lines will go north. The 4 banks of AC filters will be arranged in the south. The switchgear for external auxiliary power supply will be arranged in the space in ACF area, in southeast of the site. Spaces will be reserved for expansion of main transformers and 500kV and 220kV outgoing lines.

4.2.4.4 Secondary Electrical Systems

See 4.1.4.4.

4.2.4.5 Civil Works

(1) Buildings

Buildings in the station include a valve hall for P I, a valve hall for P II, a control building, a 11kV switchgear room, a 400V common power distribution room, two 500kV relay and battery rooms (respectively the first 500 kV relay room and battery room and the second 500kV relay room and battery room), a spare parts warehouse, an integrated pump house, a deep well pump house, an administrative building, a security guard room and a gate. The total construction area is about 26468 m^2.

(2) Structures

The similar as in 4.1.4.5.2. Foundation dimensions and buried depth are calculated based on the data available from the geological report. Gantry foundation will be buried to 2.0m~3.5m deep. Equipment support foundation will be buried to 1.5m~2.5m. Foundation shall be placed on undisturbed soil layer, otherwise pile foundation should be adopted.

4.2.4.6 Water, Heating, Ventilation and Fire Protection

See 4.1.4.6.

5. HVDC Transmission Line Route Selection and Project Planning

5.1 Project Overview

5.1.1 General

The Matiari-Lahore ± 660kV HVDC transmission line starts at Matiari converter station about 38km northeast to Hyderabad and ends at Lahore converter station approximately 40km southwest of Lahore. The line goes from southwest to northeast and crosses Sindh and Punjab, measuring 810km in aviation line. The length determined at feasibility study stage (the recommended route) is 878km, with a buckling factor of 1.08. The altitude ranges from 20 to 200m along the line.

The line corridor is mainly flat terrain, including flat ground of 342km (38.9%), and desert of 496km (56.5%), swamp of 40km(4.6%). The highest temperature is 52.5°C, the lowest temperature -5°C, the 3-sec gust wind speed at 10m above ground is 160km/h(44.44m/s), the corresponding 10-minute average wind speed at 10 meters above ground is 31.1m/s.The corridor goes through ice-free areas.

According to the feasibility study, the following are recommended: conductor uses 4×JL1/G3A-1250/70 and 4×JL1X1/LHA1-800/550;both2 shield wires use 24-fiber OPGW-120;towers use lattice steel self-supported type (1977 towers, 2.25 towers/km), including 257 tension towers (13%), 1720 suspension towers (87%).

5.1.2 Design Scope

The scope of design of this project covers the Matiari-Lahore ± 660kV HVDC transmission line and investment estimation.

5.1.3 Main Design Basis

(1) LAVALIN feasibility study report provided by NTDC

(2) NTDC Draft Reply on Queries from CET - Gadani HVDC Transmission Project (Transmission Lines Part)

(3) "Minutes of meeting of Pakistan HVDC transmission project feasibility study" China Power Equipment Co., Ltd., July 14, 2014

(4) MINUTES OF MEETING HELD ON DATED 04.03.2015 IN WAPADA HOUSE, LAHORE HVDC PROJECT (SPIP) CMB networking summary

(5) Minutes of Meetings for HVDC Transmission Line Project from Matiari to Lahore Held on March16-25, 2015 at NTDCL Head Office Wapda House, Lahore, Meeting Minutes March 25, 2015

(6) Minutes of Meetings for HVDC Transmission Line Project from Matiari to Lahore Held on May 20, 2015 at GM Planning (Power), PIA Building, Lahore,

Meeting Minutes May 20, 2015

(7) May 4, 2015 NTDC's reply to route recommendation by us Preliminary Route alignment / coordination from MATIARI-LAHORE HVDC transmission line

(8) May 19, 2015 NESPAK adjustment (KMZ files) on the recommended route

(9) The summary of internal audit meeting of the project on feasibility study report

5.1.4 Standards and Specifications

According to the main design principles agreed with NTDC, the engineering, construction, operation and maintenance of the HVDC transmission project will be performed according to the IEC, IEEE or the Chinese Standards for the DC portion of the HVDC Transmission Project. The following standards and specifications will be used at the current stage:

(1) Electrical design and material standards and specifications

DL 5497-2015:Technical code for design of HVDC overhead transmission line

IEEE 142-2007 Grounding of industrial and commercial power system

CIGRE 388 Impacts of HVDC Lines on the Economics of HVDC Projects

IEC 61089 Round wire concentric lay overhead electrical stranded conductors

IEC 60794-1-1,2001 Optical fibre cables-Part 1-1:general specification –general

IEC 61396 Electrical mechanical and physical requirements and test methods of Optical ground wire

IEC 61284 Overhead lines-requirements and tests for fittings

IEC 61325-1995 Ceramic or glass insulator units for d.c. systems-definitions,test methods and acceptance criteria

(2) Structural design and material standards and specifications

ASCE 74-2009-Guidelines for Electrical Transmission Line Structural Loading

IEC 60826 - Design criteria of overhead transmission lines

ASCE 10-97 - Design of latticed steel transmission structures

American concrete institutes (ACI318)

IEEE Guide for Transmission Structure Foundation Design and Testing (IEEE Std 691-2001)

ASTM A615/A615M-2009: "Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement".

5.2 Route

5.2.1 Route Overview

The project starts at Matiari converter station in Hyderabad, Sindh, and ends at Lahore converter station, Lahore, Punjab. The overall direction is from southwest to northeast, passing through the Sindh and Punjab provinces. The route length in the recommended plan is 878km.

5.2.2 Route Plan

5.2.2.1 Route Selection Principles

Before selecting the route, technical, social, economic, environmental, planning and other factors shall be considered. As for this project, following factors have been mainly considered:

- Minimum line length. In terms of requirements of power system plan, the line length, topography, geology, hydrology, meteorology, traffics, trees, minerals, handicap facilities, cross-cutting, construction, operation, views of local government and other factors have been considered to make and compare several kinds of plans, so as to secure and economize the route.
- Avoid complex obstacles to reduce the impact of line construction on local economic development.
- Close to the road to facilitate construction, operation and maintenance.
- Parallel to the existing line.
- Close to load centers in order to facilitate power network plan
- Avoid house demolition in accordance with the Pakistani Engineering Construction habits and requirements

5.2.2.2 Factors Affecting Route Selection

Main obstacles and cross-cutting of this project are as follows:

(1) Deh-akro wildlife sanction (Wildlife protection area);

(2) lal-suhanra Forest Park, changa-manga Forest Park;

(3) Rahim Yar Khan, Bahawalpur, and Bhai Pheru towns (county scale)

(4) SINDH River;

(5) SUTLEJ River;

(6) RAVI River;

5.2.2.3 Route Plan Selection

According to reconnaissance in mid-March 2015 and route report of LAVALIN, in feasibility study stage, 3 route plans--East, Middle and West plans---have been made. The east plan maximizes the use of Thar-Lahore HVDC line route of LAVALIN, and feasibility of these 3 plans have been preliminarily investigated and confirmed through site reconnaissance. Route sketch map of 3plans are shown in Figure 5.2.2-1 and 5.2.2-2.

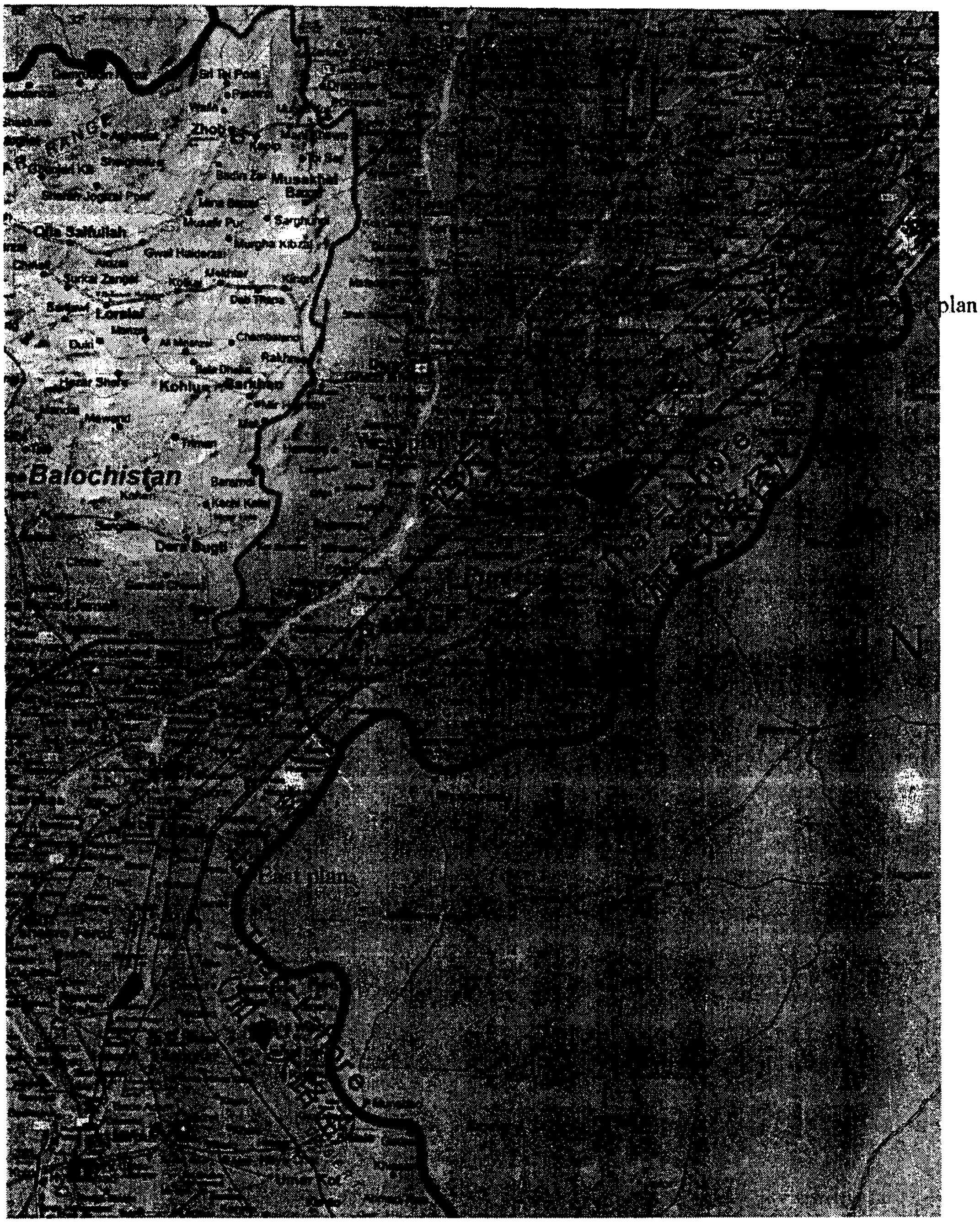


Figure 5.2.2-1: Line route sketch map (administrative division)

Figure 5.2.2-2: Line route sketch map (satellite map)

According to feedback on routes from NTDC, the middle plan is recommendatory. The middle route starts at Matiari converter station in Hyderabad, Sindh, and ends at Lahore converter station, Lahore, Punjab. The overall direction is from southwest to northeast, passing through the Sindh and Punjab provinces. The route length in the recommended plan is 878km.

5.3 Meteorological Conditions

Refer to Table 5.3-1 for the main meteorological elements in the project.

Table 5.3-1: List of main meteorological elements for project design

Meteorological element	Temperature (°C)	Wind Speed (m/s)	Ice Thickness (mm)
Minimum temperature	-5	0	0
Annual average temperature	25	0	0
Maximum wind speed	15	44.44(31.1)	0
Icing conditions	/	/	/
Maximum temperature	52.5	0	0
Failure	-1.1	0	0
Thunderstorm Days	32/year		

Note: The reference wind speed is the 3-sec gust wind speed at 10m above ground, the corresponding 10-min average wind speed at 10 meters above ground is in the following bracket.

5.4 Selection of Conductor and Earth Wire

5.4.1 Selection of Conductor

5.4.1.1 Principles for Selection of Conductor

According to the characteristics of DC transmission line, as selecting conductors, comprehensive consideration shall be given to the following factors in term of electrical characteristics, mechanical properties and economic efficiency:

(1) Current density;

(2) Current carrying capacity;

(3) Radio interference level (RI);

(4) Corona audible noise (AN);

(5) Electric energy loss

(6) Mechanical properties;

(7) Annual cost;

(8) Others (impacts on tower weight, insulators, fittings and foundation; and manufacturing and construction conditions, operational experience and so on).

5.4.1.2 Boundary Conditions for Selecting Conductors

(1) Power system conditions

The power system boundary condition for selection of conductor is shown in Table 5.4.1-1.

Table 5.4.1-1 Powers System Boundary Condition for Selection of Conductor

Operating voltage (kV)	±660
Transmission capacity (MW)	4000
Rated current (A)	3030
Overload current(A)	3333
Annual maximum loss hours (hours)	6200
Electricity price ($)	$0.0838 (¥0.5)
Operation period (year)	30
Discount rate	10%

(2) Electromagnetic environmental requirements for selection of conductor

There are no relevant standards available in Pakistan, so China's standard DL 5497-2015: *Technical code for design of HVDC overhead transmission line* will apply, which specifies that:

For an area at an altitude of 1000m or below, the radio interference limit shall not exceed 58 dB (μV/m) at 20m from the projection at the ground of the positive polarity conductor of DC overhead transmission line, at 80% time, 80% confidence degree, and 0.5MHz frequency.

For an area at an altitude above 1000m, the audible noise limit (L50) caused by corona at 20m from the projection at the ground of the positive polarity conductor of DC overhead transmission line in a sunny day shall not exceed 45dB (A); in the case of the above sea level above 1000m and the line is passing through a non-residential area, it shall be controlled below 50dB (A).

5.4.1.3 Selection of Conductor

When selecting the type of Conductor, 13 schemes of conductor are compared. They are respectively:

4×JL/G3A-900/40,4×JL/G3A-1000/45,4×JL/G1A-1120/90,4×JL1/G3A-1250/70,4×JL1/G2A-1520/125;

6×JL/G1A-630/45,6×JL/G2A-720/50,6×JL/G1A-800/555,6×JL/G3A-900/40,6×JL/G3A-1000/45,6×JL/G1A-1120/90,6×JL1/G3A-1250/70,6×JL1/G2A-1520/125.

Taking current-carrying capacity, electromagnetic environment, mechanical properties, tower load, economical efficiency, conductor manufacture, stringing construction, operation, maintenance and various other factors into comprehensive consideration, and integrating the actual situation of natural conditions in the work, aluminum conductor steel reinforced 4×JL1/G3A−1250/70 is the optimal scheme for this HVDC line project. The sub-conductor is square arrangement with the spacing of 500mm.Pole spacing for 4×JL1/G3A−1250/70 will be 17m.

. Refer to Table 5.4.1-2 for the technical parameters of conductors.

Considering the Matiari converter station is about 170km north to the coastline, and the HVDC goes north to Lahore which will be further away from the coastline, aluminum alloy-core aluminum stranded conductor will used for about 214km from Matiari converter station

Table 5.4.1-2 Technical parameters of conductors

Item \ Conductor type		JL1/G3A−1250/70	JL1/LHA1-800/550-54/37
Structural strands/diameter, mm	Outer layers	Aluminum 76/4.58	High Conductivity Aluminum 54/4.35
	Core	Steel 7/3.57	Aluminum Alloy37/4.35
Cross section, mm^2	Outer layers	Aluminum 1252.09	High Conductivity Aluminum802.53
	Core	Steel 70.07	Aluminum Alloy 549.88
	Total	Total cross section 1322.16	Total cross section 1352.41
Diameter, mm		47.35	47.85
Elastic modulus, N/mm^2		62200	55000
Coefficient of thermal expansion, 1/°C×10-6		21.1	23.00
Calculated weight, kg/km		4011.1	3744.5
Calculated tensile strength, kN		294.23	292.96
DC resistance of conductor at 20°C (Ω/km)		0.02291	0.02260

5.4.2 Selection of Earth Wire

The earth wires use 2 OPGW cables by the requirement of communication. According to the conclusion on selection of typical earth wire, the cross-section of OPGW for this project shall apply 120mm^2, and the diameter shall be about 14mm. In this stage the provisionally applied OPGW model is OPGW-15-120-2 (24-fiber), for which the main technical parameters are given in the below table.

Table 5.4.2-1 Summary of OPGW parameters in the project

Item	OPGW-15-120-2
Calculated sectional area (mm^2)	121.1
Calculated outside diameter (mm)	15.2
Calculated weight (kg/m)	0.711
Calculated tensile strength (N)	101300
Elastic modulus (N/mm^2)	132000
Coefficient of thermal expansion(1/°C)	13.8×10^{-6}
Breaking stress (N/ mm^2)	836.00
Maximum operating stress /safety factor (N/ mm^2)	280/2.98
Average operating stress /% (N/ mm^2)	115/13.76%

5.4.3 Safety factor for Conductor and Earth Wire

The safety factor of conductor and earth wire should be no less than 2.5.The everyday tension of conductor and earth wire should be not more than 25%. The sag of earth wire should be not more than the sag of conductor.

5.4.4 Anti-Vibration solutions for Conductor and Earth Wire

For the conductors in the project, it is recommended to take protective measures by spacers, vibration dampers and preformed armor rods. And anti-vibration solutions for OPGW will be provided by the manufacturer during construction.

5.4.4.1 Vibration Dampers for Conductor

Refer to Table 5.4.4-1 for the installed quantity of vibration dampers for conductors.

Table 5.4.4-1 Installed quantity of vibration dampers on conductor

Span range (m)	**Installed Quantity (pieces) (one sub-conductor, one side)**
500m and below	0
500-800	1
800-1200	2
1200-1500	3

5.4.4.2 Spacers for Conductor

It's proposed in the project to apply four-bundle conductor, arranged as a normal quadrilateral, with a sub-conductor spacing of 500mm. Space dampers for four-bundle conductor are recommended for the project. The space damper shall be installed unequally distantly. The average sub-span is 55m.

5.5 Insulation Coordination

5.5.1 Pollution

According to the investigations made on the insulation configuration of existing lines along the line to be built in the project, on the basis of the analysis on the general situation with respect to meteorology, environment and pollution of the areas that the line corridor pass through, and as well as our operational experience in electric power system, the length of segments partitioned on the basis of pollution area throughout the line and the salt deposit density are recommended in Table 5.5.1-1.

Table 5.5.1-1 Partition of pollution area throughout the line

Pollution area	Equivalent salt deposit density (mg/cm^2)	Non soluble deposit density (mg/cm^2)	Length of line segment (km)
Light pollution area	0.05	0.30	0
Medium pollution area	0.08	0.48	221
Heavy pollution area	0.15	0.90	657

5.5.2 Type and Parameter of Insulator

Synthetic insulator can be adopted for suspension string, and porcelain insulator for tension string in the project. Outside dimensions and technical parameters of DC porcelain insulators shall be selected as per Table 5.5.2-1.

Table 5.5.2-1 Outside dimensions and technical parameters of DC porcelain insulator

Insulator Model	Rated Electro mechanical failure load kN	Structural height mm	Nominal diameter of insulator mm	Creepage distance mm	Flashover voltage kV				Ball&Socket Size	Single insulator weight kg
					DC flashover voltage		50% lightning impulse flashover voltage			
					Dry	Wet	Positive polarity	Negative polarity		
XZP-420	420	205	400	650	150	60	150	160	28	24.0
XZP-210	210	170	320	545	140	55	140	150	20	13.6

5.5.3 Number of Disk Insulator and Length of Synthetic Insulator

Refer to Table 5.5.3-1 and Table 5.5.3-2 for the selected number of disk insulators and the length of synthetic insulator for this project.

Table 5.5.3-1 Insulation Configuration of Tension Insulator String

Pollution area	Light pollution area ($0.05mg/cm^2$)	Medium pollution area ($0.08mg/cm^2$)	Heavy pollution area ($0.15mg/cm^2$)
Number of Insulators	56	73	81

Table 5.5.3-2 Insulation Configuration of Synthetic Insulator

Pollution area	**Light pollution area ($0.05mg/cm^2$)**	**Medium pollution area ($0.08mg/cm^2$)**	**Heavy pollution area ($0.15mg/cm^2$)**
Length of synthetic insulator string (m) /Creepage distance (m)	8.5/33.4	8.5/33.4	9.2/38.4

5.5.4 Clearance

Refer to Table 5.5.4-1 for the clearance of tower recommended for the project.

Table 5.5.4-1 Clearance at tower head for ±660kVDC line (m)

Above sea level (m)	500
Operating voltage clearance(m)	1.70
Switching overvoltage clearance (m)	4.40

Note: The maximum switching overvoltage ratio throughout the line is provisionally taken as 1.82pu.

5.6 Insulator String and Hardware

5.6.1 Value of Safety Factor

In reference to the stipulations of "Technical regulations on design of HVDC overhead transmission line", combined with the experience in construction and operation of Ningdong-Shandong ±660kV HVDC lines and other ±500kV HVDC lines, the safety factor adopted for the hardware in this project is shown in Table 5.6.1-1.

Table 5.6.1-1 List of safety factor for hardware

Condition	Maximum load	Maintenance	Line breakage	String breakage
Safety factor	2.5	1.5	1.5	1.5

5.6.2 Suspension String of Conductor

In general, it is recommended to use V type string for the suspension insulator string in this project.

Refer to the following drawing for the pattern of arrangement.

The conductor suspension string adopted in this project is shown in the following table through calculation:

Table 5.6.2-1 Main hardware string of conductor

Name	Applicable circumstance
300kN composite insulator single string V type suspension string	Ordinary load
420kN composite insulator single string V type suspension string	Relatively high load
300kN composite insulator double string V type suspension string	Important crossing

5.6.3 Strain String of Conductor

Triple-string 420kN disc type insulator string can be selected for strain string at ordinary segment through calculation, and double string 210kN disc type insulator string shall be adopted for the slack span of tower into gantry.

5.6.4 Jumper String

Double string V type string cage type hard jumper of 160kN composite insulator shall be adopted for the whole line. According to the structural arrangement and clearance analysis, the included angle of V type string shall not be less than 85°.

5.6.5 Earth Wire String

Single string 120kN hardware string shall be adopted for earth wire suspension hardware string and strain hardware string, and the whole line shall be reliably grounded.

5.6.6 Main Fittings

The main fittings in the line shall include tower connecting fittings, suspension wire clip, split yoke plate, spacer and grading ring, etc.

5.6.6.1 Tower Connecting Fittings

For simplifying the design of suspension point and facilitating construction, it is recommended to adopt GD suspension plate for the hardware at suspension point of strain string, and adopt EB suspension plate for the hardware at suspension point of suspension string. The diameter of screw shall no longer been changed, and only the aperture and thickness of connection between suspension plate and hardware shall be adjusted.

5.6.6.2 Yoke Plate

It is recommended to adopt integral yoke plate for the suspension yoke plate and strain yoke plate in this project.

5.6.6.3 Wire Clip

It is recommended to adopt handbag type corona shielding suspension wire clip for the conductor suspension wire clip in this project, and it is recommended to adopt hydraulic type for the conductor strain wire clip.

5.6.6.4 Grading Ring and Shielding Ring

For suspension ring and strain ring, the installation position of grading ring shall be between the second piece and the third piece of insulator, the grading effect is relatively good, 100mm annular pipe shall be adopted for both grading ring and shielding ring and the radius of ring shall be 500mm.

5.7 Distance to Ground and Clearing of Route

Value for the distance to ground and overhead crossing of ±660kV HVDC transmission line shall be taken temporarily by relevant requirements in chapter 13 of "Technical regulations for design of HVDC overhead transmission line" and the experience in design of Ningdong-Shandong ±660kV HVDC project.

For residential areas, the synthetic field intensity shall be limited at 30kV/m in rainy days and 25kV/m in sunny days; and the ion flow density shall be limited at 100nA/m^2 in rainy days and 80nA/m^2 in sunny days.

For non-residential areas, the synthetic field intensity shall be limited at 36kV/m in rainy days and 30kV/m in sunny days; and the ion flow density shall be limited at 150nA/m^2 in rainy days and 100nA/m^2 in sunny days.

5.7.1 Distance to Ground

The distance to ground of this project is shown in the following table.

Table 5.7.1-1 Distance to ground of ±660kV HVDC line

Place	Vertical distance (m)	Clear distance (m)	Horizontal distance (m)
Agricultural cultivation area	16		
Non-agricultural cultivation area	14		
Difficult transport area	13.5		
Hillsides accessible on foot		11	
Hillsides, cliffs and rocks inaccessible on foot		8.5	
Building	15		
Building (maximum designed sag)	14.0		
Building(maximum designed wind deflection)		13.5	
Building(Conductor at opposite side under circumstance of no wind)			6.5
Tree (fruit tree)	10.5(12.0)	10.5	

Note: The calculation condition for distance to ground is the sag at +75℃.

5.7.2 Distance of Overhead Crossing

The distance of overhead crossing to the object of crossing in this project is shown in the following table.

Table 5.7.2-1 Distance of crossings

No.	Name of object of crossing		Minimum distance (m)	Calculation condition
1	Railway	To the rail top	18	The sag when conductor temperature is + 80℃
		To the catenary or line of contact (pole top)	8(10.5)	The sag at +52.5℃
2	Road	Grade 1－3	18	Grade 1 Road shall be calculated by 80℃, and others shall be calculated by +52.5℃
3	Non navigable river	To once-in-a-century water level	10	The sag at+52.5℃
4	Power line	Within length of span	8	The sag at+52.5℃
		Pole top	10.5	The sag at+52.5℃
5	Communication line		14	The sag at+52.5℃
6	Special pipe		14	The sag at+52.5℃

No.	Name of object of crossing		Minimum distance (m)	Calculation condition
7	Cableway		8	The sag at+52.5℃

Table 5.7.2-2 Minimum horizontal distance

Item				Minimum horizontal distance (m)
Railway	Tower boundary to track center		Crossing	35 m, or determined through negotiation
			Parallel	tower height plus 3.1 m,
Road	Crossing	Tower boundary to track center		15.0 or determined through negotiation
	Parallel	Track boundary to subgrade boundary	Open area	tower height
			Route restricted area	10.5 or determined through negotiation
Navigable River	Side phase conductor to upper limb of slop (lines in parallel with guying road)			tower height
Non-Navigable River				
Telecommunication Line	To side pole conductor（Parallel）		tower height	tower height
			Route restricted area under the maximum wind deflection)	11
Power Line	To side pole conductor（Parallel）		Open area	tower height
			Route restricted area	13 m to closest conductor and 8.5 to tower(under the maximum wind deflection)
Special Pipeline&Cableway	To any part		Open area	tower height
			Route restricted area under the maximum wind deflection)	13

5.7.3 Principle for Clearing of Route

When HVDC transmission line is adjacent to private house, the undistorted synthetic electric field on the ground surface in the location of private house under circumstance of wet conductor shall not exceed 15kV/m. The scope of house demolition in the line corridor shall be as follows in principle:

(1) It shall be demolished without exception when it is located at and within 6.5m

from the ground projection of side conductor.

(2) For houses outside 6.5m, the clear distance shall be guaranteed to be 14m at the time of maximum wind deflection, and they can be left unmoved when the synthetic electric field of house ground 6.5m outside the side conductor is less than the restricted value of 15kV/m, otherwise, the all houses within the line corridor shall be pulled down and removed.

Ordinary forest trees below the line corridor shall be removed in principle, and economic crops and fruit trees shall be overhead crossed.

5.8 Lightning Protection and Grounding

For design of grounding for lightning protection of transmission lines, it is proposed to mainly adopt the following measures:

(1) Dual earth wire shall be adopted for the whole line, and the protection angle of earth wire shall be not more than 0°.

(2) The distance between two earth wires on the tower shall not exceed 5 times the vertical distance between conductor and earth wire, so as to guarantee the joint protection effect of two earth wires.

(3) At the time of no wind at +15℃, the distance between conductor and earth wire at the center of span shall meet the stipulations in "Technical guide for HVDC overhead transmission line": $S \geqq 0.012L+1.5$ (S is the distance between conductor and earth wire, and L is length of span);

(4) The footing resistance of tower should be restricted as to table 5.8-1..

Table 5.8- 1 The limiting values of tower footing resistance

Area	agricultural district	desert	desert
earth resistivity ρ (Ω•m)	$0< \rho \leqslant 1000$	$1000< \rho \leqslant 2000$	$\rho > 2000$
limiting values of tower footing resistance R (Ω)	10	20	25

5.9 Tower family

Analysis shows that the most economical span for this project shall be 460m, since certain margin shall be taken into consideration for wind span at the time of actual locating, combined with the utilization rate of wind span for tower in the previous project, the service conditions for tower in this project are shown in Table 9.3-1. Lattice tower will be used in this project

Table 5.9.3-1 Tower family

Tower Type	Angle	Wind Span (m)	Weight Span (m)	Range of Nominal Height (m)	Basic Nominal Height (m)
ZP1	0°	480	600	36~54	45
ZP2	0°	580	750	48~78	69
ZPT	0°	480	600	36~51	51
JP1	0-20°	450	650	30~42	42
JP2	20-40°	450	650	30~42	42
JP3 Terminal Tower	0-60°	450	650	30~42	42

NOTE: considering the section of this HVDC project is relatively long, in order to limit the extent of the damage in a long section, an enhanced suspension tower ZPT will be used for every 3.5km within a constant section.

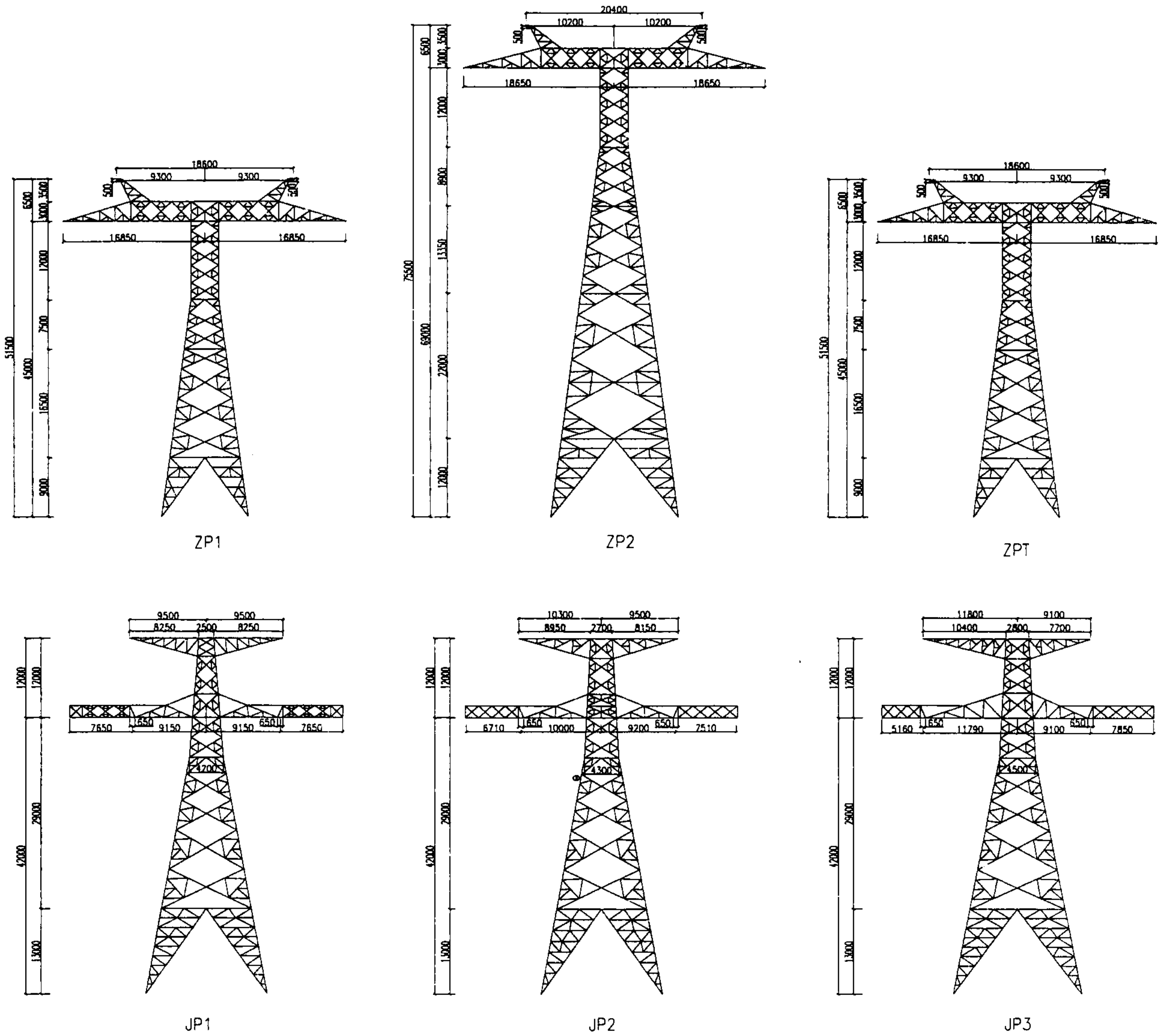


Figure 5.9.3-1 Outlines of tower

5.10 Tower and FoundationDesign

5.10.1 Tower Design

5.10.1.1 Specifications, code and relevant design documents to be observed

The specifications, codes and relevant design documents to be observed during the design of the tower are as follows:

ASCE 74-2009-Guidelines for Electrical Transmission Line Structural Loading

IEC 60826 - Design criteria of overhead transmission lines

ASCE 10-97 - Design of latticed steel transmission structures

GB/T 3098.1 Mechanical Properties of Fasteners—Bolts, Screws and Studs,

GB/T 3098.2 Mechanical Properties of Fasteners—Nuts-Coarse Thread

GB/T 5117 Covered Electrodes for Manual Metal Arc Welding of Non-alloy and Fine Grain Steels

GB/T 5118 Covered Electrodes for Manual Metal Arc Welding of Creep-resisting Steels.

GB 50661 Code for Welding of Steel Structures.

GB/T 1591 High Strength Low Alloy Structural Steels

GB/T 700 Carbon Structural Steel.

GB 50017 Code for Design of Steel Structures

.etc, and/or other approved standard.

5.10.1.2 Calculation Model of Tower

The calculation analysis of tower is based on the finite element method and the 3D truss model according to the mechanics theory; PLS-TOWER software is used as the analysis software of tower in this project.

5.10.1.3 Wind Pressure in Basic Design

The designed basic wind velocity is determined as 160km/h (height 10m from the ground and time distance 3s) according to the technical data that have been collected. The corresponding earth wires, insulators and tower wind pressure are calculated as per the specification, and the wind load shape coefficients of conductor, earth wire and insulator are all 1.0.

5.10.1.4 Safety Factors

According to the existing project experiences, it is recommended to use the safety factors in the following table.

Description	Safety factor
Normal condition	1.7
Broken Wire condition	1.5
Installation condition	1.5

5.10.1.5 Load Conditions

According to the relevant provisions of ASCE74-2009, the load conditions and load combinations usually to be considered in the design are shown in the following table:

Operation condition name	Description of load condition
Normal Condition	Vertical Load: Dead weight of conductor, earth wire, insulator, hardware, tower,worker etc. Horizontal Load: wind pressure, angle tension, tower body wind velocity; Wind load direction: 90°, 45°
Failure Containment case	Structure failure load, e.g.broken wire load, etc.
Installation condition	Structure erection load; Stringing tension load; Worker load

5.10.1.6 Material for Tower

It is recommended to use China's supplies for the steel products of tower. Three categories of China's steel products in the following table shall be adopted while designing the tower at the current stage.

Steel products:

Mild steel: Q235B

High tensile steel: Q345B, Q420B

The characteristics of steel products are as follows:

Standard	Grade	Fy (Mpa) Yield Strength, Fy (Mpa)		Minimum Tensile Strength
		T<=16	t>16	Mpa
GB 700	Q235B	235	225	375
GB1591	Q345B	345	325	470
GB1591	Q420B	420	400	580

Bolts: Grade 6.8 in ISO 898

Yield point: $480N/mm^2$

Tensile strength: $600N/mm^2$

Bolts: Grade 8.8 in ISO 898

Yield point: $640N/mm^2$

Tensile strength: $800N/mm^2$

(1) The members of tower all use the hot-rolled equal-leg angle steels. The high-strength steel shall be selected according to the economic comparison. In general, it is not suitable to adopt the high-strength steel for the members whose slenderness ratio is greater than 80 or whose specification is less than 125×10 (excluding the tension member).

(2) When using the Q420 high-strength steel products, the drilling technology shall be used to make the holes. The drilling technology shall be used to make the holes when the thickness of Q345 and Q235 is equal to and greater than 14mm.

(3) Q235B and Q345B steel electrodes shall use E43 type and E50 type. The welding operation shall be avoided as far as possible for the Q420B high-strength steel.

(4) The connecting bolts shall use M16(Grade 6.8), M20(Grade 6.8) and M24 (Grade 8.8) common rough bolts.

5.10.1.7 Other Descriptions

(1) Anti-corrosion measures of tower

The hot-galvanized anti-corrosion measures shall be performed to all members of towers (including stub angle), bolts (including locking fastening nut and anti-theft bolts), gaskets and washers.

(2) Locking and antitheft measures

Antitheft bolts shall be used within the range of 5.10.0m over the ground of the shortest leg. The point of suspension connecting members all use the dual-cap bolts and the locking measures of one standard nut with one thin nut shall be taken for other bolts.

(3) Step bolts and others

The climbing step bolts shall be provided in the main members of tower, and they shall be mounted in a diagonal form. As for the tower with the full height of over 60m, the simple access platform shall be set up in appropriate position and the safety fence shall be set up at the periphery of the platform.

(4) Anti climbing device

The anti climbing device shall be set above the first septal surface using the barbed wire steel and set a door locking with bolts, nuts, fastening nut

5.10.2 Foundation Design

5.10.2.1 Design Specifications

(1) American concrete institutes (ACI318)

(2) IEEE Guide for Transmission Structure Foundation Design and Testing (IEEE Std 691-2001)

(3) GB 50010 Code for Design of Concrete structures

(4) GB1499.1 Steel for the reinforcement of concrete: Hot rolled plain bars

(5) GB1499.2 Steel for the reinforcement of concrete: Ribbed bars

(6) JGJ 18 Specification for welding and acceptance of reinforcing steel bars

.etc, and/or other approved standard.

5.10.2.2 Selection of Foundation Types

Valleys and plains area: the drilled shaft foundation can be adopted in the locations distributed by plastic and hard-plastic clay if there is no underground water; the pad&chimney foundation can be adopted for the soft plastic clay according to the site conditions; the pile foundation can be adopted for the tower location that does not meet the requirement of natural foundation and the pile can use the borehole grouting piles; the pile foundation can be adopted in the locations distributed by silty sands if there exist the liquefied sandy soils and the pile can use the borehole grouting piles.

Desert Land: remove the surface floating sand in the dune area and use the middle compact silt and fine sand as the bearing stratum of the foundation. If there is no underground water, the drilled shaft foundation and pad&chimney foundationcan be adopted without consideration of the liquefaction of siltysands. The pile foundation can be adopted for the tower location that does not meet the requirement of natural foundation and the pile can use the borehole grouting piles.

(1) Pad&chimney foundation

The main feature of this foundation is that the main column slope of the foundation is consistent with that of the tower leg. The result of this design enables the horizontal force perpendicular to the axial line of the foundation to be reduced for at least 50% and the axial action force of the foundation only increases by 1-2%. This result has significantly improved the force bearing situation of the foundation columns and base plates (slabs) to minimize the impact of the foundation horizontal force on the foundation slabs and improve significantly the stability of the foundation. Meanwhile, due to significant reduction of eccentric bending moment, the dimension of foundation slabs controlled by downward stability is correspondingly reduced so that the concrete quantity and slab reinforcement amount are reduced, which can greatly save the consumption of foundation materials. Foundation of this kind can be used in most of the locations in this project.

(2)Drilled shaft foundation

The drilled shaft foundation applies to the hard-plastic and plastic clay geological condition without underground water.

The application of the drilled shaft foundation has avoided the large excavation: on one hand, it has reduced the destruction to the environment; on the other hand, it has significantly enhanced the uplift-resisting ability of the foundation because the internal friction angle and cohesion of undisturbed soil has been brought into the full play due to the reduction of the disturbance for the undisturbed soils. The soil is used to replace the formwork and the reinforced framework and concrete of the foundation is directly grouted into the shaped soil structure to reduce the construction cost, which indicates the higher economic benefit and environment benefit.

(3) Pile foundation

In the area with flow-plastic geological condition, deeper foundation bearing stratum, flooding impact, higher diffuse water depth and river-crossing area, etc., the method of borehole grouting piles for the foundation is a kind of widely applied method in the design. The friction force with the surrounding soil and the pile end bearing capacity are used to bear the uplift force and down pressure of the foundation. It is characterized by convenient construction and safety and reliability. The disadvantages include big construction difficulty and high construction cost.

5.10.2.3 Safety Factors

It is recommended to use the safety factors in the following table.

Description	Safety factor
Uplift Condition	1.2
Compression Condition	1.2

5.10.2.4 Foundation Materials

For foundation materials, the equivalent quality materials can be used, such as GB、ASTM or other codes.

5.10.2.4.1 Foundation concrete

Foundation material is designed according to the following principles. The compressive strength of concrete shall be 21Mpa for normal type of foundation、27.5MPa for pile foundation and the quality of concrete shall conform to the ACI standards. For corrosive areas, improve concrete strength grade according to corrosion grades

5.10.2.4.2 Steel products for the foundation

For Chinese materials, the main reinforcement of the foundation adopts HRB400 reinforced bars and the stirrup and the structural reinforcement use the HPB300 reinforced bars.

For ASTM materials, characteristic strength of reinforcement (fy):

60 grade 420Mpa

5.10.2.5 Connecting Way of Tower and Foundation

The connecting way of stub angle is recommended in this project.

6. Electrode and Electrode Line at Converter Station

6.1 Electrode at M C/S

6.1.1 **Electrode** Site Selection

Based on preliminary field investigation, the following four sites are tentatively considered as candidate sites of **electrode** at sending-end.

Site: 1 (recommended by the Pakistani party): 25°53'31.16"N, 68°48'42.73"E;

Site 2 (recommended by the Pakistani party): 25°47′52.38″N, 68°51′43.68″E;

Site 3: 25°24′33.93″N, 68°49′53.76″E;

Site 4: 25°18'29.94"N, 68°41'9.82"E.

Further field investigation shows that a gas pipeline is routed around 1 km west of site 2, that is, the pipeline passes between site 1 and site 2. And the Hyderabad-Mirpur Khas Railway passes about 9 km north of site 3. As such, all the three sites are not appropriate. Therefore, site 4 is tentatively considered as the site of **electrode**.

6.1.2 System Conditions

DC rated capacity:	4000MW
Rated voltage of the DC Line:	±660 kV
Maximum continuous rated current:	3030A
Maximum overload current (2h):	3333A
Injection current at the electrode due to bipolar imbalance:	below 30.3 A;
Maximum design temperature:	90°C
Maximum permissible pace voltage of the ground:	$7.42+0.0318\rho_s$ (V/m)
Continuous monopolar earth return operation time:	1 month

6.1.3 Main Technical Indexes

Type of **electrode**: shallowly-buried;

Shape of electrode: dual-ring (with a radius of 380/270m);

Material and quantity of electrode: **FeSi** (with a diameter of 50), 2730 pieces (1.5 m per piece);

Active material and quantity: calcined petroleum coke, 4280t;

Total length of **electrode**: 4085 m

Burial depth: 3.5 m (outer ring) and 3 m (inner ring)

Current guiding mode: buried power cables

6.1.4 Main Technical Schemes

(1) The **electrode** is of a regular dual-ring shape, the radius and burial depth of the outer ring are 380 m and 3.5 m respectively; and those of the inner ring 270 m and 3 m respectively. Both the outer ring and inner ring are divided into four sections and have Φ50 **FeSi**. In this project, coke is adopted as the packing, and the sectional area of coke for the outer ring is 0.95m×0.95m and that for the inner ring is 0.8m×0.8m.

(2) 82 infiltration holes and marking piles and 16 inspection wells are provided at the site of **electrode**. The dimensions and burial depth of the marking piles are 150 mm ×150 mm×1200 mm and 800 mm respectively.

(3) Current guiding cables are directly buried. Four cable trenches with a sectional area of 1.2m (width) × 0.3m (depth) are dug from the incoming line center tower to the outer ring of **electrode** at a depth of 1.5 m and covered with concrete precast slab; cable trenches with a sectional area of 0.3m (width) × 0.3m (depth) are also dug at 2 m inside of each ring at a depth of 1.5 m and covered with concrete precast slab.

(4) The enclosure is 14 m (length) ×15 m (width), and the ground within the enclosure is hardened. An incoming line structure is set up within the enclosure, which comprises blocking reactor, blocking capacitor and busbar.

6.2 Electrode at L C/S

6.2.1 **Electrode** Site Selection

Based on preliminary field investigation, the following two sites are tentatively considered as candidate sites of **electrode** of receiving end.

Site 1: 30°52'12.55"N, 73°52'17.28"E;

Site 2 (recommended by the Pakistani party): 30°50'41.47"N, 73°43'35.47"E;

Therefore, site 1 is tentatively considered as the site of **electrode**.

6.2.2 Main System Conditions

DC rated capacity:	4000 MW
Rated voltage of the D.C. Line:	±660 kV
Maximum continuous rated current:	3030 A

Maximum overload current (2h):	3333 A
Injection current at the electrode due to bipolar imbalance	Below 30 A
Maximum design temperature:	90℃
Maximum permissible pace voltage of the ground:	$7.42+0.0318\rho_s$ (V/m)
Continuous monopolar earth return operation time:	one month

6.2.3 Main Technical Indexes

Type of **electrode**:	shallowly-buried
Shape of electrode:	dual-ring (with a radius of 380/270m);
Material and quantity of electrode:	**FeSi** (with a diameter of 50), 2730 piece) (1.5 m per pieces)
Active material and quantity:	calcined petroleum coke, 4280t
Total length of **electrode**:	4085 m
Burial depth:	3.5 m (outer ring) and 3 m (inner ring)
Current guiding mode:	buried power cables

6.2.4 Main Technical Scheme

(1) The **electrode** is of a regular dual-ring shape, the radius and burial depth of the outer ring are 380 m and 3.5 m respectively; and those of the inner ring 270 m and 3 m respectively. Both the outer ring and inner ring are divided into four sections, and have Φ50 **FeSi**. In this project, coke is adopted as the packing, and the sectional area of coke for the outer ring is 0.95m×0.95m and that for the inner ring is 0.8m×0.8m.

(2) 82 infiltration holes and marking piles and 16 inspection wells are provided at the site of **electrode**. The dimensions and burial depth of the marking piles are 150 mm ×150 mm×1200 mm and 800 mm respectively.

(3) Current guiding cables are directly buried. Four cable trenches with a sectional area of 1.2m (width) × 0.3m (depth) are dug from the incoming line center tower to the outer ring of **electrode** at a depth of 1.5 m and covered with concrete precast slab; cable trenches with a sectional area of 0.3m (width) × 0.3m (depth) are also dug at 2 m inside of each ring at a depth of 1.5 m and covered with concrete precast slab.

(4) The enclosure is 14 m (length) ×15 m (width), and the ground within the enclosure is hardened. An incoming line structure is set up within the enclosure, which comprises blocking reactor, blocking capacitor and busbar.

6.3 Electrode Line

6.3.1 Meteorological

The main meteorological elements in the project is shown as below in the following table.

Table 6.3.1-1 **List of main meteorological elements for project design**

Meteorological element	Temperature (°C)	Wind Speed (m/s)	Ice Thickness (mm)
Minimum temperature	-5	0	0
Annual average temperature	25	0	0
Maximum wind speed	15	44.44(31.1)	0
Icing conditions	/	/	/
Maximum temperature	52.5	0	0
failure	-1.1	0	0
Thunderstorm Days	32/year		

Note: the reference wind speed is at 10m average height and 10min range

6.3.2 Selection of Conductor and Earth Wire

(1) Selection of conductor wire

The design maximum continuous rated current and design maximum continuous overcurrent of earth electrode are 3030A and 3333A respectively. It is recommended to use 2 steel-core heat-resistant aluminum alloy strand JNRLH1/G1A-630/45 as the conductor. The technical parameters are given in the table below.

Table 6. 3. 2-1 **List of technical parameters of JNRLH1/G1A-630/45**

Item		Unit	Value
Construction	Heat-resistant aluminum alloy wire	Number of strand/diameter mm	45/4.22
	Galvanized steel wire	Number of strand/diameter mm	7/2.81
Sectional area	Aluminum	mm^2	629.4
	Steel	mm^2	43.41
	Sum	mm^2	672.81
Outer diameter		Mm	33.75
DC resistance at 20 °C		Ω/km	0.04667
Calculated tensile strength		kN	149.6
Integrated elasticity coefficient		N/mm^2	63700
Integrated linear expansion coefficient		1/°C	20.78×10^{-6}
Calculated weight		kg/km	2078.4

(2) Selection of earth wire

Galvanized steel strands GJ-80 are used as earth wire. The table below gives its characteristic parameters.

Table 6.3.2-2 Mechanical and physical characters of earth wire

Item / Type		GJ-80
Structure Number of wire/diameter	Aluminum (mm)	–
	Steel (mm)	11.4/3.8
Calculated sectional area (mm^2)	Aluminum	–
	Steel	79.39
	Total	79.39
Outer diameter (mm)		11.4
Calculated weight (kg/m)		0.6300
Calculated tensile strength (N)		100100
Modulus of elasticity (10 MPa)		18500
Linear expansion coefficient (1/°C)		0.0000115

(3) Safety factor for conductor and earth Wire

The safety factor of conductor and earth wire should be no less than 2.5.The everyday tension of conductor and earth wire should be not more than 25%. The sag of earth wire should be not more than the sag of conductor.

(4) Anti-vibration of conductor and earth wire

The installation of spacers can prevent vibration of bundle conductor to a certain extent. According to the design code and past experience with earth electrode line, FR-4 damper shall be installed all along the 2-bundle conductor provided with spacers.

FR-1 damper is adopted for earth wire GJ-80 of the project for vibration prevention. The number of dampers is as shown in Table 6.2.1-3.

Table 6.2.1-3 Number of dampers

Span (m)	L≤450	450≤L<800	800≤L<1200		NRLH60GJ-600/45 conductor
Number	1	2	3		
Span (m)	L<300	300≤L<600	600≤L<900	≥900	GJ-80 earth wire
Number	1	2	3	4	

6.3.3 Insulation Design

(1) Selection of insulator

Insulators of the project are all approved domestic products. The DC disc insulators are adopted in the conductor insulator string. Both the suspension insulator and tension insulator are model U160BP/170(XZP-160). The electromechanical properties of insulator are as shown in table 6.3.3-1.

Table 6.3.3-1 Electromechanical properties of conductor insulator

Code of insulator	U160BP/170	
Material	Porcelain	Glass
Disc diameter (mm)	320~340	320~340
Nominal structure height *H* (mm)*	170	170
Nominal creep distance *L* (mm)*	≥545	≥545
Connection marks*	20	20
Electromechanical breaking load required (kN)	160	160
Separate tensile test load (kN)	80	80
1min positive DC wet withstand voltage (kV)	55	60
Lightning impulse withstand voltage (kV)	140	140
1min positive and negative DC dry withstand voltage (kV)	140	150
Impulse breakdown voltage (p.u.)	2.8	2.8
Wireless disturbance voltage 10kV, 1MHz (V)	50	50
DC corona extinction voltage (kV)	50	50
Porcelain degradation rate/spontaneous explosion rate (%)	≤0.01	/

Glass spontaneous explosion rate (%)	/	≤0.02

(2) Selection of insulator quantity and arcing horn clearance

Based on recent research on earth electrode line, it is recommended to provide five insulators for the suspension string and tension string respectively near the converter station (within 40% of the length of earth electrode line away from the converter station), three insulators for the suspension string and four insulators for the tension string near the earth electrode (40%-100% of the length of earth electrode line away from converter station). Besides, the arcing horn shall be installed. The number of insulators and arcing horn clearance are as shown in the table below.Table 6.3.3-2 Insulator quantity and arcing horn clearance

Distance from converter station	Number of insulators (suspension/tension/jumper)	Arcing horn gap (mm)
0-40%	5/5/3	700
40-100%	3/4/3	400

(3) Air Gap of Tower Body

Under atmospheric conditions, the clearance between the charged part and tower body shall be designed to match the arcing horn clearance. The clearance between the charged part and tower body shall be no less than the arcing horn clearance to ensure that the discharge occurs on the arcing horn rather than between the conductor and tower body. The clearance varies depending on the distance between the tower and converter station, as shown in table 4-2 in details.

6.3.4 Insulator Strings and Fittings

(1) Assembling of Insulator String

For suspension insulator strings of conductor, 160kN single and dual strings are used; and for those of earth wire, 70kN suspension insulator strings are used.

For tension insulator strings of conductor, 160kN dual strings are used; and for those of earth wire, XDP-100CN insulators with the acing horn are adopted, which are assembled in single strings (two insulators).

For jumper insulator strings of conductor, 160kN single strings are used.

(2) Main Fittings

The heat resistant NY-630/45N tension clamp and CF-630/45 suspension clamp are adopted for the conductor.

The heat resistant NY-80G tension clamp and XGU-2 suspension clamp are adopted for the earthing wire.

(3) Value of Safety Factor

The safety factor adopted for the hardware in this project is shown in Table

6.3.4-1.

Table 6.3.4-1 List of safety factor for hardware

Condition	Maximum load	Maintenance	Line breakage	String breakage
Safety factor	2.5	1.5	1.5	1.5

6.3.5 Clearance to the Earth and Passage

The clearance between the conductor and earth and the distance between the conductor and objects crossed are as shown in table 6.3.5-1 and 6.3.5-2.The operating temperature of conductor is 135°C.

Table 6.3.5-1 Minimum distance between the conductor and the building/woods

No.		Minimum distance (m)	calculation condition
1	Residential area	7.0	Maximum sag
2	Nonresidential area	6.0	Maximum sag
3	Traffic Inconvenience area	5.0	Maximum sag
4	Hillsides accessible on foot	5.0	Maximum wind displacement
5	Hillsides, cliffs and rocks inaccessible on foot	3.0	Maximum wind displacement
6	Vertical distance to the building	5.0	Maximum sag
7	Minimum clearance to the building	4.0	Maximum wind displacement
8	Vertical distance to forest taking consideration of natural growth of trees	4.0	Maximum sag
9	Minimum clearance to trees of the park, green area or tree reserve	3.5	Maximum wind displacement
10	Vertical distance to the fruit tree, commercial crop and urbane roadside tree	4.0	Maximum sag

Table 6.3.5-2 Distance between conductor and objects/obstacles crossed

No.	Name of objects crossed		Minimum distance (m)	Calculation Condition
1	Railway	Clearance from track top	7.5	Maximum sag
		Clearance from load-bearing cable or contact wire	3.0	Maximum sag
2	Road	Class 1	7.0	Maximum sag
3	Non-navigable rivers	Clearance from 100-year flood level	3.0	Maximum sag
4	Power line		3.0	Maximum sag
5	Communication line		3.0	Maximum sag

6.3.6 Lighting Protection and Grounding

The following measures are mainly proposed in the lighting protection and earth design of power transmission line:

(1)Provide the singe earth line with a shielding angle of 30 degrees all the way;

(2) Keep the distance between two earth lines of the tower within five times of the vertical distance between the conductor and earth line to ensure combined protection from both earth lines.

(3) In calm days with a temperature of +15°C, the distance between the conductor and lightning wire at the center of span shall meet the requirement in the *Design Code for*

110kV-500kV Overhead Transmission Line: S≥0.012L+1 (where S refers to the distance between the conductor and lighting wire and L refers to the span);

(4) The footing resistance of tower should be restricted as to table 6.3.6-1..

Table6.3.6-1 The limiting values of tower footing resistance

Area	agricultural district	desert	desert
earth resistivity ρ (Ω•m)	0< ρ ≤1000	1000< ρ ≤2000	ρ > 2000
limiting values of tower footing resistance R (Ω)	10	20	25

6.3.7 Tower Family

The service conditions for tower in this project are shown in Table 6.3.7-1. Lattice tower will be used in this project

Table 6.3.7-1 tower family

Tower Type	Angle	Horizontal span (m)	Vertical span (m)	Range of nominal height (m)	Nominal height (m)
ZP1	0°	380	480	18-33	24
ZP2	0°	450	600	21-36	30
ZPK	0°	600	800	45-60	54
JP1	0-30°	400	500	15-27	27
JP2	30-60° (including the terminal)	400	500	15-27	27

6.3.8 Tower and Foundation Design

6.3.8.1 Tower Design

The specifications, codes and relevant design documents to be observed during the design of the tower are as follows:

ASCE 74-2009-Guidelines for Electrical Transmission Line Structural Loading

IEC 60826 - Design criteria of overhead transmission lines

ASCE 10-97 - Design of latticed steel transmission structures

GB/T 3098.1 Mechanical Properties of Fasteners—Bolts, Screws and Studs,

GB/T 3098.2 Mechanical Properties of Fasteners—Nuts-Coarse Thread

GB/T 5117 Covered Electrodes for Manual Metal Arc Welding of Non-alloy and Fine Grain Steels

GB/T 5118 Covered Electrodes for Manual Metal Arc Welding of Creep-resisting

Steels.

GB 50661 Code for Welding of Steel Structures.

GB/T 1591 High Strength Low Alloy Structural Steels

GB/T 700 Carbon Structural Steel.

GB 50017 Code for Design of Steel Structures

.etc, and/or other approved standard.

6.3.8.2 Calculation Model of Tower

The calculation analysis of tower is based on the finite element method and the 3D truss model according to the mechanics theory; PLS-TOWER software is used as the analysis software of tower in this project.

6.3.8.3 Wind Speed in Basic Design

The designed basic wind velocity is determined as 160km/h (height 10m from the ground and time distance 3s) according to the technical data that have been collected.

6.3.8.4 Tower Load (including the load conditions)

General load conditions to be considered in design and corresponding loads are as shown in the table below:

Table 6.3.8-1 Tower Load

Operation condition name	Description of load condition
Normal Condition	Vertical Load: Dead weight of conductor, earth wire, insulator, hardware, tower, worker etc. Horizontal Load: wind pressure, angle tension, tower body wind velocity; Wind load direction: 90°, 45°
Failure Containment case	Structure failure load, e.g.broken wire load, etc.
Installation condition	Structure erection load; Stringing tension load; Worker load

6.3.8.5 Material for Tower

It is recommended to use China's supplies for the steel products of tower. Two categories of China's steel products in the following table shall be adopted while designing the tower at the current stage.

Steel products:

Mild steel: Q235B

High tensile steel: Q345B

The characteristics of steel products are as follows:

(1) The members of tower all use the hot-rolled equal-leg angle steels. The high-strength steel shall be selected according to the economic comparison. In general, it is not suitable to adopt the high-strength steel for the members whose slenderness ratio is greater than 80 or whose specification is less than 125×10 (excluding the tension member).

(2) Q235B and Q345B steel electrodes shall use E43 type and E50 type. The welding operation shall be avoided as far as possible for the Q420B high-strength steel.

(3 The connecting bolts shall use M16(Grade 6.8), M20(Grade 8.8) and M24 (Grade 8.8) common rough bolts.

6.3.8.6 Other Descriptions

(1) Anti-corrosion measures of tower

The hot-galvanized anti-corrosion measures shall be performed to all members of towers (including stub angle), bolts (including locking fastening nut and anti-theft bolts), gaskets and washers.

(2) Locking and antitheft measures

Antitheft bolts shall be used within the range of 10.0m over the ground of the shortest leg. The point of suspension connecting members all use the dual-cap bolts and the locking measures of one standard nut with one thin nut shall be taken for other bolts.

(3) Step bolts and others

The climbing step bolts shall be provided in the main members of tower, and they shall be mounted in a diagonal form. As for the tower with the full height of over 60m, the simple access platform shall be set up in appropriate position and the safety fence shall be set up at the periphery of the platform.

(4) Anti climbing device

The anti climbing device shall be set above the first septal surface using the barbed wire steel and set a door locking with bolts, nuts, fastening nut

6.3.8.7 Foundation Design

(1) Type Selection

The pad&chimney foundation can be adopted for the soft plastic clay according to the site conditions.

(2) Materials

The grade of concrete strength of the foundation is generally C25 and C30. As for the tower location with corrosion, the grade of concrete strength shall be improved based on the specific corrosion. The cushion layer and protective cap shall all use the C15 concrete. The main reinforcement of the foundation adopts HRB400 reinforced bars and the stirrup and the structural reinforcement use the HPB300 reinforced bars.

(3) Connection of Tower and Foundation

The connecting way of stub angle is recommended in this project.

(4) Foundation Insulation and Corrosion Prevention

Insulation and corrosion prevention measures shall be taken for the tower foundation within 2.0km from the electrode according to relevant specifications.

NATIONAL TRANSMISSION & DESPATCH
COMPANY (NTDC) LIMITED PAKISTAN

FEASIBILITY STUDY

FOR

±660kV HVDC PROJECT

FROM MATIARI TO LAHORE IN PAKISTAN

VOLUME Ⅱ-1

SYSTEM PROTECTION

Pak Matiari-Lahore Transmission Company (Private) Limited

January 2017, Beijing, P.R. China

±660kV HVDC PROJECT
FROM MATIARI TO LAHORE IN PAKISTAN
GENERAL LIST OF CONTENTS

TECHNICAL DEFINITIONS

The following technical definitions apply to this Specification:

Purchaser	National Transmission And Despatch Company Limited (NTDC)
Company	The project company for development, investment, construction, operation and maintenance of the ±660kV HVDC project from Matiari to Lahore in Pakistan.
HVDC System	All of the relevant equipments and systems in bipolar operation, including converter transformers, converter valves, DC yard equipment, AC filter, control& protection system, DC transmission line, electrode and electrode line, etc.
HVDC Project	HVDC System and the relevant construction works in this project. the relevant construction works including outlet and inlet line of converter station, buildings and structures, related auxiliary production facilities and living facilities.
M-L T/L	Matiari-Lahore Transmission Line
AC yard	AC switchgear area in converter station
DC yard	DC switchgear area in converter station
Life yard	Living facilities and part of auxiliary production facilities area in converter station
T area	Transformer area
M-E T/L	Matiari Electrode Grounding Transmission Line
M E/G	Matiari Electrode Grounding
L-E T/L	Lahore Electrode Grounding Transmission Line
L E/G	Lahore Electrode Grounding
M C/S	Matiari Converter Station
L C/S	Lahore Converter Station
M AC busbar	Matiari AC busbar
L AC busbar	Lahore AC busbar
M AC system	Matiari AC system
L AC system	Lahore AC system

P I	Pole I
P II	Pole II

The following abbreviations apply to this Specification:

AC	Alternating Current
ACI	American Concrete Institute
A/D	Analog to Digital
AN	Audible Noise
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing Material
BIL	Basic Impulse Insulation Level
BS	British Standard
BSL	Basic Switching Impulse Insulation Level
CB	Control Building
CCITT	International Consultative Committee on Telephone and Telegraph Systems
CT	Current Transformer
CTV	Capacitive Voltage Transformer
D/A	Digital to Analog
DC	Direct Current
DIN	Deutsches Institute fur Normung
EEI	Edison Electric Institute
EIA	Environmental Impact Assessment
ESCR	Effective Short Circuit Ratio
ESDD	Equivalent Salt Deposit Density
FAT	Factory Acceptance Tests
HF	High Frequency
HVDC	High Voltage Direct Current
IEC	International Electrotechnical Commission

IEEE	Institute of Electrical and Electronics Engineers
I/O	Input/Output
ISO	International Standards Organization
LED	Light Emitting Diode
MMI	Man Machine Interface
MVU	Multiple Valve Unit
NFPA	National Fire Protection Association
OPGW	Optical Fiber Composite Overhead Ground Wire
P&C	Protection and Control
PLC	Power-line Carrier
PT	Potential Transformer
RF	Radio Frequency
RI	Radio Interference
RIV	Radio Interference Voltage
RTU	Remote Terminal Unit
RPC	Reactive Power Controls
SCADA	Supervisory Control and Data Acquisition
SER	Sequence of Events Recorder
SLG	Single Line to Ground Fault
SMC	Station Master Clock
SPC	Software Production Control
SWC	Surge Withstand Capability
TFR	Transient Fault Recorder
UPS	Uninterruptible Power Supply
VDT	Video Display Terminal
VDU	Video Display Unit
VF	Voice Frequency
VT	Voltage Transformer

1. General

1.1 Design Basis

(1) Program for Feasibility Study on ±660kV HVDC PROJECT FROM MATIARI TO LAHORE IN PAKISTAN

(2) NTDCL Specification P-204:2008

(3) IEC standard

1.2 Project Overview

It is planned to complete the two poles of ±660kV HVDC PROJECT FROM MATIARI TO LAHORE IN PAKISTAN in 2019 which has a bipolar capacity of 4000MW for transmitting power from Matiari converter station to Lahore converter station.

1.3 Scope of Design

The scope of design for the Project covers the AC system protection (including 500kV AC transmission line protection, 500kV Busbar protection, 500kV Breaker Failure protection , 500kV shunt reactor protection), dispatch automation, and energy measurement system for Matiari and Lahore converter station systems.DC protection and DC/AC filter protection will be considered in the secondary design of electrical system.

1.3.1 AC protection equipment(including500kV AC transmission line protection, 500kV Busbar protection, 500kV Breaker Failure protection, 500kV shunt reactor protection,132kV line protection) shall be in accordance with NTDCL specification P:204:2008 and relevant IEC standards.

1.3.2 Other AC protection and control (including 500/35kV step-down transformers protection, 35kV reactor protection , 35kV bus bar protection, 35 kV transformers protection, 10kV transformers protection, 132kV busbar protection , fault recorder, etc.) shall follow IEC.

2. Relay Protection and Stability Control Device

2.1 Current Situations of Relay Protection

At present, the 500kV lines in Pakistan power grid are provided with distance protection and multiplex carrier channels are used to transmit the protection information. The models of audio interface devices of the multiplex carriers include ISWT3000, NSD550, and DIP5000.

Recently built 500kV power plants or substations in Pakistan employ computer-based 500kV line protection, bus protection, 500kV circuit breaker protection and fault recorders.

2.2 Principles for Configuration of AC System Protection

2.2.1 Protection of 500 kV Lines

(1) R11 Distance Protection relay Panel – (Set-I).

The main equipment for relay panels are elucidated below:

Sr. No.	**Description.**	**Quantity.**
1.	Distance Relay Set-I as specified in clause 1.12.1(P204:2008)	One
2.	Auto-reclosure with Built-in synchro-check relay as specified in clause 1.12.3(P204:2008)	One
3.	Over voltage relay as specified in clause 1.12.13(P204:2008)	One
4.	Multiple contact high speed, high burden, self reset tripping relay Having (8NO + 2NC) contacts with hand reset flag as specified in clause 1.12.21(P204:2008)	Three Nos.
5.	D.C. Supervision Relay as specified in clause 1.12.23(P204:2008)	One No.
6.	Test block.	Min five Nos. or as per approved scheme.

(2) R12 Distance Protection relay panel – (Set-II).

The main equipment for relay panels are elucidated below:

Sr. No.	Description.	Quantity.
1.	Distance Relay Set-II as	One No.

	specified in clause 1.12.2(P204:2008)	
2.	Auto-reclosure with Built-in synchro-check relay as specified in clause 1.12.3(P204:2008)	One No.
3.	Three phase and one earth fault element non-directional over current and earth fault relay as specified in clause 1.12.8(P204:2008)	One No.
4.	Multiple contact high speed, high burden, self reset tripping relays having (8NO + 2NC) contacts with hand reset flag as specified in clause 1.12.21.Quantity to suit the tripping schemes can be increased.	Four Nos.
5.	D.C. Supervision Relay as specified in clause 1.12.23(P204:2008)	One No.
6.	Test block.	Min 6 Nos. or as approved scheme.

2.2.2 Protection of 500kV Circuit Breaker

(1) R15 Breaker failure protection relay panel for three breakers.
The main equipment for relay panels are elucidated below:

Sr. No.	Description.	Quantity.
1.	Breaker failure relay with two stage timers as specified in clause 1.12.9(P204:2008)	Three Nos. for 500 KV circuit breaker.
2.	Multiple contact high speed, high burden, hand and electrical reset lockout tripping relay as specified in clause 1.12.20(P204:2008)	Three Nos. (18NO+2NC) OR Six Nos.(8NO+2NC)for each bus bar breaker failure protection.
3.	Multiple contact high speed, high burden, hand and electrical lockout tripping relay as specified in clause 1.12.20(P204:2008)	Two Nos.(18NO+2NC) OR Four Nos.(8NO+2NC) for mid breaker B.F.
4.	Electrical Reset Relay as specified in clause	One No.

	1.12.21(P204:2008)	
5.	DC supervision relay as specified in clause 1.12.23(P204:2008)	One No.
6.	Test block.	Quantity as required to suit the scheme.

(2) R16 Trip circuit supervision relay panel for three breakers.

The main equipment for relay panels are elucidated below:

Sr. No.	Description.	Quantity.
1.	Trip circuit supervision relay for each phase as specified in clause 1.12.22(P204:2008)	18 Nos. for 500 KV circuit breakers.
2.	Auxiliary relays as specified in clause 1.12.24(P204:2008)	Quantity as required to suit the scheme.
3.	DC supervision relay as specified in clause 1.12.23(P204:2008)	Two Nos.

2.2.3 R17 Bus Protection

The main equipment for relay panels are elucidated below: High impedance bus differential as specified in clause 1.12.10(P204:2008) OR preferable low impedance bus differential relay as specified in clause 1.12.11(P204:2008).

Sr. No.	Description.	Quantity.
1.	Bus bar protection for 500 KV bus 1 alongwith Bus Wire Protection Relay for 500KV bus bar No.1	One
2.	Bus bar protection for 500 KV bus 2 alongwith Bus Wire Protection Relay for 500KV bus bar No.2	One
3.	Multiple contact high speed, high burden, hand and electrical reset tripping relay as specified in clause 1.12.20(P204:2008) (a) for 500KV bus bar No1 (b) for 500KV bus bar No.2	Three Nos. (18NO+2NC) OR Six Nos.(8NO+2NC). Three Nos. (18NO+2NC) OR Six Nos. (8NO+2NC)
4.	DC supervision relay as specified in clause 1.12.23 (a)for 500KV bus bar No1 (b)for 500KV bus bar No.2	One No. One No.

5	Test Block	Quantity as required to suit the scheme.

2.2.4 Shunt reactor protection panel R20

Sr. No.	Description.	Quantity.
1.	Percentage biased differential relay as specified in clause 1.12.6	One No.
2.	Restricted Earth fault relay as specified in clause 1.12.7	One No.
3.	Over current and earth fault relay as specified in clause 1.12.8	One No.
4.	Trip circuit supervision relay for each pole of circuit breaker.	Six Nos.
5.	Breaker failure relay as specified in clause 1.12.9	One No.
6.	Multiple contact, high speed, high burden, hand and electrical reset lockout tripping relay having (8NO+2NC) contacts as specified in clause 1.12.20	Quantity required as suit the scheme.
7.	Test block.	Three Nos.

Note:Quantities of protection panels/relays mentioned in the above table shall be finalized in light of scope of work during detail design and with reference to NTDCL specification P-204:2008.

2.2.5 Fault Recorder

To analyze the accidents of power system and the action of relay protection devices, fault recorders should be provided in the relay rooms to record the line current and voltage, action of protection devices, and operation of protection channels. These information can be uploaded to the dispatch center via the protection and fault information slave station.

(1) The fault recorders should be computer-based and in conformance to the applicable industrial standards.

(2) The fault recorders in the substations should be of the same model and be networked together, and connected to the relay protection and fault recording information management slave station for uploading the information to the dispatch department for accident analysis and resolution.

(3) The fault recorders should be equipped with multiple GPS synchronization

interfaces for better analysis on the occurrence time sequence of faults.

(4) The fault recorders should have optimum analysis and local networking functions.

(5) The fault recorders should have optimum fault distance measurement function.

2.3 Configuration Scheme of Relay Protection

Refer to:

Fig.Volume II-1-1: Single Line Diagram of 500kV Protection System of Matiari; Fig.Volume II-1-2: Single Line Diagram of 500kV Protection System of Lahore.

2.4 Basic Requirements for Protection Devices

2.4.1 General Requirements

(1) The size of AC system protection panel (including 500kV line protection, 500kV Bus bar protection, 500kV Breaker Failure protection, 500kV shunt reactor protection) shall be 800 x 800 x 2200 mm (Width x Depth x Height).

The size of Other protection & control panel (including 500/35kV step-down transformers protection, 35kV reactor protection , 35kV bus bar protection, 35 kV transformers protection, 10kV transformers protection, fault recorder, etc.) shall be 800 x 600 x 2200 mm (Width x Depth x Height).

(2) For installation against AC system of HVDC transmission project, contractor shall provide 500kV protection relays & 132kV line protection relays(including only 500kV AC transmission line protection, 500kV Busbar protection, 500kV Breaker Failure protection, 500kV shunt reactor protection,132kV line protection , lockout relays, DC supervision relays,test block etc) as per requirements specified in NTDCL specification P-204:2008 and country of origin of protection device inside the panel shall be European/USA/Canada make and Type & ordering codes shall be finalized after deciding any one of the following approved manufacturers.

1.M/s Siemens Europe

2. M/s Schneider Electric Europe

3.M/s GE, Canada

4.M/s SEL USA

5.M/s ABB Europe

6.M/s Alstom Europe

(2) The protection devices shall have the characteristics matching with those of the connected current transformers and be adaptive to the CVT or bus PT on the line side.

(3) The logic circuit of each protection device should be powered by independent

DC-DC converter, and when the DC voltage is lost, the protection device should not act inadvertently and should provide output contact start event records and alarm signals.

(4) The protection device should not act inadvertently even if any component is damaged. In addition, automatic detection function should be provided to give alarm signals when the circuit is abnormal.

2.4.2 Technical Requirements for Fault Recorder

(1) Digital fault recorders which can monitor the operation of power system continuously should be used. The fault recorders should start recording when any starting component acts. When the fault is eliminated or the system oscillation stops, the starting component should return and stop recording after the pre-set time. The recording function should works even during the single-phase reclosing process.

(2) When a fault or oscillation occurs to the power system, the starting components of the fault recorders should be able to start. Manual starting buttons should be provided separately.

(3) The fault recorders should record and save the electrical waveforms from 150ms before the fault till the fault disappearance, and clearly record the waveforms of at least five harmonics.

(4) The fault recorders should record the current, voltage, remote protection signals, active power, reactive power, system frequency, and protection action signals. The sampling frequency for analog signals should not be less than 2000Hz.

(5) Each fault recorder should be provided with one display and its own printer to print the recorded information when needed.

(6) The resolution of the event records should be less than 1.0ms.

(7) The fault recorders should be provided with synchronization device to receive the GPS synchronization clock pulses. Such device should be able to indicate the second, minute, hour, date, month, and year.

2.5 Sequence of Documents/Activities of AC protection Equipment. (during detailed design);

a. Approval of Single Line Diagram of AC protection Equipment.

b.Approval of protection and Metering Concept Diagram of AC protection Equipment..

c. Approval of Make,Type,Country of origin and ordering codes of AC protection

Equipment for 1.3.1 of this technical specfication.

d. Approval of protection and control trip and interlocking logic schemes / diagrams of AC protection Equipment..

e. Approval of AC/DC schematics & interconnection wiring diagrams of AC protection Equipment.

f. Approval of AC & DC auxiliary supply distribution schematic diagram of AC protection Equipment..

g. Vetting of protection relay settings of AC protection Equipment.

h. Vetting of test protocols & credentials of testing & Commissioning engineers of AC protection Equipment..

i. For witnessing Factory Acceptance test of AC Protection Panels of section 1.3.1 at manufacturer works.

j. For witnessing Factory acceptance test of HVDC Control and Protection Panels at manufacturer works.

k. Witnessing of commissioning/testing activities.

2.6 Stability Control Device

According to the security and stability study report written by China Electric Power Research Institute, for worst case, the system keeps transient stability in case of HVDC monopole block fault. In case of HVDC bipolar block fault, the 3960MW unit switch-off and 3000MW load shedding shall be performed to restore the system to stable state. An increase of spinning reserve rate of units in the whole grid can decrease load shedding after a bipolar block fault occurs. System security level will be enhancing, consider the AC compensation network and more Lahore side units in service.

While Pakistan Power Grid constructs HVDC system, the stability control system is recommended to be installed in the receiving/sending-end of HVDC transmission project so as to ensure the safety of power grid at detailed design/implementation stage.

According to the 3960MW unit switch-off, HUBCO CPP, PORT QASIM CFPP, THAL NOVA, ENGRO THAR, TEL and SSRL should be resectable in order to meet the requirements. According to the 3000MW load shedding, 20 stations in receiving-end power grid should be set as load shedding substation, assuming that 150MW load shedding is allowed in each substation.

Generally speaking, two sets of stability control master station devices should be configured in Matiari, the same as Lahore. Two sets of stability control substation devices for unit switch-off should be configured in every one of the six power plants at the sending end. Two sets of stability control substation devices for load shedding should be configured in every one of the 20 station in receiving-end power grid.

3. System Dispatch Automation

3.1 Dispatch Administrative Relations

In accordance with the dispatch administrative principles of Pakistan, the operating conditions of Matiari and Lahore Converter Stations and 500 kV lines will be subject to the monitoring of the National Power Control Center (NPCC), and the telecontrol information should be delivered to the NPCC.

In detailed design, CET will submit a detailed signal list regarding HVDC to NPCC for final approval.

3.2 SCADA system Information

The SCADA information shall satisfy the following principles:

(1) Complete telecontrol information should be collected in a timely manner to fully reflect the operating conditions of the power grid.

(2) Information collection shall meet the needs of all levels of dispatch centers for hierarchical management and independent accounting.

(3) Information collection shall meet the requirements of power grid security monitoring and advanced application functions.

(4) The SCADA information shall be directly collected and transmitted to NPCC in real-time.

3.2.1 Telemetering

- Current, voltage, active power and reactive power of 500 kV AC lines;
- Voltage and frequency of 500 kV AC busbar;
- Direct current and harmonic current per pole;
- Electrode line current, harmonic current and ampere-hours;
- DC busbar voltage and harmonic voltage per pole;
- Neutral bus voltage;
- Current active power, maximum and minimum transmitted power and power ramp rate per pole;
- Firing angle α of the rectifier station/extinction angle γ of the inverter station;
- Reactive power and busbar voltage of AC filter bank;

- Reactive power of AC filter subbank;
- Current, voltage, active power and reactive power on the AC side of converter transformer;
- Current and voltage on the valve side of converter transformer;
- Tap changer positions of converter transformer;
- Oil temperature and winding temperature of converter transformer.

3.2.2 Telesignaling

- Position signal (two-position signal) of circuit breaker in AC switchyard;
- Position signal (two-position signal) of disconnector in AC switchyard;
- Position signal (two-position signal) of earthing switch and lock-out signal for the line side;
- 500 kV AC busbar protection operation signal;
- 500 kV AC line protection operation signal;
- 500 kV AC circuit breaker failure protection operation signal and reclosing operation signal;
- DC operation mode signal (bipolar/monopolar/MR/GR, power direction, reduced voltage operation, additional control, etc.);
- DC control mode signal (power control/current control/joint control and independent control, etc.);
- Position signal of circuit breaker in DC switchyard;
- Position signal of disconnector and earthing switch in DC switchyard;
- Converter transformer protection operation signal;
- Converter valve main protection operation signal;
- Pole main protection operation signal;
- Bipole main protection operation signal;
- Main alarm signals of converter valve.

3.2.3 Teleregulation/Telecontrol

- 500 kV AC circuit breaker opening/closing control;
- Switching of reactive power compensation device;

- Master/slave control station selection command;
- Lead pole selection command;
- DC circuit breaker closing/opening command;
- (Bipole) pole start/stop command;
- DC operation mode selection command;
- DC control mode selection command;
- (Bipole) pole current/power step up, step down and stop command;
- Automatic power curve power and time setting command.

3.3 SCADA System Scheme

The SCADA system is configured in combination with the scheme for network control system. The telecontrol system and the network control system share the data acquisition unit. Redundant telecontrol workstations are connected to the SCADA system. The data is directly transmitted to the SCADA workstation without being processed by the host station of network control system. The SCADA workstation is operating independent of the background network control system without interference.

The SCADA information of converter station should be transmitted to the NPCC through GATEWAY.

3.4 Energy Metering System

3.4.1 Provision of Metering Points

The metering points of Matiari and Lahore Converter Stations are tentatively provided at the following locations:

- Outgoing line side of 500 kV AC line
- AC side of converter transformer
- Incoming line side of external auxiliary power supply

3.4.2 Configuration of Energy Metering System

Two (main and backup) bi-directional 0.2s multi-rate energy meters are installed at each metering point. The main metering system is supplied by the purchaser;

And backup metering system is supplied by the company. Details are as follows:

Table 3.4-1: Configuration of energy meters at metering points

Metering Point	Quantity of Energy Meters		Accuracy
	Matiari	Lahore	
Each circuit of 500 kV line	10×2	6×2	0.2s for active, 1.0s for reactive
AC side of converter transformer	2×2	2×2	0.2s for active, 1.0s for reactive
External auxiliary power supply	2×2	2×2	0.2s for active, 1.0s for reactive

Matiari and Lahore Converter Stations are provided with two sets of energy remote terminals, to which energy meters are connected through serial ports. The energy remote terminal shall reliably and accurately collect and store the metering data from all energy meters and transmit to the network control system.

NATIONAL TRANSMISSION & DESPATCH
COMPANY (NTDC) LIMITED PAKISTAN

FEASIBILITY STUDY

FOR

±660kVHVDC PROJECT

FROM MATIARI TO LAHORE IN PAKISTAN

VOLUME Ⅱ-2

SYSTEM COMMUNICATION

Pak Matiari-Lahore Transmission Company (Private) Limited

January 2017, Beijing, P.R. China

±660kV HVDC PROJECT
FROM MATIARI TO LAHORE IN PAKISTAN

GENERAL LIST OF CONTENTS

TECHNICAL DEFINITIONS

The following technical definitions apply tothis Specification:

Purchaser	National Transmission And Dispatch Company Limited (NTDC)
Company	The project company for development, investment, construction, operation and maintenance of the ±660kV HVDC project from Matiari to Lahore in Pakistan.
HVDC System	All of the relevant equipments and systems in bipolar operation, including converter transformers, convertor valves, DC yard equipment, AC filter, control& protection system, DC transmission line, electrode and electrode line, etc.
HVDC Project	HVDC System and the relevant construction works in this project. the relevant construction works including outlet and inlet line of converter station, buildings and structures, related auxiliary production facilities and living facilities.
M-L T/L	Matiari-Lahore Transmission Line
AC yard	AC switch gear area in converter station
DC yard	DC switch gear area in converter station
Life yard	Living facilities and part of auxiliary production facilities area in converter station
T area	Transformer area
M-E T/L	Matiari Electrode Grounding Transmission Line
M E/G	Matiari Electrode Grounding
L-E T/L	Lahore Electrode Grounding Transmission Line
L E/G	Lahore Electrode Grounding
M C/S	Matiari Converter Station
L C/S	Lahore Converter Station
M AC busbar	Matiari AC busbar
L AC busbar	Lahore AC busbar
M AC system	Matiari AC system
L AC system	Lahore AC system

P I	Pole I
P II	Pole II

The following abbreviations apply to this Specification:

AC	Alternating Current
ACI	American Concrete Institute
A/D	Analog to Digital
AN	Audible Noise
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing Material
BIL	Basic Impulse Insulation Level
BS	British Standard
BSL	Basic Switching Impulse Insulation Level
CB	Control Building
CCITT	International Consultative Committee on Telephone andTelegraph Systems
CT	Current Transformer
CTV	Capacitive Voltage Transformer
D/A	Digital to Analog
DC	Direct Current
DIN	Deutsches Institute fur Normung
EEI	Edison Electric Institute
EIA	Environmental Impact Assessment
ESCR	Effective Short Circuit Ratio
ESDD	Equivalent Salt Deposit Density
FAT	Factory Acceptance Tests
HF	High Frequency
HVDC	High Voltage Direct Current
IEC	International Electrotechnical Commission

IEEE	Institute of Electrical and Electronics Engineers
I/O	Input/Output
ISO	International Standards Organization
LED	Light Emitting Diode
MMI	Man Machine Interface
MVU	Multiple Valve Unit
NFPA	National Fire Protection Association
OPGW	Optical Fiber Composite Overhead GroundWire
P&C	Protection and Control
PLC	Power-line Carrier
PT	Potential Transformer
RF	Radio Frequency
RI	Radio Interference
RIV	Radio Interference Voltage
RTU	Remote Terminal Unit
RPC	Reactive Power Controls
SCADA	Supervisory Control and Data Acquisition
SER	Sequence of Events Recorder
SLG	Single Line to Ground Fault
SMC	Station Master Clock
SPC	Software Production Control
SWC	Surge Withstand Capability
TFR	Transient Fault Recorder
UPS	Uninterruptible Power Supply
VDT	Video Display Terminal
VDU	Video Display Unit
VF	Voice Frequency
VT	Voltage Transformer

VOLUME Ⅱ-2 CONTENTS

1 General

The system communication design of this project mainly includes DC fiber-optic communication, relevant channel organization, communication equipment configuration in converter stations, etc.

2 Project Overview

The Pakistan Matiari-Lahore DC Transmission Project is planned to realize bipolar operation with a bipolar power transmission capacity of 4000 MW, and a line length of about 878 km from the sending end Matiari Converter Station to the receiving end Lahore Converter Station.

2.1 MatiariConverter Station

In this phase, the construction scale for Matiari Converter Station is tentatively determined as follows:

(1) One circuit of ±660 kV/4000 MW HVDC transmission line.

(2) 500 kV AC outgoing lines: twelve circuits for this phase, one to Moro Substation, one to Dadu New Substation,two to Jamshoro Substation, two to Hubco New Plant, two to Qasim Plant, two to Thar Plant, and two spare. The connectionsfrom Matiari Converter Station to 500 kV system are shown in Figure2.1-1.

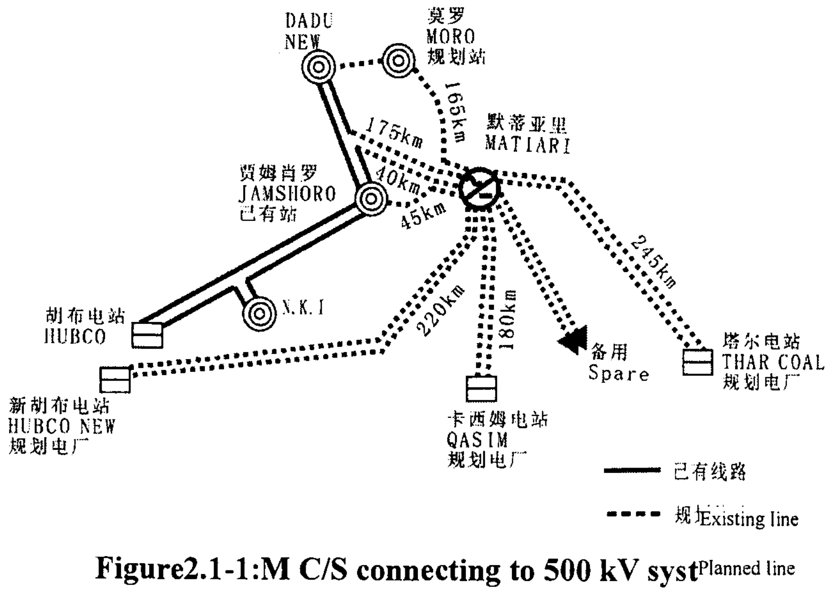


Figure2.1-1:M C/S connecting to 500 kV syst

2.2 Lahore Converter Station

In this phase, the construction scale for Lahore DC Converter Station is tentatively determined as follows:

(1) One circuit of ±660 kV/4000 MW HVDC transmission line.

(2) 500 kV outgoing lines: six circuits for this phase, two to Lahore South Substation, two to Lahore Substation, two to Lahore North Substation, with space for future expansion. The connections from Lahore Converter Station to 500 kV system are shown in Figure 2.2-1.

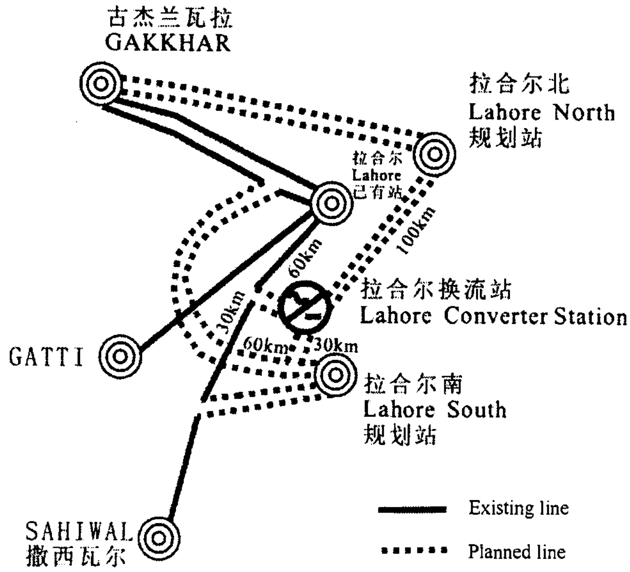


Figure 2.2-1:L C/S connecting to 500 kV system

2.3 Dispatch Relations

In accordance with the dispatch administrative principles of Pakistan, the operating conditions of Matiari and Lahore Converter Stations and 500 kV lines will be subject to the monitoring of the National Power Control Center (NPCC), and the telecontrol information should be delivered to the NPCC.

3 Needs Analysis

3.1 Requirements of DC Control & Protection on Communication Channel

Table 3.1-1: Requirements of DC control & protection on communication channel

No.	Type of Service	Channel Type	Qty.	Remarks
1	Pole 1 main pole control channel	2Mbit/s	1	
2	Pole 2 main pole control channel	2Mbit/s	1	
3	Pole 1 main protection channel	2Mbit/s	3	
4	Pole 2 main protection channel	2Mbit/s	3	
5	Pole 1 spare pole control channel	2Mbit/s	1	
6	Pole 2 spare pole control channel	2Mbit/s	1	
7	Pole 1 spare protection channel	2Mbit/s	3	
8	Pole 2 spare protection channel	2Mbit/s	3	
9	DC station control channel	2Mbit/s	2	
10	DC fault location channel	2Mbit/s	2	

3.2 Requirements of Matiari C/S Channel

Table 3.2-1: Requirements of M C/S

No.	Type of Service	Channel Type	Qty.	Remarks
1	Telecontrol channel: Matiari Converter Station-NPCC	2Mbit/s	1	
2	500 kV AC line protection channel: Each circuit from Matiari Converter Station to 500kV Substation/Plant	2Mbit/s	1	
		PLC channel	1	
3	System dispatch switched network	2Mbit/s	2	

3.3 Requirements of Lahore C/S Channel

Table 3.3-1: Requirements of L C/S

No.	Type of Service	Channel Type	Qty.	Remarks
1	Telecontrol channel: Lahore Converter Station—NPCC	2Mbit/s	1	
2	500 kV AC line protection channel: Each circuit from Lahore Converter Station to 500kV Substation	2Mbit/s	1	
		PLC channel	1	
3	System dispatch switched network	2Mbit/s	2	

4 System Communication Scheme

4.1 Construction Scheme of Optical Fiber Cables

(1) HVDC OPGW

Table 4.1-1: Construction scheme of DC OPGW

No.	Cable Section	Cable Type	Number of Fibre Core	Line Length (km)	Remarks
1	Matiari Converter Station—Lahore Converter Station	2 OPGWs	24	878	G.652

(2) AC OPGW of Matiari Converter Station

The construction for AC optical fiber cable of Matiari Converter Station is not the scope of this project. According to the planning of NTDC, the construction scheme of AC optical fiber cable mentioned above are as followings.

Table 4.1-2: Construction scheme of AC OPGW of M C/S

No.	Cable Section	Cable Type	Number of Fibre Core	Line Length (km)	Remarks
1	One circuit of 500 kV AC outgoing line from Matiari Converter Station to Moro Substation	1 OPGW	24	160	Not in The Company Scope
2	One circuit of 500 kV AC outgoing line from Matiari Converter Station to Jamshoro Substation	1 OPGW	24	50	Not in The Company Scope
3	Two circuits of 500 kV AC outgoing lines from Matiari Converter Station to Hubco New Plant	1 OPGW	24	225	Not in The Company Scope
4	Two circuits of 500 kV AC outgoing lines from Matiari Converter Station to Qasim Plant	1 OPGW	24	188	Not in The Company Scope
5	Two circuits of 500 kV AC outgoing lines from Matiari Converter Station to Thar Plant	1 OPGW	24	252	Not in The Company Scope

(2) AC Optical Fiber Cable of Lahore Converter Station

Except for Lahore Converter Station-Lahore Substation 500kV AC optical fiber cable, the construction for other AC optical fiber cable of Lahore Converter Station is not the scope of this project. According to the planning of NTDC, the construction scheme of AC optical fiber cable mentioned above are as followings.

Table 4.1-3: Construction scheme of AC OPGW of L C/S

No.	Cable Section	Cable Type	Number of Fibre	Line Length	Remarks

			Core	(km)	
1	Two circuits of 500 kV AC outgoing lines from Lahore Converter Station to Lahore South Substation	1 OPGW	24	30	Not in The Company Scope
2	Two circuits of 500 kV AC outgoing lines from Lahore Converter Station to Lahore Substation	1 OPGW	24	60	OPGW and Accessories provide by The Company
3	Two circuits of 500 kV AC outgoing lines from Lahore Converter Station to Lahore North Substation	1 OPGW	24	100	Not in The Company Scope

Note: According to the Minutes of Meeting between The Company and NTDC. The Company offer the OPGW from Lahore Converter Station to 500kV Lahore Substation. NTDC offer parameters, length etc. The Company is in charge of procurement, but not in charge of design, construction and operation.

4.2 Construction Scheme of DC Fiber-optic Communication Circuits

4.2.1 Scale of DC Fiber-optic Circuits

Using the DC OPGW, two 2.5Gb/s SDH links will be set up between Matiari Converter Station and Lahore Converter Station, thereby forming the main channel there between.

As the distance of DC line between Matiari Converter Station and Lahore Converter Station is about 878km, optical communication repeater stations are necessary. Three optical repeater stations nearby Khairpur, Rahimyar Khan and Hasilpurwill be constructed.

4.2.2 Configuration of DC System Communication Equipment

Two sets of SDH equipment will be respectively provided for Matiari Converter Station, Rahimyar Khan Repeater Station, Hasilpur Repeater Station, Khairpur Repeater Station and Lahore Converter Station, totally 10 sets. The capacity of each SDH is 2.5Gb/s. The SDH route is Lahore Converter Station- Hasilpur Repeater Station- Rahimyar Khan Repeater Station- Khairpur Repeater Station- Matiari Converter Station.

PDH equipment will be provided for each of the above 5 communication stations. Otherwise, If the SDH equipment has the PDH function, use the SDH (including PDH function cards) instead of separate PDH equipment. Existing PDH equipment will be used at NPCC to cater to the need of this project.

Network management system will not be configured; the 10 SDH sets in this project will be managed by the existing NMS in NPCC. License for SDH equipment shall be procured by the Company.

Clock synchronization system will not be configured or provided by the Company.

For HVDC Fiber-optic Communication system, this project will set up NMS for amplifiers management, The server of NMS will be installed at Lahore Converter Station, where as a terminal will be installed at Matiari Converter Station and each repeater station.

4.3 Construction Scheme of Communication Repeater Station

(1)General Communication Repeater Station

In this phase, there are three repeater stations: Khairpur, Rahimyar Khanand Hasilpur repeater stations. All the three repeater stations are used for Optical Communication. Every repeater station area is about 1600m^2. These repeater stations are under or near tower and manned. The drinking water if needed will be send from residence near the repeater stations.

(2)Location of Communication Repeater Station

From Matiari to Lahore. The location of three communication repeater stations are as follows :

1) Khairpur repeater station, tentative site coordinate: E69°04′48.7″,N27°23′28.1″.

2) Rahimyar Khan repeater station , tentative site coordinate: E70°53′07.2″,N28°30′32.7″.

3) Hasilpur repeater station , tentative site coordinate: E72°34′32.6″,N29°38′52.1″.

The locations may be adjusted within a small scope.

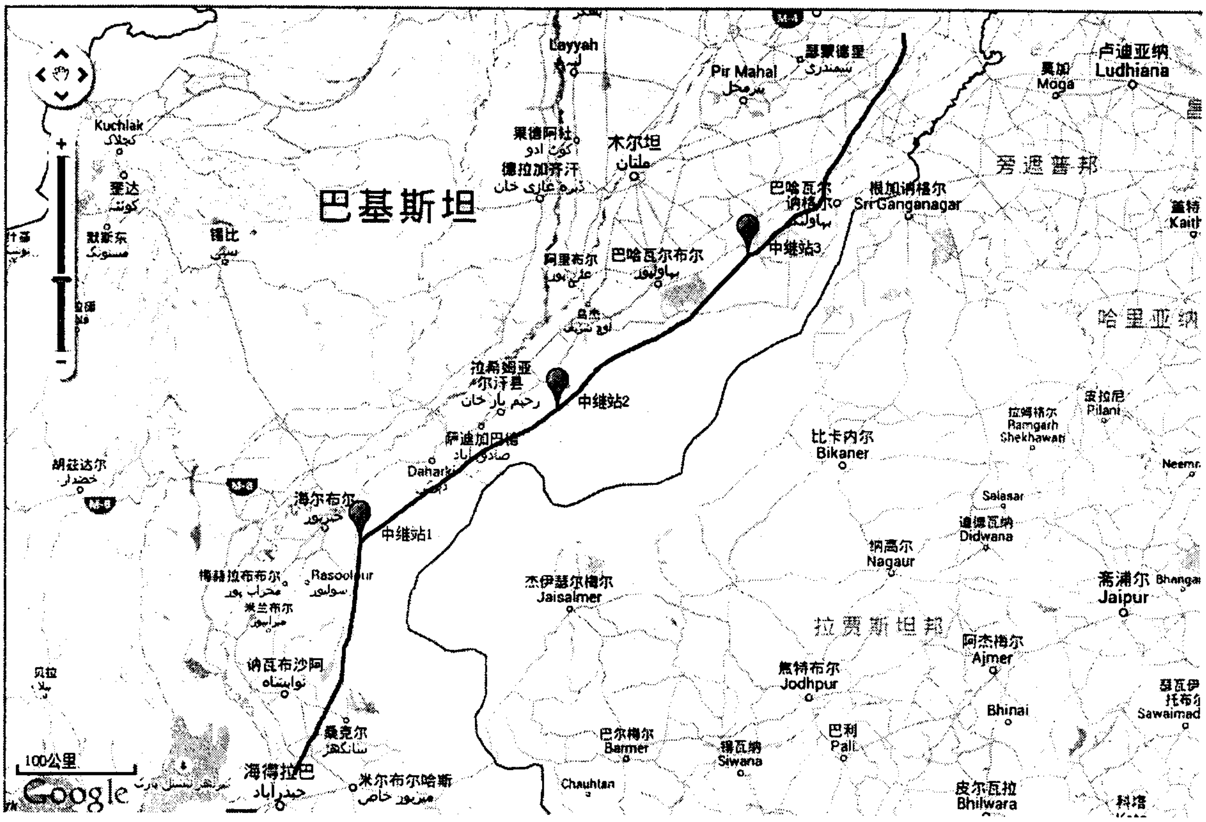


Figure 4.3-1 The location of three communication repeater stations(tentatively)

(3)Architecture of Communication Repeater Station

Only the electrical and civil facilities within the enclosure are considered. Access roads, external power supply and other external facilities beyond the enclosure are supplied by NTDC. The flood level above ground with 50-year recurrence interval. The structure type of main relay station and backup power generator building is reinforced concrete moment-resisting frame which is supported on footings. Partition is masonry wall. Both internal and external walls are painted. The masonry security fence is decorated with cement mortar and supported on strip foundation. Equipment supports are selected as steel latticed structures with reinforced single footings. Transformer is supported on reinforced concrete foundation.

(4)Power supply of Communication Repeater Station

The main power supply of repeater stations is sourced from the 11 kV spare bay of nearby substation or 11kV transmission line nearby. The standby power supply uses double diesel generator system. In case of failure of the external power supply, the repeater station will be powered by diesel generator system. In case of failure of Generators the communication equipment will be powered by batteries (500AH) for 10hours.The diesel generator system uses its own relay protection, such as over current, over frequency, low voltage etc. Automatic Transfer Switch will be used to switch among external power and double diesel generator system. There is also a

3kVA UPS for communication equipment and power environment monitoring devices, with external 100Ah battery group.

(5)Monitor of Communication Repeater Station

Alarm information of the communication equipment and power environment information will be sent to L C/S.

(6) General layout Communication Repeater Station

Rahimyar Khan repeater station has two areas: HVDC equipment area and communication building area. Khairpur repeater station and Hasilpur repeater station only have communication building area. All the repeater stations are under or near tower and manned.

HVDC equipment area is taking HVDC tower for center and symmetrical arranged. Communication building area for all repeater stations has communication building, emergency generator building, etc.

4.4 AC Fiber-optic Communication Circuits

Matiari Converter Station to opposite plants and substations will utilize SDH type of communication, each direction will set up 2×622Mb/s SDH links. The SDH cards of Matiari Converter Station is in the scope of this project, the SDH equipment and SDH cards of opposite plants and substations, are not in the scope of this project.

Lahore Converter Station to 500kV Lahore Substation、Lahore South Substation and Lahore North Substation will utilize SDH type of communication, each direction will set up 2×622Mb/s SDH links. The SDH cards of Lahore Converter Station is in the scope of this project, the SDH equipment and SDH cards of opposite side plants and substations, are not in the scope of this project.

4.5 AC Power Line Carrier Communication

Matiari Converter Station to opposite plants and substations will set up 1 PLC links on each 500kV AC line for now, which will be backup of transmission of line protection signal.

Lahore Converter Station to opposite substations will set up 1 PLC links on each 500kV AC line for now, which will be backup of transmission of line protection signal.

All the above PLC links will use phase-phase coupling type.

The Company considers AC PLC equipment in Matiari Converter Station and Lahore Converter Station. The AC PLC equipment of opposite side plants and substations, are not in the scope of this project.

4.6 Channels and Routing Assignment

4.6.1 DC Protection & ControlCommunication Channel

Main channel: Matiari Converter Station—HVDC OPGW fiber communication circuit 1—Lahore Converter Station;

Alternate channel: Matiari Converter Station—HVDC OPGW fiber communication circuit 2—Lahore Converter Station.

4.6.2 Channel to Dispatch Center

(1) Matiari Converter Station—NPCC

Main channel: Matiari Converter Station—HVDC OPGW fiber communication circuit—Lahore Converter Station—500kV Lahore Substation—500kV Ghakkar Substation—500kV New RewatSubstation—220kV New Rewat Substation—220kV ISDU Substation—220kV ZP Substation—NPCC.

Alternate channel: Matiari Converter Station—HVDC OPGW fiber communication circuit—Lahore Converter Station—500kV Lahore Substation—500kV Ghakkar Substation—500kV New Rewat Substation—220kV New Rewat Substation—220kV ISDU Substation—220kV ZP Substation—NPCC.

(2) Lahore Converter Station—NPCC

Main channel: Lahore Converter Station—500kV Lahore Substation—500kV Ghakkar Substation—500kV New RewatSubstation—220kV New Rewat Substation—220kV ISDU Substation—220kV ZP Substation—NPCC.

Alternate channel: Lahore Converter Station—500kV Lahore Substation—500kV Ghakkar Substation—500kV New RewatSubstation—220kV New Rewat Substation—220kV ISDU Substation—220kV ZP Substation—NPCC.

The Company will be responsible for Data Link between Matiari and Lahore converter Station. From Lahore Converter station onward NPCC, Telecom NTDC will provide the data Link. The safety of the dispatching channel from 500kV Lahore Substation to NPCC is not depended on this project.

4.6.3 AC Line Protection Channel

Line protection signals of 500 kV line from Converter Station to opposite plants and substations, will be multiplex–transmitted by 2Mbit/s fibre channel and PLC channel respectively.

4.6.4 Organization of Data Route Up to NPCC

The Company will be responsible for purchase of equipment in converter station , the

necessary works at stations/sites up to NPCC is not in the scope of the Company. The Purchaser shall be in charge of receiving the SCADA information in NPCC side, including the SCADA equipment possible expansion and the SCADA information checking work. The Purchaser is responsible to provide telecommunication channel from the HVDC project to NPCC and Purchaser (if required).

5 Communication in Converter Station

5.1 Communication Power Supply

Two sets of communication power supply will be provided in duplicate configuration for both Matiari and Lahore Converter Stations, each including two sets of 300A high frequency switching communication DC power supply equipment, two DC distribution panels, and two 1200Ah maintenance-free battery banks.

5.2 System Dispatch Exchange

One system dispatch and station administrative exchange with a capacity of 192 ports will be provided for Matiari Converter Station and Lahore Converter Station respectively. The exchange can be connected to the private power dispatch exchange network via 2Mbit/s digital interface or 2/4 E&M line analog interface, the PBX in Lahore Converter Station access to the Lahore Substation with E1 and E&M channels. the PBX in Matiari Converter Station access to the Jamshoro Substation with E1 and E&M channels, thereby realizing communication with the dispatch center(NPCC).

5.3 Communication Room

The communication equipment of Matiari and Lahore Converter Stations are centralized in the communication equipment room of the main control building, and the batteries are in the communication battery room.

5.4 Broadcasting System

One set of broadcasting system will be provided in Matiari Converter Station and Lahore Converter Station respectively, covering the main control building, valve hall, outdoor switchgear and other areas. The public address and paging function can be used to broadcast messages and alarm signals, and the broadcasting function can be used to notify mobile workers.

5.5 Intra-station Cabling

For Matiari and Lahore Converter Stations, communication cables will be laid in the entire station, and cables for computer network and cable television will be laid in the main control building and administration building.

NATIONAL TRANSMISSION & DESPATCH
COMPANY (NTDC) LIMITED PAKISTAN

FEASIBILITY STUDY

FOR

±660kV HVDC PROJECT

FROM MATIARI TO LAHORE IN PAKISTAN

VOLUME Ⅲ-1

MATIARI CONVERTER STATION

Pak Matiari-Lahore Transmission Company (Private) Limited

January 2017, Beijing, P.R. China

±660kV HVDC PROJECT

FROM MATIARI TO LAHORE IN PAKISTAN

GENERAL LIST OF CONTENTS

TECHNICAL DEFINITIONS

The following technical definitions apply to this Specification:

Purchaser	National Transmission And Despatch Company Limited (NTDC)
Company	The project company for development, investment, construction, operation and maintenance of the ±660kV HVDC project from Matiari to Lahore in Pakistan.
HVDC System	All of the relevant equipments and systems in bipolar operation, including converter transformers, converter valves, DC yard equipment, AC filter, control& protection system, DC transmission line, electrode and electrode line, etc.
HVDC Project	HVDC System and the relevant construction works in this project. The relevant construction works include outlet and inlet lines of converter station, buildings and structures, related auxiliary production facilities and living facilities.
M-L T/L	Matiari-Lahore Transmission Line
AC yard	AC switchgear area in converter station
DC yard	DC switchgear area in converter station
Life yard	Living facilities and part of auxiliary production facilities area in converter station
T area	Transformer area
M-E T/L	Matiari Electrode Grounding Transmission Line
M E/G	Matiari Electrode Grounding
L-E T/L	Lahore Electrode Grounding Transmission Line
L E/G	Lahore Electrode Grounding
M C/S	Matiari Converter Station
L C/S	Lahore Converter Station
M AC busbar	Matiari AC busbar
L AC busbar	Lahore AC busbar
M AC system	Matiari AC system
L AC system	Lahore AC system

P I	Pole I
P II	Pole II

The following abbreviations apply to this Specification:

AC	Alternating Current
ACI	American Concrete Institute
A/D	Analog to Digital
AN	Audible Noise
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing Material
BIL	Basic Impulse Insulation Level
BS	British Standard
BSL	Basic Switching Impulse Insulation Level
CB	Control Building
CCITT	International Consultative Committee on Telephone and Telegraph Systems
CT	Current Transformer
CTV	Capacitive Voltage Transformer
D/A	Digital to Analog
DC	Direct Current
DIN	Deutsches Institute fur Normung
EEI	Edison Electric Institute
EIA	Environmental Impact Assessment
ESCR	Effective Short Circuit Ratio
ESDD	Equivalent Salt Deposit Density
FAT	Factory Acceptance Tests
HF	High Frequency
HVDC	High Voltage Direct Current
IEC	International Electrotechnical Commission

IEEE	Institute of Electrical and Electronics Engineers
I/O	Input/Output
ISO	International Standards Organization
LED	Light Emitting Diode
MMI	Man Machine Interface
MVU	Multiple Valve Unit
NFPA	National Fire Protection Association
OPGW	Optical Fiber Composite Overhead Ground Wire
P&C	Protection and Control
PLC	Power-line Carrier
PT	Potential Transformer
RF	Radio Frequency
RI	Radio Interference
RIV	Radio Interference Voltage
RTU	Remote Terminal Unit
RPC	Reactive Power Controls
SCADA	Supervisory Control and Data Acquisition
SER	Sequence of Events Recorder
SLG	Single Line to Ground Fault
SMC	Station Master Clock
SPC	Software Production Control
SWC	Surge Withstand Capability
TFR	Transient Fault Recorder
UPS	Uninterruptible Power Supply
VDT	Video Display Terminal
VDU	Video Display Unit
VF	Voice Frequency
VT	Voltage Transformer

Volume Ⅲ-1 Contents

1. Overview of Project

1.1 Design Basis

1.1.1 *National Power System Expansion Plan 2011-2030, Main Report*, Canada SNC-Lavalin International Corporation, Pakistan National Technology Service Company, 2011

1.1.2 *State of Industry Report 2013*, Pakistan National Electric Power Regulatory Authority (NEPRA)

1.1.3 Parts of *Feasibility Study of HVDC/HVAC 1300km Long Transmission Line from Karachi to Up-country for Dispersal of 2500-3000MW Power from Imported Coal Based Power Project*, Canada SNC-Lavalin International Corporation, Pakistan National Technology Service Company, 2013

1.1.4 NEPRA *Grid Code*

1.1.5 *Transmission Services Agreement*

1.1.6 Minutes of meeting signed between China and Pakistan

1.1.7 Supporting documents for this project (environmental assessment and social stability reports)

1.1.8 Laws, regulations, specifications and codes of Pakistan

1.2 Scope of Design

It includes the design of converter station, grounding electrodes, DC transmission line and grounding electrode lines, and the preparation of technical equipment specifications and investment estimation.

1.3 Major Design Principles

1.3.1 The works in this stage is done according to *Regulations on Contents Depth of Feasibility Studies of Transmission and Distribution Projects* (DL/T 5448-2012);

1.3.2 The design and construction experience of the 660kV DC project from Ningdong to Shandong in China is fully absorbed to optimize the main design scheme and improve design quality;

1.3.3 The DC transmission voltage rating shall be considered as ±660 kV, transmission capacity as 4000 MW and transmission size as one circuit;

1.3.4 The number and locations of AC outgoing circuits of the converter station are subject to the minutes of meeting signed between China and Pakistan;

1.3.5 The feasibility of station site shall be demonstrated from station water source, station power supply, transportation, land nature and surrounding grounding electrodes. Geological stability assessment is made for the site scheme through exploration and survey. If there is any unfavorable geological condition in the station and surrounding areas, judgment shall be made for its hazardous degree and development trend, and prevention and control measures shall be proposed;

1.3.6 In design, proper design measures need to be taken by combining the domestic situations of Pakistan. In addition, local laws, regulations and standards of Pakistan need to be strictly followed and local customs need to be considered for the design of public and auxiliary facilities.

1.4 Overview of Site Selection

From August 24 to 30 in 2014, China Electric Power Equipment and Technology Co., Ltd. (CET) carried out site survey for the converter station site and transmission line corridor and made further communication with the related personnel from Pakistan on the specific matters regarding this project. In this survey, 3 sites were respectively selected for the converter stations at both ends and were compared in the preliminary feasibility study report.

From March 15 to 26 in 2015, 15 persons from CET carried out investigation and site survey for the DC transmission line from Matiari to Lahore in Pakistan. The persons from NTDC had made full preparation before this and suggested several station sites and grounding electrode fields based on their actual local situations to the persons from CET. In this survey, the persons from CET determined project scale and grid connection scheme, defined the suggested station sites as the candidates for feasibility study, and carried out on-the-spot investigation for sensitive and key points of the line with fruitful achievements gained.

Because of the difficulty in land acquisition for the recommended site of Matiari Converter Station, NTDC proposes to change the station site. From August 14–20, 2016, under the organization of China Electric Power Equipment and Technology Co., Ltd. (CET), CSEPDI professionals and Pakistan personnel jointly carried out supplemental site survey for the converter station site in Pakistan and proposed a new station site which is about 8 km away from the original station site and is to north by east of the latter.

1.5 Overview of Grid Connection

The grid connection scheme for the converter station at sending end is as follows:

The AC side of the DC sending-end converter station, with the voltage of 500kV, is connected to 500kV line from Jamshoro to Moro through π connection. The fossil-fired power generating units with the voltage rating of 500kV are connected into the converter station. There are 10 circuits of outgoing lines provided for the sending-end converter station in this phase, in which 1 is connected to Dadu New,2 are connected to Jamshoro, 1 is connected to Moro and 6 are connected to the power stations. The grid connection scheme for the sending-end converter station is shown in Figure 1.5-1.

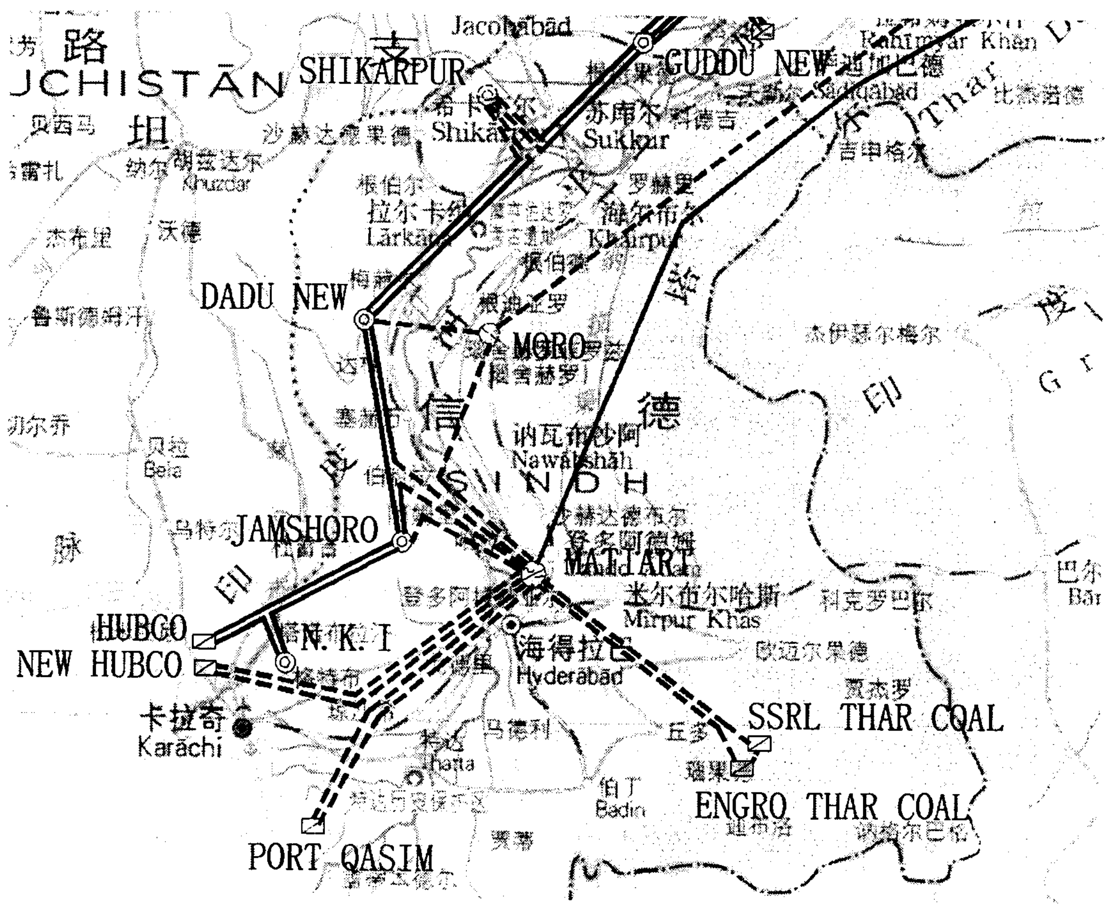


Figure 1.5-1: Grid connection scheme for sending-end converter station

1.6 Main Technical Schemes

No.	Item	Technical Scheme
	Main connection scheme	
1	Connection of converter valve bank and DC side	The converter valve banks are wired in series by using one 12-pulse converter group for either pole and there are two 12-pulse converter groups in total. Typical bipolar DC connection is used for DC yard and smoothing reactors, DC passive filters, DC voltage measurement devices, DC current measurement devices, DC isolating switches, high-speed change-over switches, neutral point equipment, DC carrier communication equipment and overvoltage protection devices are symmetrically provided on either pole.

No.	Item	Technical Scheme
	Connection on the 500kV AC side	The 3/2 circuit breaker connection method is used for 500kV AC yard. The long-term targets of this converter station include 12 500kV AC outgoing lines, 4 banks of AC filters (hereinafter referred to as ACF) and 2 converter transformer banks. There are 18 elements in total, which form 8 complete strings and 2 incomplete strings. In this phase, there are 10 outgoing lines, 4 ACF banks and 2 converter transformer banks. There are 16 elements, which form 7 complete strings and 2 incomplete strings; 1 500/35kV step-down transformer is respectively connected to either of the bus. 7 of the 10 outgoing lines in this phase are provided with line high-voltage reactors. It is provisionally assumed that the incoming lines of converter transformers are provided with AC PLCs.
	Connection of 500kV AC filter field	AC filters are connected in series by using ACF banks. The 500kV ACF banks are wired by using single bus. In the whole station there are 16 sub-banks of ACFs and parallel capacitors, which form 4 banks, with 4 sub-banks each.
	Connection of 500kV step-down transformers	The 500kV side of the two 500/35kV step-down transformers is respectively connected to two 500kV bus.
	Connection of 35kV AC area	Connection is made by using single bus and switchgears are arranged in an outdoor and open manner. In the whole station there are two 35kV buses, four 60 Mvar low-voltage reactor banks and two 35/11.5kV station transformers.
2	Switchgear and general electric arrangement	
	Arrangement of valve hall and converter transformer	6 banks of double converter valves are provided for either pole, and installed in a suspension manner. 6 single-phase two-winding converter transformers are arranged in a line on the AC incoming line side of valve hall to match up with arrangement of the valve halls. The bushings of converter transformer on valve side are inserted into the valve hall and connected to 12-pulse converter valve bank after the Y/Δ connection in valve hall.
	Arrangement of switchgear at DC switch field	Outdoor DC yard scheme is used for DC yard. The DC yard equipment is installed on the both poles in symmetric manner, DC neutral bus equipment is located in the center of DC yard, pole bus equipment is arranged on both sides and 2 DC filter banks are provided between the DC neutral bus and the pole bus. DC filters and pole bus dry-type smoothing reactors are arranged at low height with guard fences around. Consideration is made to properly heighten the equipment foundation. The capacitors for DC filters are installed with supporting arrangement scheme.
	Arrangement of 500kV AC switchgear	The 3/2 circuit breaker connection method is used for the connection on 500kV AC switchgear, which is arranged in three rows. Two banks of converter transformers are directly connected at elevated places respectively and the ACF banks #1, #2, #3 and #4 are connected through overhead lines.
	Arrangement of 500kV AC filters	String connection method for ACF banks is used for connection of AC filters. In this phase there are 16 sub-banks, including 9 sub-banks with the capacity of 150 Mvar and 7 sub-banks with the capacity of 180 Mvar, which are divided into 4 banks. The ACF banks are arranged in a line.
	Arrangement of 500kV step-down transformers	Two step-down transformers are respectively connected to two 500kV main buses through the open-type AC switchgear.
	Arrangement of 35kV switchgear	The connection is made by using single bus and the switchgear are arranged in an outdoor and open manner. Low-voltage reactors and station transformers are respectively located on both sides of bus.

No.	Item	Technical Scheme
	Arrangement of switchgear for connecting off-station power supplies	132kV switchgear in the station are wired with single bus and arranged in an open manner. There are two 132kV outgoing lines and one incoming line for 132/11.5kV station transformer and the bus PT is provided.
3	Electrical secondary equipment	
	DC control system	High voltage DC control system is of layered and distributed structure. Configuration is made from sampling unit, data transmission bus and primary device to control outlet based on the principle of full duplication.
	DC Protection System	High-voltage DC protection and control systems are separated and independent and the protection systems for two poles on functions and panels are completely independent. High-voltage DC protection is provided based on protected areas, the protection system of this converter station is divided into the following 7 protected areas and redundancy configuration is made based on the triple principle.
	Computer monitoring system	The converter station is designed as attended one. The compute monitoring system is a comprehensive automation system integrated with control, measurement, telecontrol and modern comprehensive management. Modularized, layered and distributed network structure is used for the compute monitoring system, so the operators can monitor and record the equipment in the whole converter station through human-machine interface in the master control room and send relevant information to the dispatching centers at all levels through telecontrol communication devices.
4	Station power supply	Three power supply lines are provided. One power supply line is connected from the outside of the station and the other two are connected from 35kV station transformers in the station.
5	Water source	Underground water is used.
6	Foundation treatment	Type of foundation such as normal foundation, conventional foundation, raft foundation, pile foundation and any special foundation type(where necessary) for the converter station will be finalized during the detail design according to the soil investigation. The total foundation cost will be reviewed accordingly.
7	Valve cooling system	Cooling circuit is a single circulating closed system. Water cooled evaporative cooling tower are used for heat exchange.

2. Site Conditions

2.1 Overview of Station Sites

The site 1 (center coordinate: N25°38’25”,E68°30’32”) is located at about 30 km northeast of Hyderabad and on the east side of national trunk highway N5. The site with flat terrain has a natural ground level of about 21 to 24 m (MSL altitude datum, the same below). Wheat and banana are planted on most parts of the site and there is some wasteland with shrubs. Some simple houses (single adobe houses) on the sides of the country road at the north of the site are to be demolished. The access road is connected from the country road connected with national trunk highway N5. The country road has bituminous pavement and ordinary road conditions with a width of about 6m , which can meet the requirements for project construction and transportation of large equipment. The site located at east bank of Indus River is about 1.5 kilometers far from the floodwall of Indus River. The level of 100-year flood at the site is 24.96 m based on the measured data of Kotri hydro-junction, so flood protection measures need to be considered for the site.

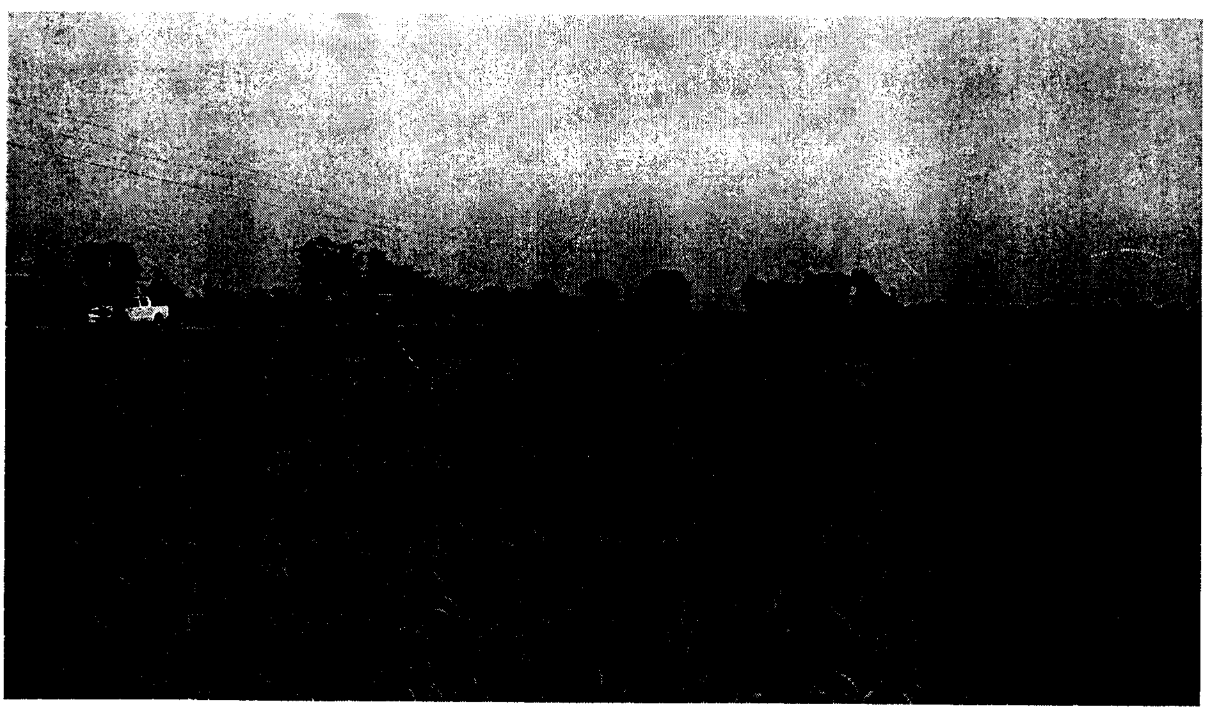


Figure 2.1-1: Site 1

Figure 2.1-2: Houses to be demolished at site 1

The site 2 (center coordinate: N25°29’34”,E68°24’49”) is located at the north side of national trunk highway N5 (National Highway No. 5). The site has an open topography and a flat terrain. There are mostly shrub wasteland and partially crops planted on the site. There are about 10 simple houses (single adobe houses) to be demolished within the site. The access road can be connected from national trunk highway N5. The highway features a bituminous pavement, and the general road conditions and width can meet the requirements for project construction and transportation of large equipment. The site located at the east bank of Indus River has a low terrain, so the influence of flood needs to be considered. There is the floodwall of Indus River at about 200 m north side of the site and the floodwall with the height of about 5 m is an earth embankment. Local residents said that maximum water level of flood in Indus River ever was close to the top of the embankment.

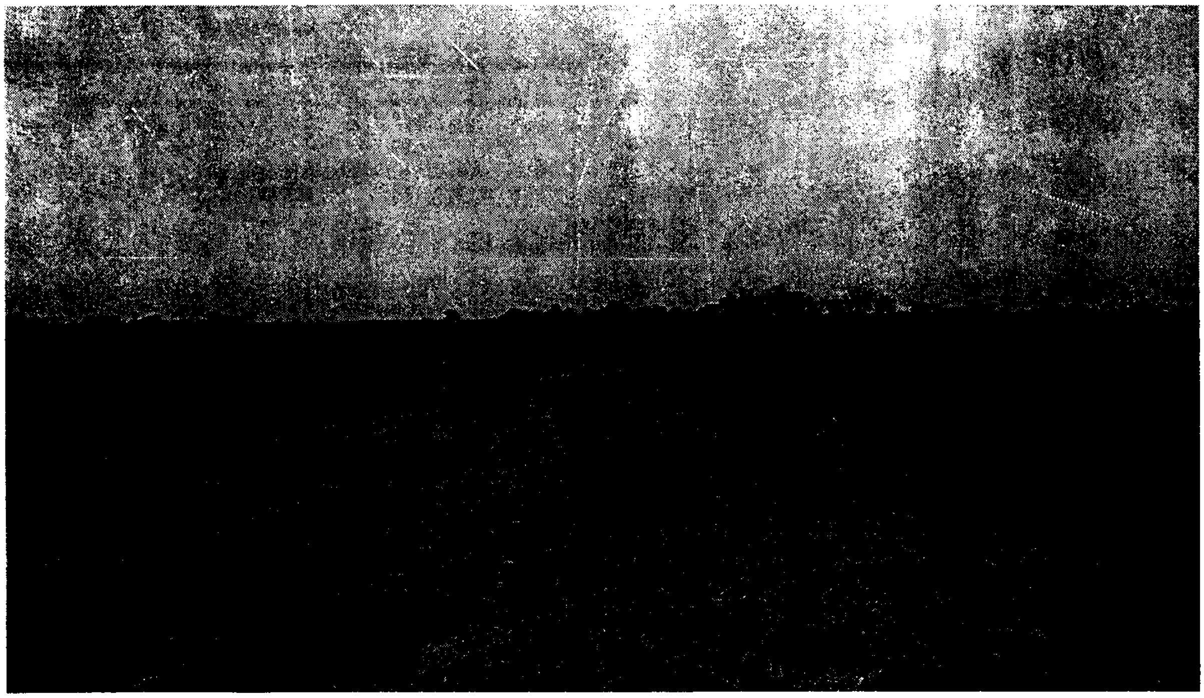


Figure 2.1-3: Site 2

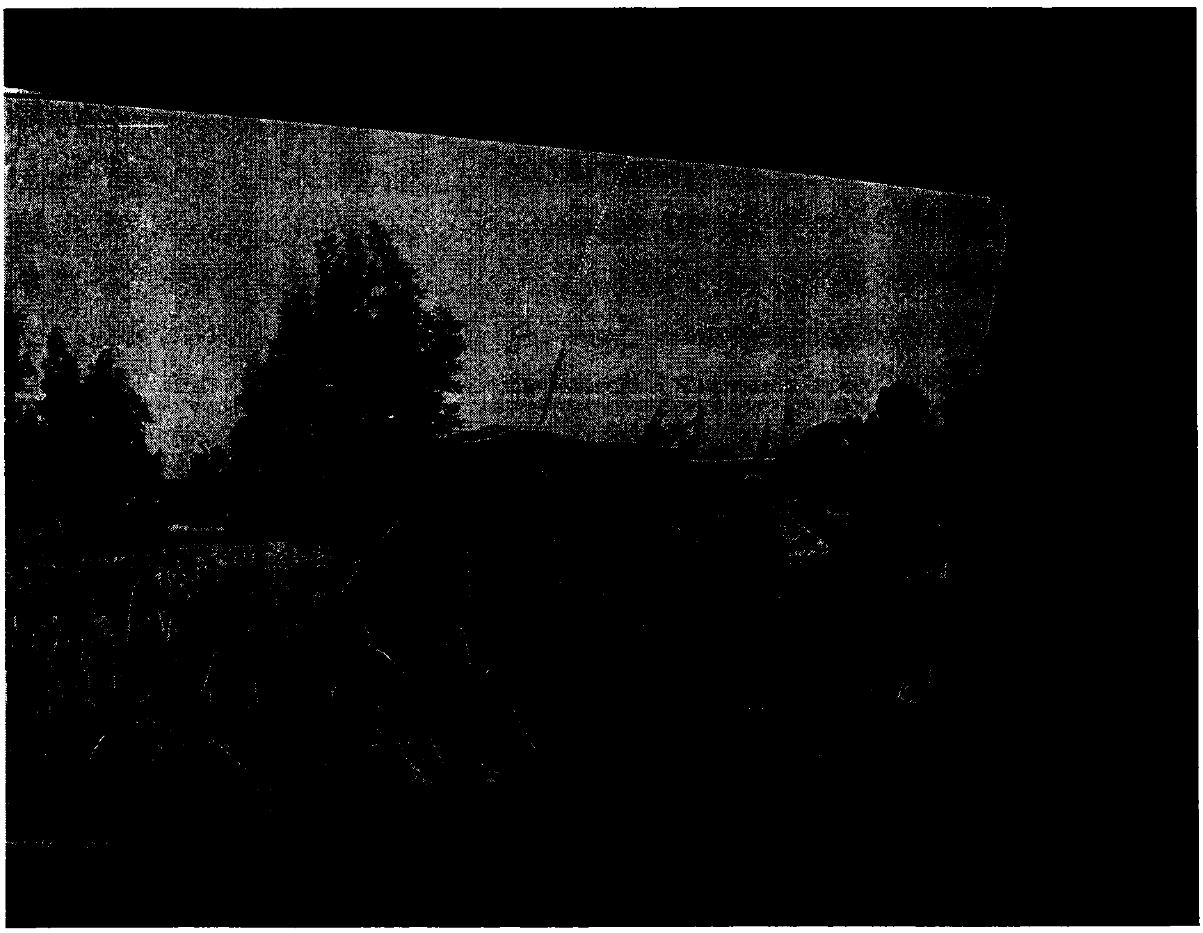


Figure 2.1-4: Houses to be demolished at site 2

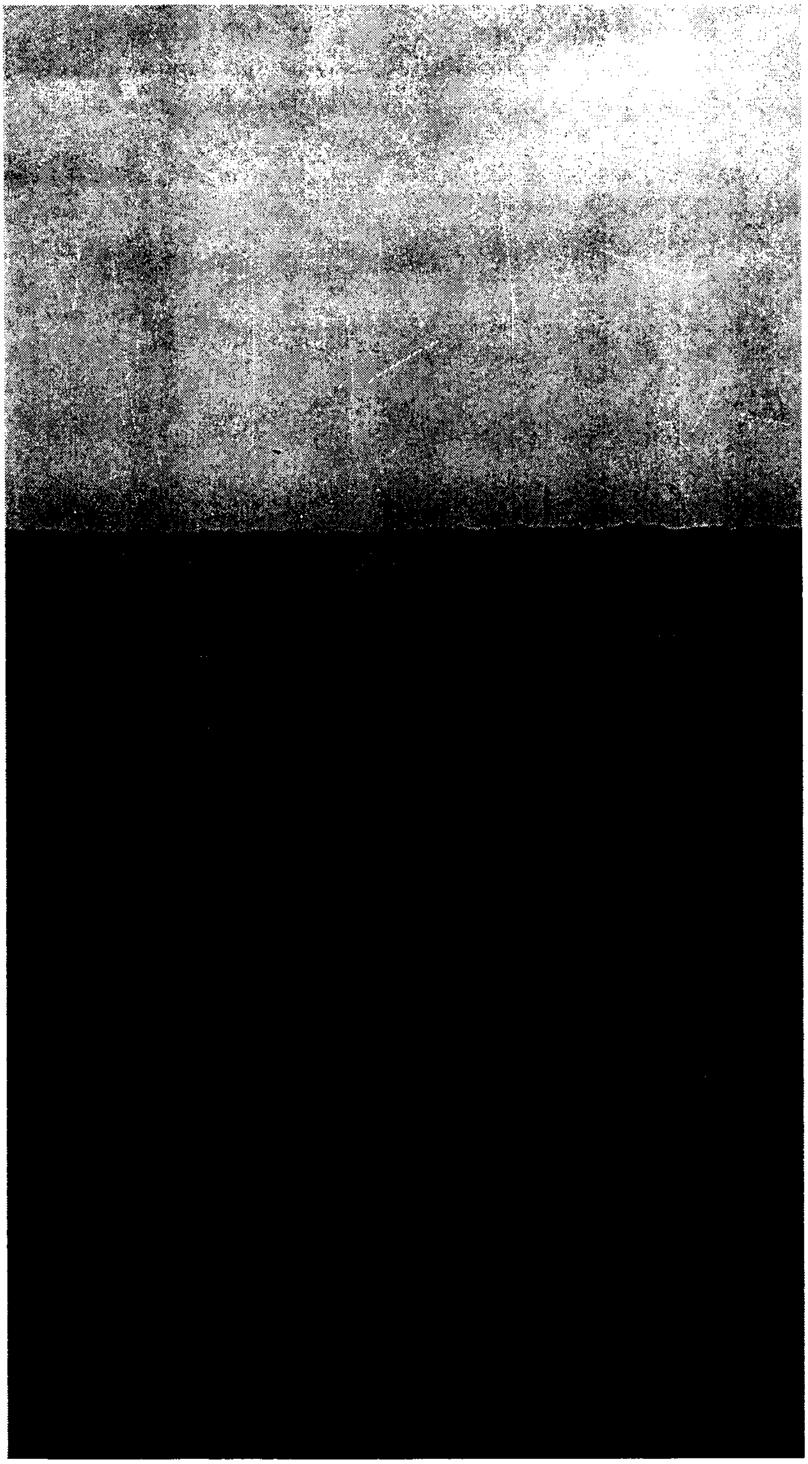


Figure 2.1-5: Floodwall of Indus river on the north side of site 2

The site 3 (center coordinate: N25°28'35",E68°25'20") is located on the east side of national trunk highway N5 (National Highway No. 5). The site has an open topography and a flat terrain. There is lush land vegetation and wheat and other crops are planted. There are no houses or other buildings and structures to be demolished within the site. The access road can be connected from national trunk highway N5. The highway with bituminous pavement and general road conditions and proper width can meet the requirements for project construction and transportation of large equipment. The site located at the east bank of Indus River has the elevation close to that of N5, so the influence of flood may need to be considered.

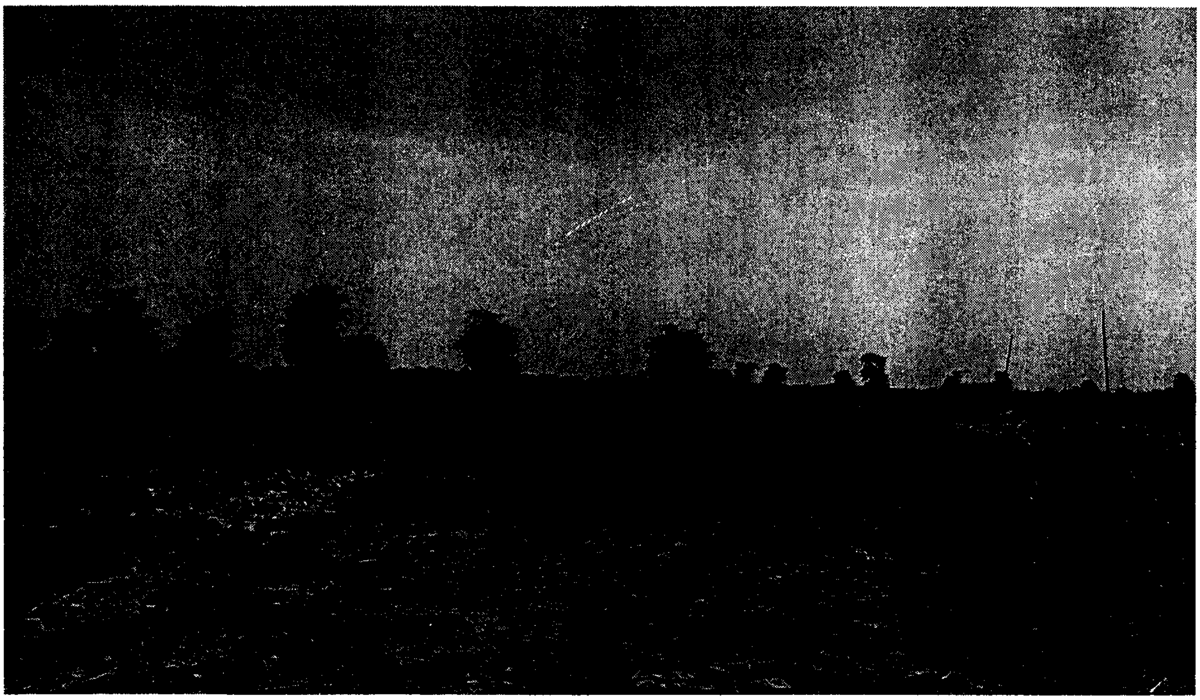


Figure 2.1-6: Site 3

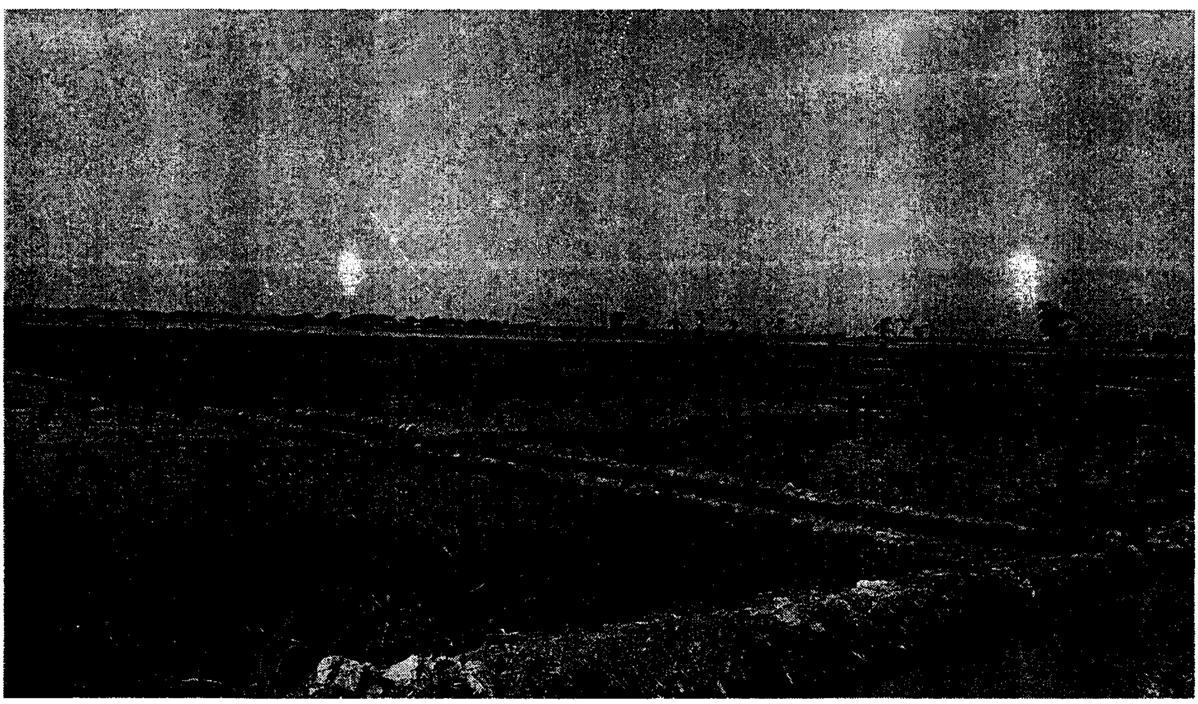


Figure 2.1-7: Site 3

According to NTDC's opinion, the feasibility study of Matiari converter station is conducted based on site 1. The other sites are not surveyed in this phase. It is planned to build the Matiari converter station on site 1.

According to the comments of NTDC, site 1 is recommended for Matiari Converter Station and feasibility study was made, and the feasibility study report was completed in December 2015.

Because of the difficulty in land acquisition for site 1, NTDC proposes to change the station site in August 2016. From August 14–20, 2016, under the organization of CET, CSEPDI professionals and Pakistan personnel jointly carried out supplemental site survey for the station site in Pakistan and proposed a new station site (i.e., site 4) which is about 8 km away from site 1 and is to north by east of site 1. This feasibility study is completed based on site 4.

The site 4, with center coordinates of 68°31'12"E and 25°42'51"N, is located at about 38 km northeast of Hyderabad and on the east side of national trunk highway N5. The station site is featured with flat terrain with a natural ground level of about 21–24 m (MSL altitude datum, the same below). Farmland spreads across the site area and dense irrigation ditches along with more than ten water wells are scattered therein. There are two neighboring brickyards to the west of the station site and one circuit of south-north 132 kV transmission line runs at a distance of about 350 m. All the residential areas around the station site are more than 200 m away from the latter. The access road is connected to the country road diverged from the national trunk highway N5. The 100-year flood level at the site is 23.8 m and, therefore, flood protection measures are required for the site.

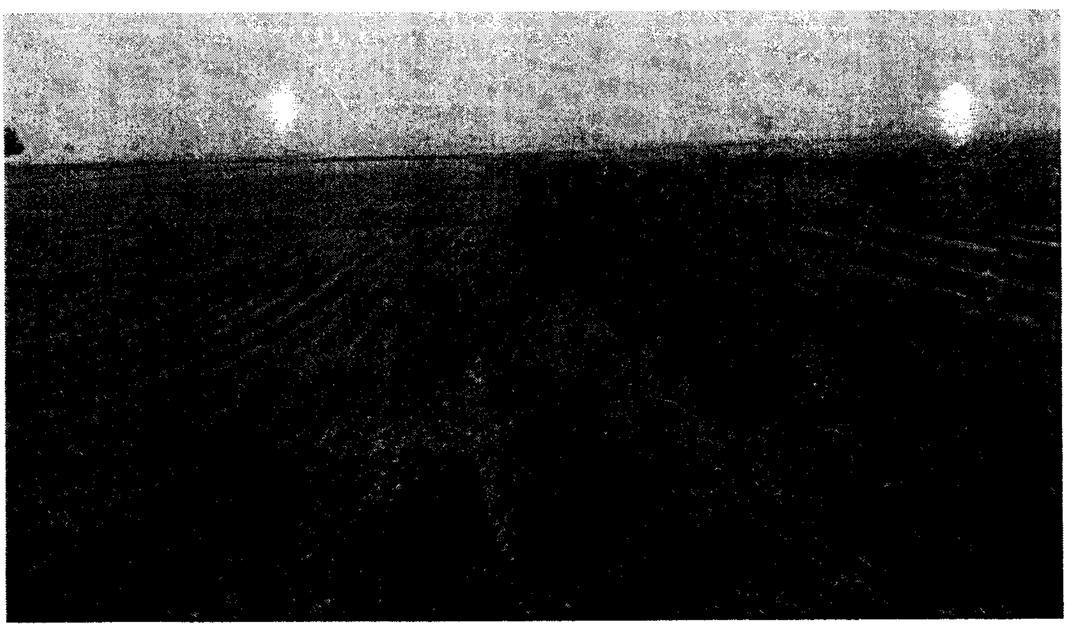


Figure 2.1-8: Site 4

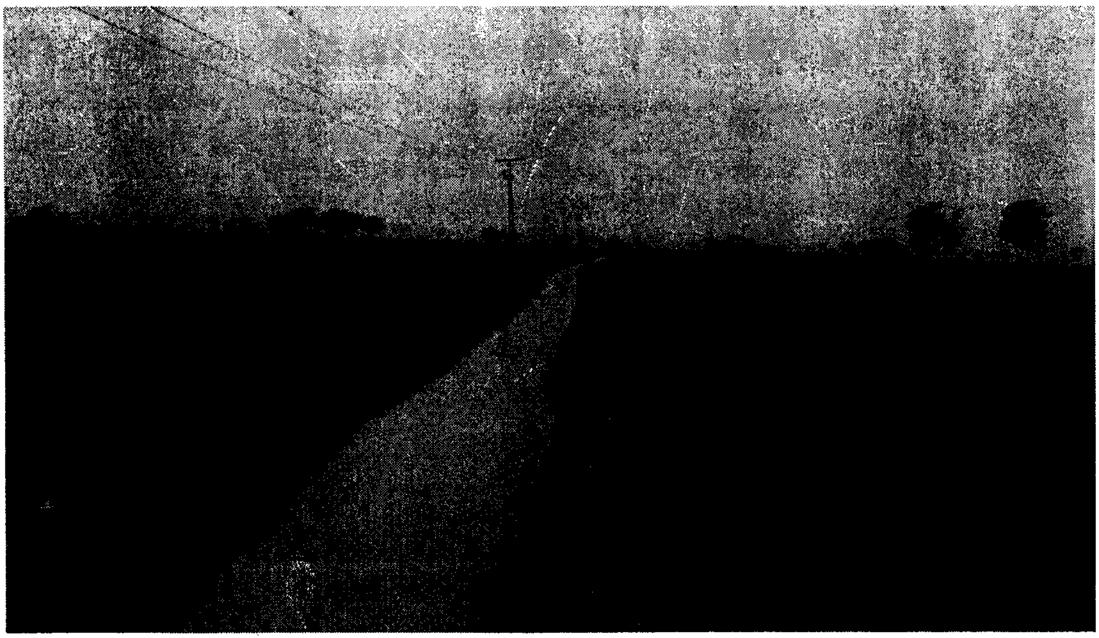


Figure 2.1-9: Site 4

2.2 Hydro-meteorological conditions

2.2.1 Flood

The hydrological environment around the site is include the Indus River 1km away from the west side, Rorhi Canal 2km away from the east side and waterlogging caused by the heavy rain in the summer.

The Sagyoon Matiari Bund is the structure protect the people and villages from Indus River's flood. The bund start from Sukkur barrage, end at Kotri barrage, and is 172 mile long. The bund locate between the Indus River and the site, about 1km far from the site. The elevation of the top is about 28.4m. According to the information from irrigation department, the bund near the site didn't broken during the 2010's flood, which is one of biggest flood in history. Under the protection of the bund, the site is safe from the Indus River's flood.

However, we must consider waterlogging caused by the heavy rain in the summer. The whole terrain of the site from north to south becomes low Due to the ability of drainage near the site is limit, the level rainwater of the site would be raise up. Considering flood overflowing risk and flood overtopping risk from Indus River and Rorhi Canal, the flood water level of the site is suggested as 23.8m.

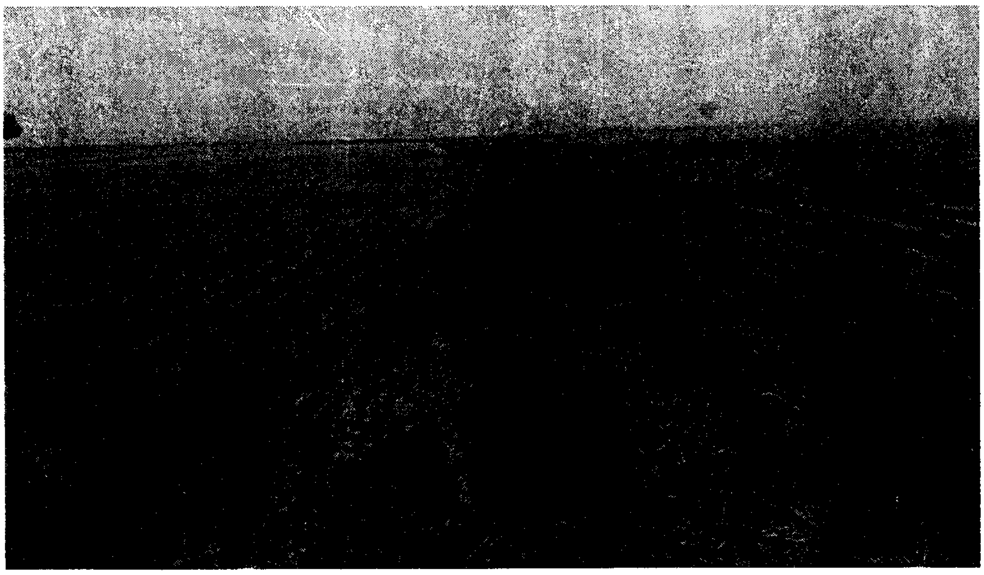


Fig. 2.2-1 Actual Situation of Sending-side Convertor Station

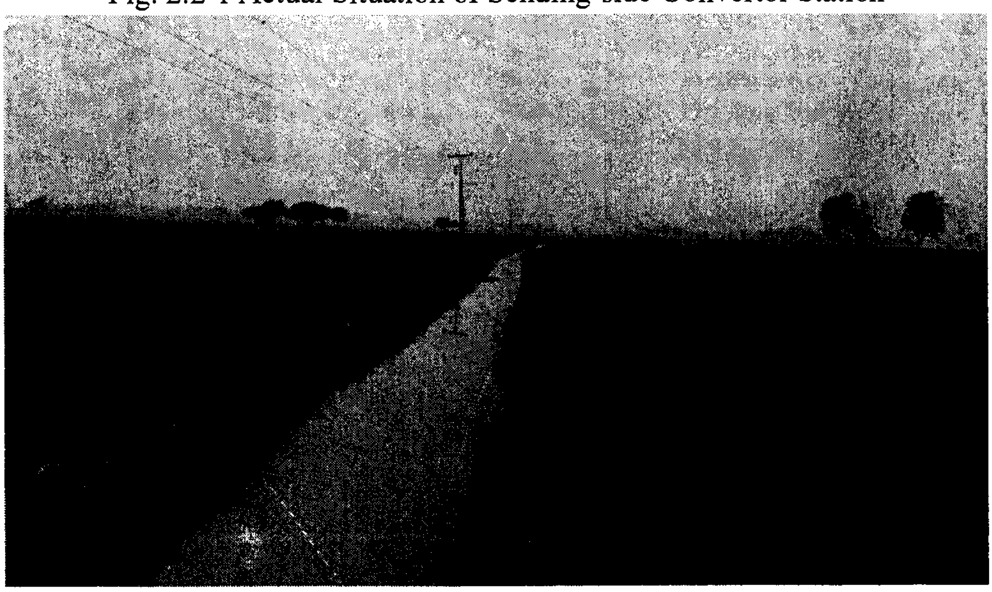


Fig. 2.2-2 Irrigation Channel near the Site

2.2.2 Meteorological conditions

In general, Pakistan has a subtropical monsoon climate. Traditionally, the climate of Pakistan is divided into four seasons: from March to April is spring and in this period the weather is not very hot or cold, but is warm and dry; from May to August is summer, and the temperature in June is highest and may be up to 45℃; the weather is rainy in July and August so this period is called as rainy season; from September to October is autumn; from November to next February is winter.

The sending-side convertor station is about 38km to the northeast of Hyderabad City. The site has the similar landform with the Weather Station of Hyderabad City, and they are in the same climate region so the meteorological data shall refer to the data of the

Hyderabad Weather Station located at N25°23′ and E68°25′ and with elevation of 40 m.

2.2.2.1 General meteorological conditions

The general meteorological data of the Hyderabad Weather Station are listed below (the data were collected from 2005 to 2014, UTC0 corresponds to the local 5:00 o'clock, and UTC12 corresponds to the local 17:00 o'clock)

Extreme maximum air temperature	47.5℃
Extreme minimum air temperature	1.5℃
Mean daily temperature difference in many years	13.1℃
Mean dry-bulb temperature in many years (UTC0)	22.4℃
Mean dry-bulb temperature in many years (UTC12)	32.3℃
Mean daily maximum air temperature in many years	34.1℃
Mean daily minimum air temperature in many years	20.9℃
Mean atmospheric pressure in many years (UTC0)	1,001.7 hPa
Mean atmospheric pressure in many years (UTC12)	1,000.7 hPa
Mean relative humidity in many years (UTC0)	74.2%
Mean relative humidity in many years (UTC12)	36.9%
Mean rainfall in many years	171.8 mm
Maximum rainfall in one day	153.0 mm
Mean number of thunderstorm days in many years	7.8 d
Maximum number of annual thunderstorm days	18 d
Prevailing wind direction	S

2.2.2.2 Designed wind speed and icing

Based on the building load regulations of Pakistan, the basic wind speed is not lower than 120 km/h and that in the coastal region is not lower than 130 km/h. According to the minutes of the meeting held before, the design wind speed for this project is taken as 160 km/h (corresponding to about 31.1 m/s), and the design icing thickness is taken as 0 mm.

2.3Engineering geology and hydrogeology conditions

2.3.1Regional geology and earthquakes

2.3.1.1 Overview of regional landforms and regional geology

Because Pakistan is located at the combining site of Eurasian Plate and India Plate, it is affected by striking of the two plates, therefore, Pakistan become the frequently occurred region of earthquakes. The Punjab and Sindh in northwest are located the northwest corner of India Plate; the western Balochistan and the North-West frontier are located at Eurasian Plate, that's the east edge of Iranian plateau crossing the Middle East and Central Asia; the northern region of northeast and Azad Kashmir are located at the edge of India Plate, in geology, they belong to the Central Asia in geology, this region becomes the frequently occurred region of earthquakes because of striking of the two plates. The project to be constructed is located at the northwest corner of India Plate.

According to the geologic structure map of Pakistan (see Fig. 2.3-1), there is Kirthar fault taking near north-south trend at about 60km on west side of the route, and at about 100km on the south side, there is Naga Parga fault taking west-east trend, and there isn't large new fault near the route, the distance requirements can be met.

2.3.1.2 Earthquakes

The striking of the Eurasian Plate and India Plate has caused rising of Himalayas Mountains, therefore, Pakistan frequently occurs earthquakes, among them, Kashmir and Kida are the frequently occurred regions of earthquakes. In 1931, the strong earthquake occurred there, and then, in 1935, the earthquake level was higher, the whole small city of Kida was almost destroyed, the military station nearby suffered heavy casualties, 0.2 million people died at least. In addition, in 1965, an earthquake that the epicenter was in Kohistan of North-West Frontier occurred, and that earthquake also caused serious casualties. The earthquake occurred in 1991 almost destroyed all the villages of North-West Frontier, but the number of casualties was much less than that in 1935. The recent earthquake was Kashmir earthquake occurred on October 8, 2005, the number of casualties was up to 73 thousands in the control region of Pakistan. The route to be constructed is located in one of relatively stable regions; where there has been no earthquake of above level-6 occurred in recent 100 years.

According to Building Code of Pakistan (2007) FIG.2.1 (SEISMIC ZONING MAP OF PAKISTAN) and FIG.A-1 (Peak Ground Acceleration (g) with 10% Probability of Exceedance in 50 years), the two convertor stations are mainly located in ZONE 2A, the Peak Ground Acceleration (g) with 10% Probability of Exceedance in 50 years is 0.14g (see Fig. 2.3-2, Fig. 2.3-3), the corresponding basic earthquake intensity is 7 degree.

In conclusion, the earth's crust where the project is located is relatively stable; the terrain is suitable for construction of the convertor station.

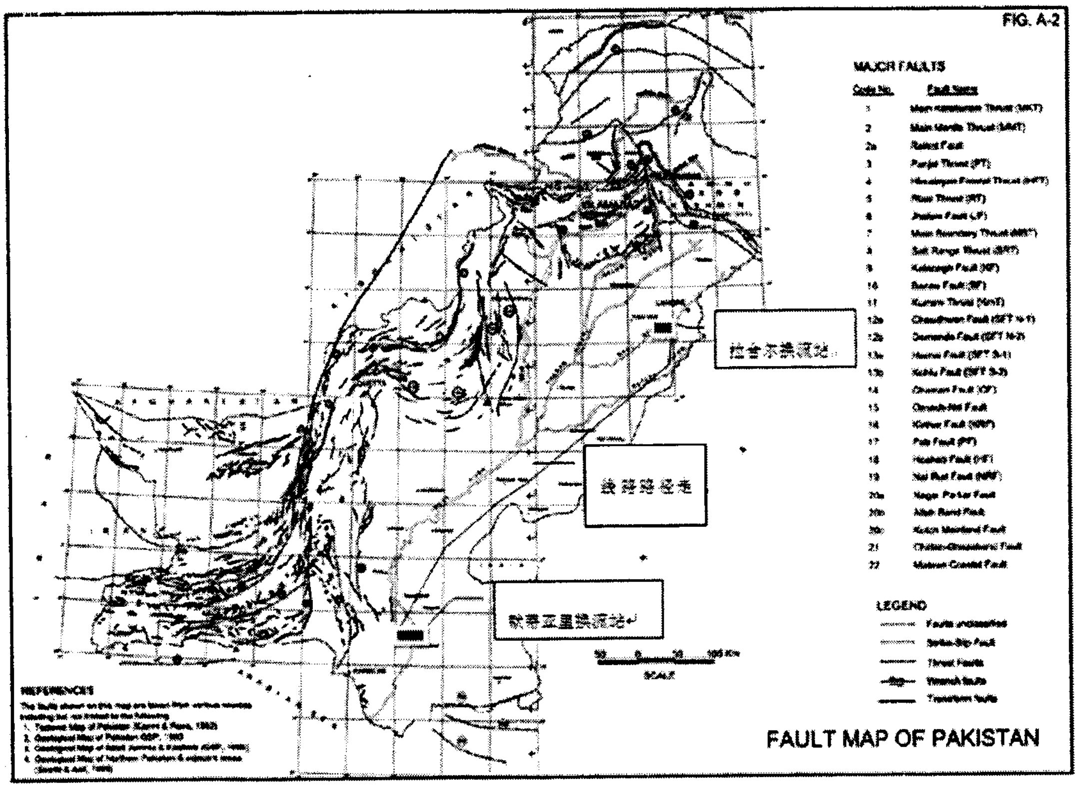


Fig. 2.3-1 Geologic structure map of Pakistan

拉合尔换流站	Lahore Convertor station
线路路径走	Route path orientation
默蒂亚里换流站	Matiari Convertor Station

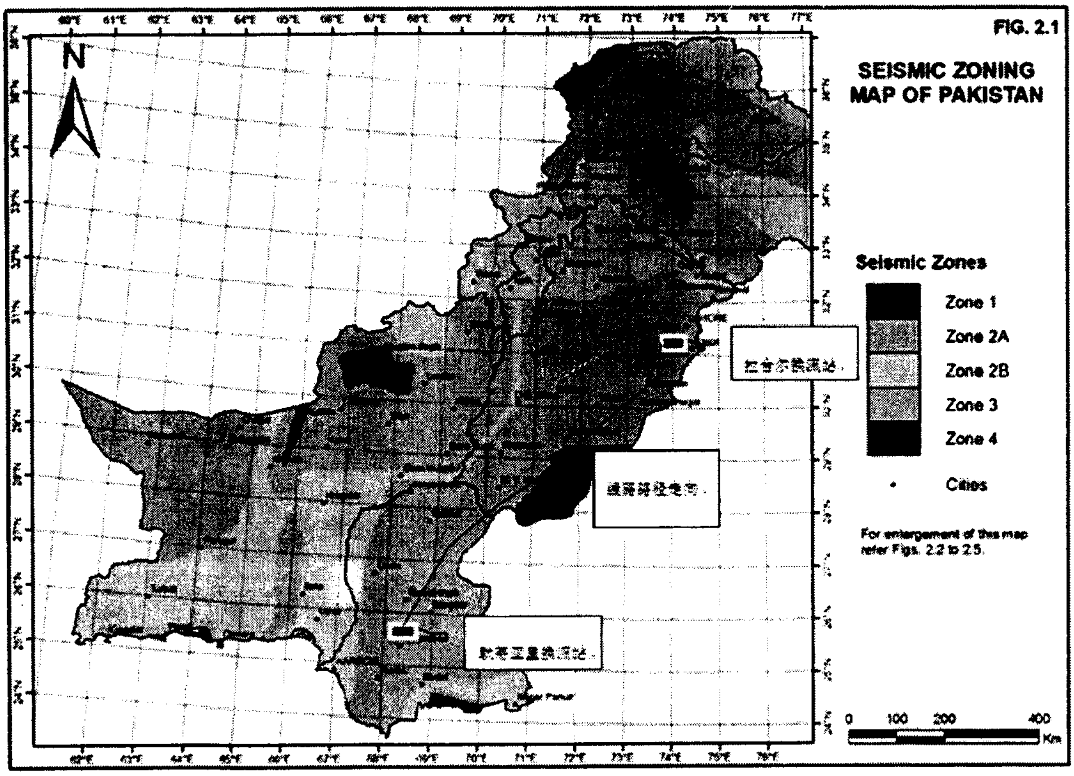


Fig. 2.3-2 Seismic zoning map of Pakistan

拉合尔换流站	Lahore convertor station
线路路径走向	Route path orientation
默蒂亚里换流站	Matiari convertor Station

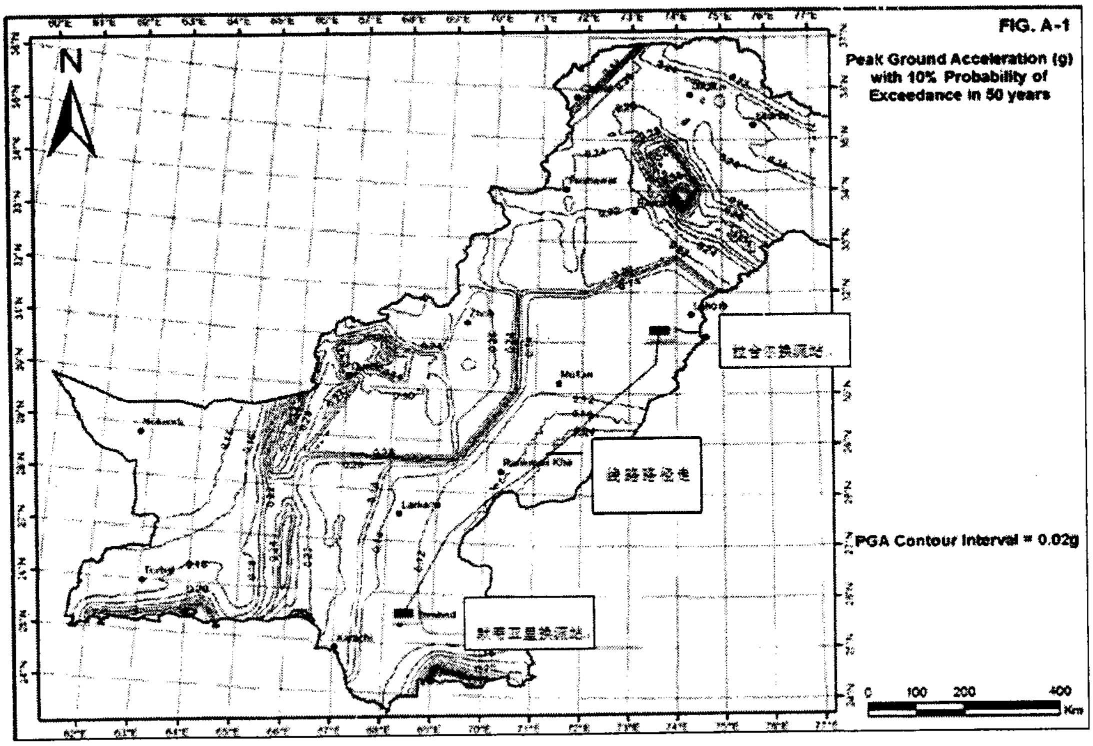


Fig. 2. 3-3 Isoline map of the ground acceleration

拉合尔换流站	Lahore convertor station
线路路径走向	Route path orientation
默蒂亚里换流站	Matiari convertor Station

2.3.2 Geotechnical engineering conditions and evaluation of Matiari Convertor Station

2.3.2.1 Landforms

Terrain of the region where the convertor station to be constructed is located is flat alluvial plain (Fig. 2.3-4), the region mainly plants wheat, the Indus River runs through this region, which is 8km far from the site.

Ground elevation of the convertor station to be constructed is about 21.9~23.4m, the relative height difference is about 1.5m, and the overall terrain is gentle. There isn't unstable side slope in range of the convertor station, no unfavorable geologic process such as ground settlement and collapse etc. The region of the station is mainly the cultivated land, with a few trees and bush.

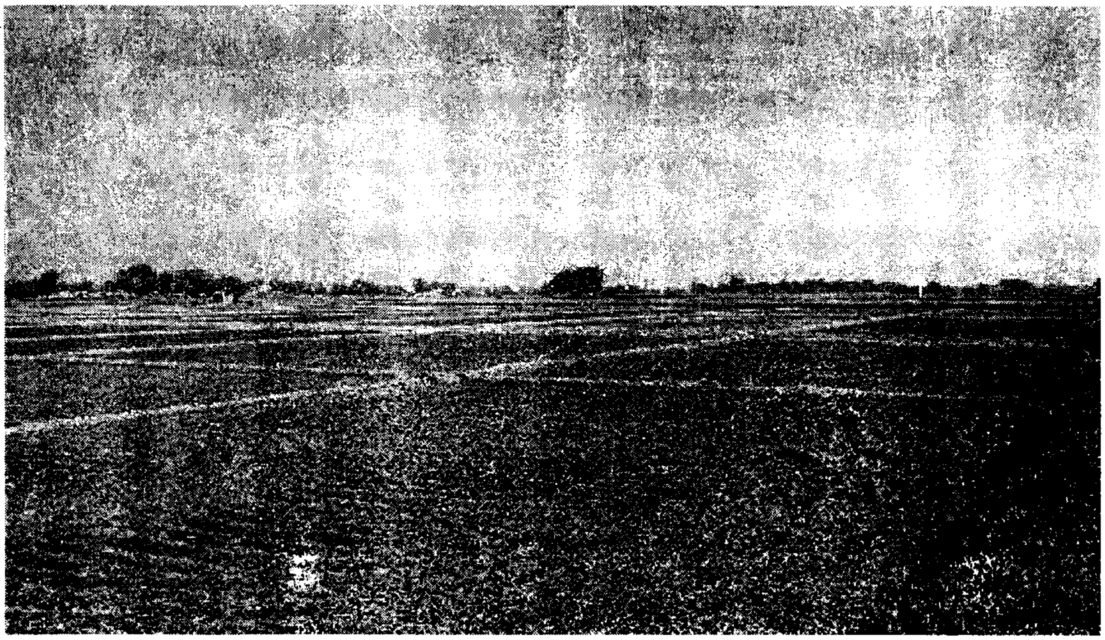


Fig. 2.3-4 Landform of the station region

2.3.2.2 Lithology of the formation

The proposed site is situated in the river alluvium plain, and within the range of exploration depth, the stratum structure of the whole site consists of the quaternary Holocene series (Q_4^{al}) alluvial deposit, the foundation rock-soil layer can be described in turn as follows:

Lay (1-1): Silty clay, gray, grayish yellow, very wet, soft plastic, containing a little silt and silty-fine sand. This layer is distributed in surface layer of the site region.

Lay (1-2): Silty clay, gray, grayish yellow, wet, plastic, containing a little silt and silty-fine sand, changed into silt and sitlty sand locally.

Lay (1-3): Silty clay, gray, grayish yellow, slightly wet, hard plastic, containing a little silt and silty-fine sand, changed into silt and sitlty-fine sand locally.

Layer (2-1): Silt: Gray, dark grey, saturated, slightly dense, containing a little silty clay and silty-fine sand, changed into silty- fine sand locally, changed into silty clay locally.

Layer (2-2): Silt: Gray, dark grey, saturated, medium dense, containing a little silty clay and silty-fine sand, changed into silty- fine sand locally, changed into silty clay locally.

Layer (2-3): Silt: Gray, dark grey, saturated, medium dense, containing a little silty clay and silty-fine sand, changed into silty- fine sand locally, changed into silty clay locally.

Layer (3-1) Silty-fine sand: Gray, dark grey, saturated, loose, with much silty clay, changed into silt and silty clay locally.

Layer (3-2) Silty-fine sand: Gray, dark grey, saturated, slight-dense, with a little silty clay, changed into silt and silty clay locally.

Layer (3-3) Silty-fine sand: Gray, dark gray, saturated, medium-dense, with a little silty clay, changed into silt and silty clay locally.

Layer (3-4) Silty-fine sand: Gray, dark gray, saturated, dense, with a little silty clay, changed into silt and silty clay locally.

Lay (4-1): Silty clay, gray, dark grey, wet, plastic, containing a little silt and silty-fine sand, changed into silt and sitlty- fine sand locally.

Lay (4-2): Silty clay, gray, dark grey, slightly wet, hard plastic, containing a little silt and silty-fine sand, changed into silt and sitlty- fine sand locally locally.

2.3.2.3 Hydrogeology

Type of the underground water in this site is mainly the pore water in Quaternary system loose soil, the underground water is relatively abundant, and the buried depth of underground water is 1.0-1.4m. Overall, within the range of exploration depth, there is continuous, stable, thicker aquifer in the site, the underground water is abundant, and the main water sources are rivers, and the underground water is slightly affected by the climate. According to the relative collected data, the underground water can meet water demands of the convertor station. We suggest conducting water-supplying hydrogeololgy exploration to the site in advance at the next stage, in order to determine position, depth and quantity of the mines.

According to the collected data and the evaluation of the environment type, the underground water has weak corrosivity to the concrete structures; according to the evaluation of stratum permeability, the underground water has slightly corrosivity to the concrete structures, and the comprehensive evaluation indicates that the underground water has weak corrosivity to the concrete structures; and which has slightly corrosivity to steel bars inside the concrete structures.

The site soil has high corrosivity to steel structures (reference to the soil resistivity).

2.3.2.4 Unfavorable geologic process

There isn't unfavorable geologic process in the region of convertor station and nearby region, such as landslide, collapse, mud-rock flow and ground settlement etc.

2.3.2.5 Mineral products and historical relics

There isn't distribution of mineral resources with explored reserves; the project doesn't cover mineral resources and historical relics and historical sites.

2.3.2.6 Evaluation of geotechnical engineering

2.3.2.6.1 Classification of the construction site

Hypsography of the construction site isn't large, the largest height difference is about 1.5m, and the main formation in the depth range of 35m underground is Quaternary plastic silty clay, slightly dense silt, medium dense silt, dense silt and loose, slightly dense, medium-dense, dense silty-fine sand. According to *Earthquake Resistant Design Code of Buildings* (GB50011-2010), the site soils shall be soft, medium-soft soil layers, and according to the preliminary determination, type of the construction site shall be class-III, which is the disadvantage section of earthquake-resistant construction site.

2.3.2.6.2 Mechanical property of the subsoil

Layer (1-1) Silty clay: Soft plastic state, with high compressibility, the physical property of this layer is poor, and this shall not be directly used as bearing stratum of building foundation without treatment.

Layer (1-2) Silty clay: Plastic state, with medium compressibility, the physical property of this layer is general, and this layer can be treated as the foundation supporting course of auxiliary buildings (structures).

Layer (1-3) Silty clay: hard plastic state, with low compressibility, the physical property of this layer is general, and this layer can be treated as the foundation supporting course of auxiliary buildings (structures).

Layer (2-1) Silt: slightly dense, with high compressibility, the physical property of this layer is poor, and this shall not be directly used as bearing stratum of building foundation without treatment.

Layer (2-2) Silt: medium dense, with medium compressibility, the physical property of this layer is general, and this layer can be treated as the foundation supporting course of auxiliary buildings (structures).

Layer (2-3) Silt: dense, with low compressibility, the physical property of this layer is general, and this layer can be treated as the foundation supporting course of auxiliary buildings (structures).

Layer (3-1) Silty-fine sand: Loose, this layer can't be treated as the foundation supporting course of buildings (structures) without treatment.

Layer (3-2) Silty-fine sand: slightly dense, the mechanical property is general, this layer can't be treated as the natural foundation supporting course of general buildings (structures) without treatment..

Layer (3-3) Silty-fine sand: Medium dense, the mechanical property is better, this layer can be treated as the natural foundation supporting course of important buildings (structures).

Layer (3-4) Silty-fine sand: dense, the mechanical property is better, this layer can be treated as the natural foundation supporting course of important buildings (structures).

Layer (4-1) Silty clay: Plastic state, with medium compressibility, the physical property of this layer is general, and this layer can be treated as the foundation supporting course of auxiliary buildings (structures).

Layer (4-2) Silty clay: hard plastic state, with low compressibility, the physical property of this layer is general, and this layer can be treated as the foundation supporting course of important buildings (structures).

2.3.2.6.3 Sandy soil liquefaction

The converter station is located in the section of alluvial plain; there is underground water level and sandy soil. According to the collected data, there is the possibility of sandy soil liquefaction, and the liquefaction grade is slight.

2.3.2.6.4 Type of the foundation

The natural foundation, pile foundation or other types can be adopted for the buildings (structures) in the site through the comprehensive analysis on the burial characteristics and engineering characteristics of foundation rock and soil of the construction site as well as the site and foundation earthquake effects and other aspects according to the characteristics of the buildings (structures), such as importance, load, requirements for deformation, etc.

2.3.2.6.4.1 Natural Foundation

According to the burial characteristics and engineering characteristics of foundation rock and soil in the site, the site and foundation earthquake effects and other aspects as well as the load deformation characteristics of buildings (structures), the foundation design scheme and the selection of foundation bearing stratum shall be respectively analyzed.

For general building and structures, when layer is used as the natural foundation stratum to meet the strength and deformation requirements and the settlement difference between adjacent foundations is within the allowance range, the natural foundation can be adopted.

2.3.2.6.4.2 Pile Foundation

1) Analysis on pile foundation bearing stratum

In the foundation soil strata distributed in the site, layer (1-2) (silty clay) is distributed widely and has better mechanical properties but with layer (2-1) (silt), layer (3-1)(silty fine sand), and therefore it is inappropriate to use this stratum as the pile foundation bearing stratum of main buildings. When this stratum is used as the pile foundation bearing stratum and underlying stratum of secondary buildings (structures), the necessary deformation checking shall be carried out so as to compare the settlement difference between adjacent foundations. Layer (3-3) (medium dense silty fine sand) with better mechanical properties is the good pile foundation bearing stratum of the site, but this stratum is locally distributed and therefore it is inappropriate to use this stratum as the pile foundation bearing stratum of main buildings. When this stratum is used as the pile foundation bearing stratum and underlying stratum of secondary buildings (structures), the necessary deformation checking shall be carried out so as to compare the settlement difference between adjacent foundations.

Layer (3-4) (dense, silty fine sand) is the underlying stratum in the site and has stable horizon, small thickness variation and better mechanical properties. For the proposed buildings (structures) in the site, according to the specific situations of each building (structure), layer (3-4) can be used as the pile foundation bearing stratum required for different bearing capacities.

2) Pile foundation scheme proposals

When the adoption of the natural foundation cannot simultaneously meet the strength and deformation requirements, it is recommended to adopt the pile foundation (cast-in-situ bored pile), use layer (3-3) (medium dense silty fine sand), layer (3-4)(dense silty fine sand), layer (4-1) (plastic, silty clay), layer(4-2)(hard plastic, silty clay) as the pile foundation bearing stratum and underlying stratum, and simultaneously carry out the corresponding strength and deformation checking and the checking of the settlement difference between adjacent foundations.

According to the engineering geological conditions of the site, the soft stratum and hard stratum is interbeded, the dense silt and hard plastic silty clay is high-compactness, precast piles cannot enter the necessary depth of the bearing stratum peacefully.

In addition, according to the on-site data collection and investigation in Pakistan, the precast piles method is less used in Pakistan, and the equipment which can be used for construction is also relatively less. The construction equipment shall be imported from China if they need to be used.

Therefore, it is recommended to adopt the cast-in-situ bored pile.

2.3.2.6.5 Problems needing attention during design and construction

The groundwater level is generally buried shallower. The strata involved during foundation pit excavation mainly include layer (1) (silty clay), layer (2) (silt), layer (3) (silty fine sand) and laye (4) (silty clay) in which layer(1), layer (2) and layer (3) has larger permeability. Therefore, the problems of groundwater permeation into the foundation pit, foundation pit wall collapse, etc. will occur during foundation pit excavation.

Considering that the speed of permeation of groundwater into the foundation pit is faster, the construction unit shall carry out the dewatering work of this area in advance before construction. It is recommended to carry out the special design for the foundation pit excavation and dewatering of the plant area. The construction measures of "dewatering before foundation pit excavation" shall be taken, and the groundwater level shall be decreased to 0.5~0.8m below the foundation pit bottom elevation before construction and excavation. It is recommended to make the special foundation pit dewatering scheme according to different building sections and foundation pit excavation depths.

In addition, the stability of the pit walls constituted by the above strata is poorer, especially the pit walls very easily collapse during the permeation of groundwater into the foundation pit and the surface water erosion resistance is weak. Therefore, the appropriate supporting measures shall be taken during foundation pit excavation. On the premise that the conditions allow, the enough slope gradient shall be provided, and it is recommended that the slope setting rate is 1.1.5-1:2. Moreover, the water interception and drainage ditch shall be arranged around the foundation pit so as to timely pump and drain the groundwater from the foundation pit during construction and excavation.

2.4 Water Supply Sources and Drainage Conditions

2.4.1 Sources of Water Supply

(1) Water demand

The water used by the converter station mainly consists of living water, process water and fire-protection water. Process water is mainly used to provide make-up water for the external cooling system of converter valve. The water consumption varies with the cooling mode. The water consumption for the complete water cooling mode is about 600 m^3/d. The consumption of domestic water and fire-protection water is considered 180 m^3/d. So the total water consumption is about 780 m^3/d when the complete water cooling mode is used.

(2) Surface water source

Surface water nearby the site is available from Indus River. To irrigate the farmland at the three rivers at the east, Pakistan carried out large-scale project to transfer water from west to east and built several hydro-junctions on Indus River and its branches. The sending-end converter station is located at the 7^{th} main stream of Indus river, which is also the upstream of the last hydro-junction Kotri Barrage. There is no branch from the hydro-junctions GadduBarrange to Kotri Barrage. Inflow has been greatly reduced after interception of water by a lot of hydro-junctions upstream. Especially in drought years, there is a risk that water cannot be obtained due to waterhead is artificially controlled by India and Pakistan.

The segment of Indus River where the station site is located is a typical wandering river segment with wide and shallow river surface, dense bottomland and intertwined braided rivers. Flow is scattered and main flow swings so that riverbed is easy to be rushed and silted. A wide range of scouring and silting is unfavorable to set intakes.

Therefore, Indus River is not suitable to be used as a water source for the converter station because its water supply is not reliable and there is a risk that water cannot be obtained.

(3) Underground water

The recommended site is located at the east bank of Indus River and underground water can be used as a water source for the converter station according to the site survey.

According to "Water hydrogeological survey report": The groundwater in site can meet water requirements of converter station. According exploration wells pumping test, Under current conditions of the recharge of shallow groundwater calculations to determine the present condition of shallow groundwater under single well recoverable resources is $528m^3$/d when the drawdown is 5m, Three wells (include an emergency well) are need as the water source of converter station.

2.4.2 Drainage Conditions

The site with flat terrain has the natural terrain elevation of about 21 to 24 m. The level of water logging is 23.8 m, so the site needs to be elevated to 24 m by filling.

The rainwater shall be collected by the storm water inlet on the ground beside road. And a rainwater pump station is needed.

The waste water of valve cooling system should first be treated to meet the waste-discharge standards of Pakistan, and then it can be drained into the rainwater pipe of station.

There is an irrigation canal besides 3.5 km on the east side of the site, so rainwater in the converter station area is drained to the irrigation canal through the buried pipelines outside of the station after being pressurized at the rainwater pumping station.

2.5 Construction Conditions

2.5.1 Site Construction Conditions

The construction site of this project is located on the east side of national trunk highway N5 (National Highway No. 5). The site with flat terrain has the natural ground level of about 21 to 24 m. Wheat and bananas are planted on most of the site and there is some wasteland with shrubs. Good external traffic conditions provide convenience for ingress and egress of construction tools and machinery and persons during construction. Conditions for supplying construction materials are good because it is near to the local main towns.

2.5.2 Supply of Construction Energy

2.5.2.1 Water source for construction

The maximum water consumption is about 20 t/h during the construction. The permanent water source for the converter station is from a well dug within the station based on local situations. Considering the big water consumption of permanent water source within the station, a provisional well can be dug during construction to meet the demand for digging permanent water well and the water demands during construction. It is suggested to solve the problem of construction water of this project by digging a well within the station.

2.5.2.2 Power supply for construction.

The maximum electricity consumption is about 1600 kVA during construction. The scheme combining permanent and provisional electricity supplies are used for construction, production and living to save project investment. According to the electrical design scheme, it is planned to connect one transmission line from 132kV line nearby the site to the station through π connection as the power supply introduced from the outside of this station. It is suggested to connect and erect lines and facilities outside the station area in advance, which are provided with step-down transformers to be used during construction. They are delivered for production after the project is put into production.

2.5.2.3 Communication during construction

To facilitate external contact during construction and ensure reliability of communication, it is planned to connect one communication optical cable from the communication line outside the station to the station, which may be applied to the local communication authority together with permanent communication lines. The communication during construction is achieved by fixed telephone, mobile phone and radio equipment on the construction site.

2.6 External Station Power Supplies

Three station power supply lines will be used for Matiari Converter Station. Two of them are connected from two 35kV AC buses by using two 35/11.5kV high voltage station transformers respectively and one of them is connected from 132kV transmission line nearby this station. The specific power supply lines will be determined by NTDC.

2.7 Planning of Incoming and Outgoing Line Corridors

HVDC outgoing line of Matiari converter station is eastward, AC outgoing is southward, From west to east, AC outgoing lines are Dadu New,Jamshoro 1st and 2nd

circuit, Hubco New station 1st and 2nd circuit, Qasim station 1st and 2nd circuit,Spare 1st and 2nd circuit ,Thar station 1st and 2nd circuit. The outgoing terrain is flat without cross-cutting in the converter station. The outgoing distribution of Matiari converter station is shown in FIG. Volume III-1-2.

3. Selection of Main Electrical Connection and Equipment

3.1 Main Electrical Connection of Converter Station

3.1.1 Main Electric Connection on AC side

The 500 kV AC side adopts 3/2 circuit breaker connection mode, which is characterized by simple function, high reliability and safety. The connection and string configuration of AC distribution devices are designed in accordance with the following principles:

1) The lines with the same name shall not be in the same string and should not be connected into the same bus as practical as possible;
2) The power supply lines should be in the same string with load lines as practical as possible;
3) All AC and DC lines shall not cross with each other as practical as possible;
4) Each converter transformer bank is provided with one AC PLC filter bank at the line incoming point provisionally;
5) According to the requirements of communication discipline personnel, all lines shall be provided with wave trapper on their outgoing line side;
6) Future expansion should be considered.

The long-term targets for Matiari converter station include 12 AC 500 kV outgoing lines, 4 banks of AC filters (hereinafter referred to as "ACF"), and 2 banks of converter transformers, i.e., totally 18 elements, which constitute 8 complete strings and 2 incomplete strings. Either of the two buses will be connected with one 500/35 kV step-down transformer. All of the long-termed planned 12 outgoing lines will be provided with high-voltage reactors, except the Jamshoro double lines and Moro line. The converter transformers are provided with AC PLC at their line incoming points provisionally.

In the current phase, 8 outgoing lines (1 to Dadu New,2 to Jamshoro, 1 to Moro, 2 to Hubco New power station, 2 to Qasim power station, and 2 to Thar power station), 4 banks of ACFs, and 2 banks of converter transformers will be built. A total of 16 elements will be incorporated into the strings, constituting 7 complete strings and 2 incomplete strings. Each of the two buses will be connected with one 500/35 kV step-down transformer. All the outgoing lines will be provided with outgoing disconnectors. All of the outgoing lines will be provided with high-voltage reactors, except the Jamshoro double lines and Moro line.

The string configuration is as shown in the following table:

Table 3.1.1-1: String configuration of 500 kV AC yard of Matiari converter station

String No.	Line on 1M Side	Line on 2M Side
Bus connection	No. 1 500/35 kV step-down transformer	No. 2 500/35 kV step-down transformer
#1 string	#1 bank of AC filters	Converter transformer for P II
#2 string	#2 bank of AC filters	Thar power station 2
#3 string	Converter transformer for P I	Thar power station 1
#4 string	NA	Reserved
#5 string	Qasim power station 2	Reserved
#6 string	#3 bank of AC filters	Qasim power station 1
#7 string	#4 bank of AC filters	Hubco New power station 2
#8 string	Hubco New power station 1	Jamshoro 2
#9 string	NA	Jamshoro 1
#10 string	Moro	Dadu New

The 35 kV AC switchgear employs single-bus connection mode. The equipments are arranged outdoors. The Matiari converter station has two 35 kV buses, 4 banks of 60Mvar low-voltage reactors, and two 35/11.5kV auxiliary transformers.

3.1.2 Main Electrical Connection on DC Side

It is recommended to use the bipolar DC connection mode on the DC side, which is a typical connection mode for 500 kV DC transmission project. On the DC side of converter station, smoothing reactors, DC passive filters, DC voltage measuring devices, DC current measuring devices, DC disconnectors, high-speed transfer switches, neutral point equipment, DC carrier communication equipment, overvoltage protection equipment, etc. are all installed symmetrically on both poles.

The above connection mode satisfies the following operating modes:

1) Bipolar and monopole ground-return operation, monopole metallic return operation, etc. (excluding the parallel DC dual-conductor + ground return operation);

2) Isolation and grounding of either pole in converter station under maintenance;

3) Isolation and grounding of either DC pole line under maintenance;

4) Isolation and grounding of one or both electrodes and electrode lines of DC systems under maintenance in the monopole metallic return operation mode;

5) Isolation and grounding of one or both electrodes or electrode lines of DC systems under maintenance in the bipolar balanced current operation mode;

6) The DC power shall not be interrupted or reduced when switching from ground return to metallic return or vice versa in the monopole operation mode;

7) Disconnection and maintenance of faulty pole shall not affect the power transmission of the normal one.

To achieve switch among the above operation modes, the following switches will be installed on the DC pole bus and DC neutral bus:

1) The pole bus is provided with disconnector, while the disconnector is provided with an earthing switch on either side.

2) Neutral Bus Switch (NBS), with an earthing switch on each side.

3) Neutral Bus Grounding Switch (NBGS)and a maintenance disconnector with an earthing switch is installed on neutral bus side.

4) The metallic switching circuit is provided with a DC high-speed switch (MRTB), which achieves transfer from monopole ground-return to monopole metallic return operation mode, while a maintenance disconnector is installed on either side. The circuit on the external side of MRTB maintenance disconnector is parallel-connected with a disconnector which is connected with an earthing switch on either side.

5) The ground switching circuit is provided with a DC high-speed switch (GRTS), which achieves transfer from monopole metallic return to monopole ground-return operation mode. A maintenance disconnector with earthing switch is installed on the valve side, and an earthing switch is installed on the line side.

6) A disconnector is installed on the neutral bus side between each of the neutral bus of two poles and the metallic return path (including provisional earthing path).

7) A disconnector is provided on each side of DC filter. The disconnector on high-voltage side shall be capable of on-load switching under normal operating conditions without affecting the operation of system.

To sum up, the main connection schemes for valve bank, converter transformer, and the DC side is recommended as follows:

1) Converter valve: one 12-pulse valve bank for each pole.

2) Converter transformer: single-phase two-winding connection mode. In the current phase, a total of 12+2 single-phase two-winding converter transformers will be installed at the Matiari converter station, the three-phase connection groups are YNy0 and YNd11 respectively.

3.1.3 Connection of Valve Bank

The long-term construction target of this project is one ±660 kV/4000 MW DC line, which will be constructed in the current phase. The AC side of converter transformer is connected to the AC 500 kV bus via the equipment within the strings of AC 500 kV switchgear. This project adopts two poles, with either of them provided with one 12-pulse valve bank, the same as routine ±500 kV DC project.

The connection of DC side and valve bank is as shown in the following figure:

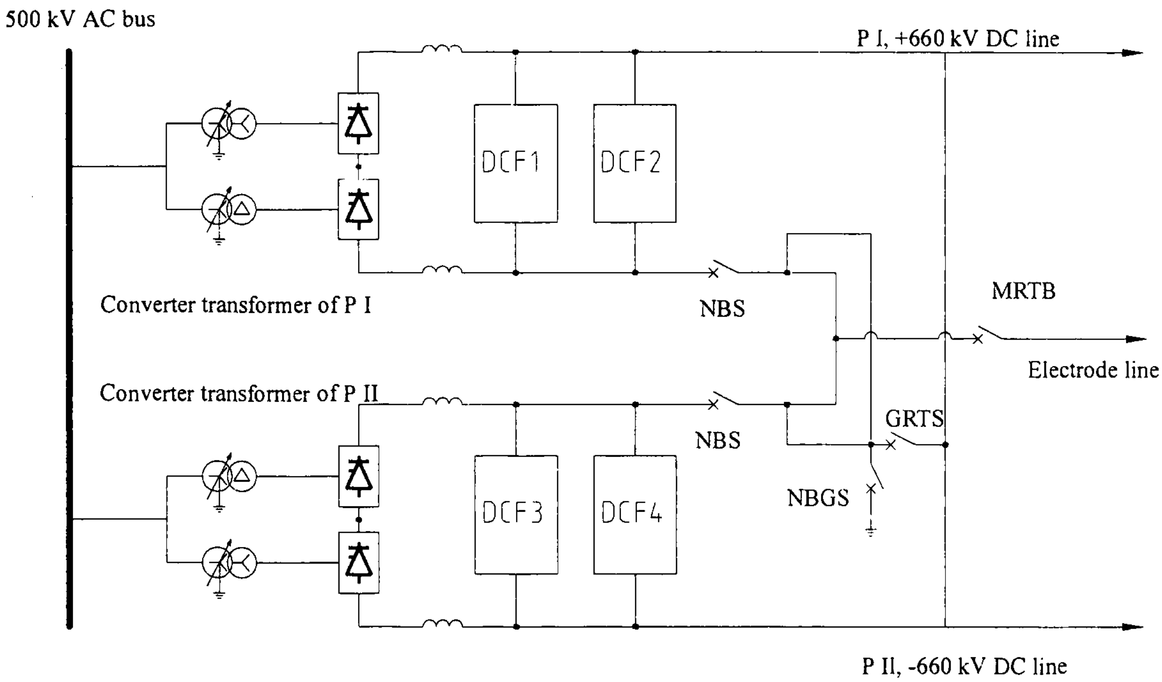


Figure 3.1.3-1: Connection of DC side and valve bank of Matiari converter station

3.2 Preliminary Determination of Converter Valve

3.2.1 Type of Converter Valve

In this project, thyristor converter valve is used. According to the existing manufacturing capability and the previous operation experience, the type and parameters of converter valves used in this project are provisionally determined as follows:

Table 3.2.1-1: Type of converter valve

	Type of Converter Valve
Converter valve	Double valve type
Mounting mode	Suspension type
Insulation type	Air-insulation
Cooling method	Water-cooling (internal-cooling)

According to the experience of other projects, the protective margin of voltage withstand level for the converter valves is provisionally determined as follow:

(1) A 10% margin over the arrester protective level for switching impulses.

(2) A 10% margin over the arrester protective level for lightning impulses.

(3) A 15% margin over the arrester protective level for steep-front impulses.

The converter valves should be capable of withstanding the rated current, overload current and various transient current. With respect to the transient overcurrent due to faults, the valves shall have the following capabilities:

(1) Short-circuit current withstanding capability with subsequent blocking;

(2) Short-circuit current withstand capability without subsequent blocking;

(3) Additional short-circuit current withstanding capability.

3.2.2 Main Parameters of Converter Valve

It is recommended to use 7.2kV/3030A 5-inch thyristor element. The height of converter valve tower is expected to be about 13 m. The rated DC current and voltage of thyristor valve are 3030A and 660kV respectively. It is recommended to use indoor air-insulated water-cooling type thyristor valve, with ETT or LTT valve.

3.2.3 Valve Cooling System

Each valve hall will be provided with one valve cooling system. The cooling system will be designed to cool the heat generated by thyristor valves and capable to operate and guarantee the design temperature range of cooling water for two hours and three seconds overload conditions, up to max specified design dry bulb ambient temperature.

Thyristor valve will be cooled by water, the hot water from the valves will be cooled down by closed evaporative cooling towers and spray water for cooling towers will be treated by reverse osmosis installation and chemical dosing unit.

3.3 Preliminary Determination of Converter Transformer

3.3.1 Short-circuit Impedance

The determination of short-circuit impedance of converter transformer shall be in accordance with the following factors:

a) Restrict short-circuit current;

b) Minimize the harmonic components;

c) Optimizing the design of converter valve, filter, and other converter-related equipment.

Furthermore, the determination of short-circuit impedance may directly affect the weight, size, and cost of transformer. If the short-circuit impedance is large, the following effects will arise:

a) The spacing and width of windings increase, and the width of converter transformer increases while the height of that decreases;

b) Higher rated power;

c) The reactive power loss during operation of converter increases;

d) The harmonic components generated by converter decrease;

e) The short-circuit current on valve side lowers;

f) No-load DC voltage rises, and the number of valve discs and the insulation level of converter valve increase accordingly.

Therefore, the determination of short-circuit impedance is an optimizing process, i.e., a process of seeking balance among the above indicators. According to the previous engineering experience, it is recommended that the short-circuit impedance of converter transformer be 18% in the current phase.

3.3.2 Rate Voltage, Type, and Capacity of Converter Transformer

The connection mode of converter transformer is one 12-pulse valve bank for each pole. The voltage, current, and resistance of DC bus on the rectifier side of converter station are ±660 kV, 3030 A, and 8.5 Ω respectively. For the U_k of 18%, the rated voltage of converter transformer on valve side is about 280.8 kV. Considering the manufacturing, transportation, and other related factors, it is recommended that 14 single-phase two-winding converter transformers with a capacity of 401 MVA should be used, with 2 of them serving as standby.

3.3.3 Voltage Regulating Mode and Tapping Range

(1) Determination of regulating mode of on-load tap

The on-load tap of converter transformer is mainly regulated in the following two modes:

a) Keep the no-load voltage on the valve side of converter transformer unchanged;

b) Keep the control angle (firing angle or turn-off angel) within a required range.

The main differences between the above two modes are described as follows:

The tapping regulation of converter transformer in the first mode is mainly used to accommodate the variation of the valve-side no-load voltage caused by the inherent voltage fluctuation of the AC grid. Such variation is generally small, so the tapping range is relatively small. The DC voltage variation caused by DC loads is supplemented by adjusting control angle. The tapping operations using this regulation mode are not frequent, so the tap switches have a longer service life.

In the second regulating mode, the converter normally operates within a small range of control angle, and the variation of DC voltage is mainly regulated and supplemented by the tap of converter transformer. This mode is characterized by low absorption of reactive power, low operation cost, low valve stress, low valve damping circuit loss, and small AC and DC harmonic components. So the operational performance of DC system in this regulating mode is good. But this regulating mode requires frequent tapping operations and a larger tapping range.

Among the long-distance HVDC transmission projects constructed in the recent years in China, 90% of them use the second regulating mode, i.e., regulating the DC operating voltage through tap while keeping the control angle within a required range. In this report, the second regulating mode is recommended. The final scheme shall be determined by the manufacturer after optimization of equipment.

(2) Determination of spacing of tapping positions

The spacing of tapping positions is related to the variation range of firing angle required for angle control, the permitted fluctuation rang of DC voltage during normal operation, the maximum measurement errors of DC operating parameters, etc. If the spacing of tapping positions is too small, more tapping positions are required, the requirement on the fluctuation of the bus steady-state voltage of converter station may be affected, the capacity of filter sub-bank is reduced, and thus the project investment will be increased. If the spacing of tapping positions is too large, a greater angle control range and a larger total amount of reactive power compensation are required, which are not cost-effective as well. According to the previous engineering experience, in the current phase, the spacing of converter transformer tapping positions is determined as 1.25% provisionally.

3.4 Preliminary Determination of Smoothing Reactor

The most important parameter of smoothing reactor is inductance, which should be optimized in accordance with the following conditions:

(1) The rise rate of fault current should be limited;

(2) The current interruption during low current load should be prevented;

(3) The DC current ripples should be restrained;

(4) Techno-economic comparison should be made among the proposed configurations of smoothing reactor and DC filter;

(5) The inductance of smoothing reactor should not lead to resonance at 50 Hz and 100 Hz with DC filter, DC line, converter transformer, capacitor at neutral point and other related equipment.

The inductance of smoothing reactors for either pole is taken as 300 mH provisionally. Dry-type smoothing reactor is used provisionally. Four smoothing reactors are provided for each pole, each reactor with an inductance of 75 mH. Throughout the converter station, there are 8 operating smoothing reactors and 1 standby reactor in total. The smoothing reactors are installed on pole bus and neutral bus separately.

3.5 Preliminary Determination of Equipment at AC Yard and AC Filter Yard

The main AC equipment used in this project is summarized as follows:

Table 3.5-1: Selection of main AC equipment

No.	Equipment Description	Main Parameters and Type Selection
I	500 kV AC switchgear	
1	Circuit breaker	550kV 4000A 63kA(3s) 160kA, with closing resistor[1]
2	Current transformer	500kV 2×2000/1A
3	500kV vertical break disconnector with single earth switch	550kV 3150A 63kA(3s) 160kA

No.	Equipment Description	Main Parameters and Type Selection
4	500kV disconnector, with single stationary contact and single earth switch	550kV 3150A 63kA(3s) 160kA , dual-column, horizontal type
5	500kV disconnector, with double stationary contacts and triple earth switches	550kV 3150A 63kA(3s) 160kA , three-column, horizontal type
6	Maintenance earth switch	550kV 63kA(3s) 160kA
7	500kV capacitive voltage transformer (three-phase, used on the incoming line, bus, and outgoing line of converter transformer)	500kV/ √3/0.1/ √3/0.1/ √3/0.1/ √3/0.1kV
8	500kV metal-oxide surge arrester	Y20W
9	500kV shunt reactor	550/ √3kV, 50Mvar 550/ √3kV, 40Mvar 550/ √3kV, 34Mvar
10	Neutral-point reactor of 500kV shunt reactor	66kV, ~500 (+10% to 10%)Ω
II	AC filter switchgear	
1	500kV AC filter/capacitor bank	Rated capacity: 150Mvar Rated capacity: 180Mvar
2	Porcelain knob type circuit breaker for the incoming line of capacitor bank	Dual-break, 550kV, 3150A, 63kA/3s, 160kA
3	Current transformer for the incoming line of capacitor bank	500kV, 1000/1A
4	Vertical break disconnector for the incoming line of capacitor bank	550kV, 3150A, 63kA/3s, 160kA, with single earth switch
5	Earth switch for the incoming line of capacitor bank	550kV, 63kA/3s 160kA
6	500kV metal oxide surge arrester	Y20W
7	500kV capacitive voltage transformer	500/ √3/0.1/ √3/0.1/ √3/0.1/ √3/0.1kV
8	Earth switch for 500kV bus	550kV, 63kA/3s 160kA
III	Station service system	
1	500kV three-phase oil-immersed transformer	SFP-130000/500, 525±2x2.5%/35kV, non-exciting regulation
2	132kV three-phase oil-immersed transformer	8MVA, 132±2x2.5%/11.5kV, ONAN, YN,d11, non-exciting regulation
3	132kV SF_6 circuit breaker	145kV 1600A 40kA 100kA
4	500kV circuit breaker	550kV 4000A, 63kA(3s), 160kA
5	500kV horizontal break disconnector with single earth switch	550kV 3150A 63kA/3s 160kA
6	132kV disconnector	145kV 1600A 40kA 100kA, dual-column, horizontally opening, single earth switch
7	500kV earth switch	500kV, 63kA (3s) 160kA

No.	Equipment Description	Main Parameters and Type Selection
8	132kV disconnector	145kV 1600A 40kA 100kA, dual-column, horizontally opening, double earth switches
9	500kV current transformer	500kV 2×2000/1A
10	132kV current transformer	132kV
11	500kV metal oxide surge arrester	Y20W
12	132kV surge arrester	132kV
13	500kV capacitive voltage transformer	500kV
14	132kV capacitive voltage transformer	132kV
15	35kV three-phase two-winding non-exiting regulation transformer	8MVA, 35/11.5kV
16	40.5kV circuit breaker	40.5kV, 2500A; 40kA; 100kA
17	40.5kV circuit breaker	40.5kV, 2000A; 40kA; 100kA
18	35kV current transformer	35kV, routine outdoor type
19	35kV voltage transformer	35kV, 35/√3: 0.1/√3: 0.1/√3:0.1/3kV
20	Dual-column horizontally-rotation disconnector	(1) 40.5kV, 2500A; 40kA; 100kA; with double earth switches (2) 40.5kV, 2000A; 40kA; 100kA; with single earth switch (3) 40.5kV, 2000A,: 40kA; 100kA; with double earth switches

Note: 1. whether the resistor is need depends on the conclusion of over voltage research.

3.6 Preliminary Determination of Equipment at DC Yard

The main DC equipment used in this project is summarized as follows:

Table 3.6-1: Selection of main DC equipment

No.	Equipment Description	Main Parameters and Type Selection
1	Dry-type smoothing reactor for pole line	680kV, 3030A, 75mH
2	Dry-type smoothing reactor for neutral line	150kV,3030A, 75mH
3	680kV DC disconnector	3030A
4	DC high-speed switch NBGS	3030A, including circuit breaker, capacitor bank, reactor, and arrester
5	DC high-speed switch NBS	3030A, including circuit breaker, capacitor bank, reactor, and arrester
6	Metallic return transfer breaker (MRTB).	3030A, including circuit breaker, capacitor bank, reactor, arrester, disconnector, and earth switch
7	Ground return transfer switch (GRTS)	3030A, including circuit breaker, capacitor bank, reactor, arrester, disconnector, and earth switch
8	DC current measuring devices	680kV, optical current transformer, with optical connectors and photoelectron equipment

No.	Equipment Description	Main Parameters and Type Selection
9	DC voltage measuring devices	680kV
10	DC pole bus arrester	680kV
11	Smoothing reactor arrester	680kV
12	12th/24th DC filter	Including C1-high-voltage capacitor, high-voltage capacitor imbalance CT, L1-high-voltage reactor, L2-neutral point reactor, T3-reactor L2 branch CT, T4-CT on the neutral point side, F3-arresters on both ends of L1, F1-arrester on the high-voltage end of L1, C2 low-voltage capacitor, F2-arresters on both ends of L2, etc.
13	6th/42th DC filter	Including C1-high-voltage capacitor, high-voltage capacitor imbalance CT, L1-high-voltage reactor, L2-neutral point reactor, T3-reactor L2 branch CT, T4-CT on the neutral point side, F3-arresters on both ends of L1, F1-arrester on the high-voltage end of L1, C2 low-voltage capacitor, F2-arresters on both ends of L2, etc.
14	Other equipment on DC side	Including high-voltage and low-voltage post insulators, low-voltage disconnector/earth switch, DC neutral bus impulse capacitor, PLC reactor, capacitor, etc.
15	DC carrier communication equipment	Including 2 reactors and 3 banks of capacitors.

4. Study on Reactive Power Compensation of Converter Station

4.1 Basic Study Principles

(1) The reactive power compensation levels and zones should be balanced locally without long-distance transmission.

(2) The total reactive power compensation capacity of converter station is generally calculated according to the reactive power consumption of DC system when transmitting rated power in rated voltage. Since there may be large fossil-fired power plants in the vicinity that the converter station serves, the reactive power provided by such power plants should be considered, provided that the system voltage regulation requirement and generator's operation requirements can be met.

The additional reactive power compensation capacity required for DC overload is balanced by the capacity of the standby compensation bank at converter station.

(3) The reactive power capacity installed at substation, in principle, is only used to compensate the reactive power loss of the main transformer of the same substation and the half of that of the outgoing lines at various voltage ratings. For the incoming lines from nearby power sources, they shall be permitted to supply more reactive power, but the voltage drop between the two ends of the line should not exceed 10%. The reactive power compensation in the existing grid and that which has been definitely planned should be simulated according to the actual condition and the planning respectively.

(4) Voltage control of AC system: According to the related code, for hub substation, the operating voltage of the bus on the LV side should be controlled to 1 ~1.1 times the rated voltage of grid in normal condition, and should not be lower than 0.95 times the rated voltage of grid after incident.

The operating voltage at any point of grid shall in no case be higher than the maximum operating voltage of grid. In normal conditions, it shall not be lower than 0.95 to 1.00 times the grid rated voltage (for the substations at the receiving end of grid, take the lowest value).

In addition, the system voltage regulation mainly relies on the adjustment of generator excitation, while using switchable, controlled reactor and capacitor as supplementary means.

(5) The power factor of maximum reactive output of generator should not be lower than the rated power factor. The power factor of minimum reactive output

should be not be higher than 0.95 for steam turbine generator, and should be controlled to prevent phase advance for hydro-generator. The voltage level at the generator end should be limited to 1.05 to 0.95 times the rated voltage.

(6) The reactive power compensation devices installed at converter station are generally considered together with AC filters. In the minimum operating mode, to meet the filtering requirement, a number of filters should be put into operation to make the capacitive reactive power of converter station surplus. Therefore, the AC system or converter station should be able to absorb some capacitive reactive power.

4.2 Calculation of Reactive Consumption of Converter Station

4.2.1 Calculation of Reactive Power Consumption of DC System

The converter station consumes a large amount of capacitive reactive power when it works. The reactive power consumption of converter station shall be calculated taking into account the various AC and DC operating modes. The reactive power consumption of converter station is related to the transmission of DC power, DC voltage, DC current, commutation angle, commutation reactance, and other factors. Calculate the reactive power consumption of the 500kV side of converter station under various operating conditions in accordance with the above-mentioned reactive power control principles. The DC steady operating voltage of converter station is controlled using the fixed firing angle (a=15°) method. The short-circuit impedance of converter transformer is taken as 18% provisionally. According to the Ningdong-Shandong ±660kV HVDC transmission project and based on the principle of not increasing the budget for commutation equipment, the 2-hour overload capacity of DC system is taken as 1.1 times the rated transmitted capacity.

The tolerance for the impedance of converter transformer is taken as ±5%. In the high reactive power operating condition, the commutation impedance tolerance of +5% should be taken; in the low reactive power operating condition, -5% should be taken. DC line resistance is a parameter affecting the reactive power consumption of converter. For the high reactive power mode, use the minimum possible resistance; for low reactive power mode, use the maximum possible resistance. The rated firing angle of rectifier it taken as 15°, while the rated turn-off angle of inverter is taken as 17°.

The calculated reactive power consumptions of converter station on sending end are as shown in Table 4.2-1.

Table 4.2-1: Calculated reactive power consumptions of the 500kV side of Matiari converter station

DC transmission capacity (MW)	Reactive power consumption of the 500kV side of Matiari converter station (Mvar)			
	=16%	=17%	=18%	=19%
Pd=4000	2050.2	2101.2	2151.8	2202
Pd=4000 (a=18°)	2293.7	2340	2389.8	2458.3
Pd=4200	2192.2	2248	2302	2441.3
Pd=2000	817.1	831.4	848.2	864.8
Pd=2000 (monopole ground return)	1025	1050.5	1075.8	1100.9
Pd=2000 (monopole metallic return)	1025	1050.5	1075.8	1100.9
Pd=400	120.3	121.1	122	122.7
Pd=400 (reduce the voltage by 10%, and increase the firing angle)	322.2	322.8	323.4	324.7

4.3 Reactive Power Support Capacity of AC System

4.3.1 Reactive Power Supply Capability of AC System

The converter station on the sending end incorporates large-sized power plant, which may provide an amount of reactive power to the converter station. However, since the fossil-fired power plant connected into the converter station through the 500 kV line is far from the converter station, it is not suitable to supply a great deal of reactive power. So it is assumed preliminarily that the AC system is incapable of providing reactive power support to the converter station on sending end.

A part of the additional reactive power compensation capacity required for DC overload operation is balanced by the capacity of the standby compensation sub-bank provided at the converter station; the other part may be provided by the AC system.

4.3.2 Reactive Power Absorption Capacity of AC System

Considering that the auxiliary AC projects in the vicinity of the converter stations at the sending and receiving ends have not yet been provided with appropriate reactive power absorption measures, it is provisionally assumed that the AC system in the vicinity of the converter stations at the sending and receiving ends is incapable of reactive power absorption, and the inductive reactive power should be compensated locally at the converter stations.

4.4 Reactive Power Compensation Configuration of Converter Station

According to calculations, the total capacity of capacitive reactive power compensation of Matiari converter station is taken as 2610 Mvar provisionally. The reactive power compensation capacitors are divided into 4 banks and subdivided into 16 sub-banks. Each sub-bank has a capacity of 150 Mvar to 180 Mvar (there are two sub-bank sizes: the low capacity size is 150 Mvar, and the high capacity size is not greater than 180 Mvar).

It is recommended that at least one 500kV power source in the vicinity be started when the DC system is put into operation.

The final division of sub-banks should be determined by further studies according to the actual conditions including switching level, system harmonics, and the arrangement of converter station.

As for inductive reactive power compensation, in this phase, 4 banks of low-voltage reactors are provided on the 35 kV low-voltage side of Matiari converter station preliminarily, each bank with a capacity of 60 Mvar. These reactors should be of outdoor dry-type air-core design. In the actual engineering design, the configuration of low-voltage reactors should be further optimized according to the actual condition of the low-voltage bus of converter station.

5. Project Planning

5.1 DC System Operation Modes

This project is a typical DC transmission project of bipolar neutral grounding at two terminals. Conventionally, its basic operation modes should include bipolar operation, monopolar ground return operation, and monopolar metallic return operation.

By referring to experience with Ningdong-Shandong ± 660kV DC transmission project, a 12-pulse converter valve group is considered for each pole. The main operation modes of the ±660kV HVDC from Matiari to Lahore project are as follows:

1) Bipolar full voltage operation;

2) Monopolar metallic return operation;

3) Monopolar ground return operation;

4) Reverse power operation;

5) Reduced voltage operation.

6) Additional control functionality required for DC system

To improve the AC system performance, the DC system should have the following control and auxiliary control functions according to experience:

1) Power swing damping in the case of major accident on the AC system;

2) Reactive power control of the converter station which is transmitting power;

3) Emergency active power support or flow reversal;

4) Control of AC system frequency;

5) Control of AC bus voltage in converter station;

6) Suppression of sub-synchronous oscillation of AC system.

5.2 Main Performance Requirements for DC System

5.2.1 DC System Ratings

With the DC system operating continuously under ratings and the Matiari converter station sending power to Lahore converter station, the following continuously operation ratings should be available on the DC line side of the converter station's smoothing reactor:

Rated power: Bipolar 4000MW, monopolar 2000MW

Rated voltage: ± 660kV

Rated current: 3030A

5.2.2 Minimum Transmission Power of the DC System

According to engineering experience, the minimum DC current of the project is tentatively taken as 10% of the rated DC current, that is, the minimum transmission power of the DC system is 10% of the rated power.

5.2.3 Reduced Voltage Operation Capability of the DC System

Based on practical experience and capacity of related equipment, the minimum voltage of the Matiari-Lahore HVDC project is tentatively considered to be 70% of the rated voltage. For 70%-100% of the rating, the transmitted power of the DC system will be 70%-100% of the rated power.

5.2.4 Power Reversal Capability of the DC System

The sending end of the project has no special requirements for power reversal, that is, the inherent capability of the DC equipment will be used and no additional equipment will be purchased.

5.2.5 Reliability Requirements for DC System

To be agreed with the owner.

5.2.6 AC System Operating Voltage and Frequency

According to the conclusions of flow and stability calculation, the operating voltage and frequency range of the AC bus of Matiari converter station is tentatively determined as follows:

(1) Operating voltage

The normal voltage at the sending end converter station for 500kV is taken as 475-540kV, the rated voltage of the 500kV bus on the converter AC side is taken as 505~525kV, and the post-accident voltage is taken as 450-550kV.

(2) System frequency

The normal fluctuation of the sending end converter station bus frequency is 50 ± 0.1Hz. In the case of a fault, the system frequency range is tentatively taken as 49.4-50.5Hz, the fluctuation range after the fault is cleared should be 50 ± 0.2Hz.

5.2.7 Overload Requirements for the DC System

HVDC systems generally run with continuous rated power, but considering the design margin of equipment, environmental temperature changes and other factors, the DC system should have a certain overload capability. The overload capability can be divided into transient overload and short-term overload capability based on the duration of overload.

A stronger transient overload capacity will help improve the system transient stability. The short-term overload capacity is mainly intended to send more power and reduce the impact on grid operation when the AC and DC equipment is out of service for some reasons.

For this project there are no special requirements for DC overload capacity. By referring to overload capacity of HVDC projects in China and other countries, the 2-hour overload capacity of the DC system is tentatively considered to be 1.1 times the rating without costs for additional equipment. The 3-second overload capability of DC system is taken as 1.2 times the rated transmission capacity without increasing additional commutation equipment.

The values of the overload capacity of the Matiari-Lahore DC system should be determined based on R&D progress of equipment, without causing additional costs or difficulty in construction.

5.3 Requirements for the Main Technical Parameters of the DC System

5.3.1 Requirements of the Grid for Electrical Connections in Converter Stations

A 12-pulse valve group is recommended for each pole. A converter station will be provided with a 500kV bus, with 3/2 circuit breaker connection. The sending end converter station is planned to have 18 500kV bays, 14 in this phase, including 6 power source incoming lines, 2 system connection lines, 1 line to Jamshoro substation, 1 line to Moro substation, 4 banks of capacitors and filters, and 2 converter transformer incoming lines.

5.3.2 Requirements of the Grid for Converter Transformer Parameters

(1) The parameters of converter transformer in the Matiari (the sending end) converter station are as follows:

Short-circuit impedance percentage Uk is tentatively considered as 18%, which will be further optimized based on equipment manufacturing capability and transportation;

Type of converter transformer: single-phase two-winding transformer, in Y0/Δ and Y0/Y connection;

Configuration of converter transformer: 12 + 2;

Single-phase two-winding capacity: Uk = 18%, 401MVA;

Tap range on the HV side of converter transformer: Uk = 18%, -7-+23.

5.4 Primary Electrical Design of Converter Station

5.4.1 Valve Hall and Converter Transformer Arrangement

Valve hall and converter transformer area are the core area of a converter station. The delivery power of the converter station is 4000MW. In addition, the costs of converter transformer and valve hall account for a large part of the total investment of the converter station, therefore, the primary consideration in arranging the valve hall and converter transformer will be their operational safety, and investment will be considered as well.

Based on the design of one 12-pulse valve group for each pole, double valve will be used.

In the case of double valve, the valve tower will be about 13m high. Each valve hall will have six valve towers. With single-phase two-winding converter transformer and double valve arrangement, the 6 converter transformers of each pole will be arranged in a line on the AC incoming line side of the valve hall. The 12 valve side bushings of the converter transformers will be led into the valve hall, then connected to the 12-pulse valve group after a Y/Δ connection in the valve hall. The converter valves in the valve hall will be double valves, six groups per pole, suspended.

5.4.2 DC Switchgear Type and Layout

Outdoor DC yard will be used.

In the DC yard, the equipment will be arranged symmetrically for the two poles. The DC neutral bus equipment will be arranged in the center of the field, the line bus equipment on two sides, and two DC filter banks will be arranged between the DC neutral bus and the pole bus. The DC filters and pole bus smoothing reactors are arranged in low locations, surrounded by security fencing. The DC filter capacitors are installed with supports.

5.4.3 500kV AC Power Switchgear

1) 500kV AC switchgear

3/2 circuit breaker connection will be used on the 500kV AC side, in three rows. Two converter transformers are directly elevated to a series. The #1, #2, #3 and #4 AC filter banks will be led to the string through overhead line.

2) Equipment on the step-down transformer circuit

The two step-down transformers will be led to the two 500kV main buses respectively through open AC switchgear.

5.4.4 AC Filter Arrangement

AC filters are connected in series in the form of banks. For this phase 16sub-banks are considered, with 9 being 150Mvar, and 7 being 180Mvar. All AC filter banks will be arranged in a line. All AC filters of the converter station will be centralized for clearing demarcation of zone and use of noise reduction measures.

5.4.5 35kV Switchgear Arrangement

35kV AC switchgear will be connected with a single bus, with the switchgear arranged outdoor. Two 35kV buses will be provided, each connected with two 60Mvar LV reactors and one 35/11.5kV auxiliary transformer.

5.4.6 Electrical General Layout Plan

The electrical general layout plan will be determined as follows:

1) The direction of ± 660kV DC and 500kV AC outgoing lines should meet the requirements of AC and DC line corridor, minimize angle towers, and avoid line crossover.

2) 3/2 circuit breaker connection will be used for the AC 500kV switchgear, connection of AC filters will be considered based on use of live tank circuit-breaker.

3) Four banks of AC filters are proposed.

4) Double valve arrangement is tentatively proposed for valve hall.

5) Outdoor DC yard is considered.

In response to the main electrical connection, the electrical general layout plan of the Matiari converter station is as follows:

The control building, valve hall, converter transformers and 35kV switchgear are arranged in the center of the station area, the DC yard in the east, and ± 660kV DC transmission lines are led to the east. The 500kV AC switchgear will be arranged in the west of the station area. The lines to Moro substation will be led from the north, and all other 500kV AC lines will be led from the south. The AC filter will be arranged in the north. Spaces will be reserved for additional main transformers, 500kV and 220kV lines.

5.4.7 Lightning Protection

Ground wire will be used as lightning protection measures for this project: ground wires will be used for the valve hall, converter transformers and 500kV AC switchgear area protection; for buildings which cannot be protected by ground wires and lightning rods (such as comprehensive building, integrated pump house, garage and other buildings), roof lightning strip will be used.

Given that copper ground wires are used in most recent converter stations in China, copper conductors are considered for the earth grid.

5.5 Secondary Electrical Design of Converter Station

(1) Design principles

(a) The converter stations will be designed on a manned basis. An integrated computer monitoring and control system will be built for the AC and DC systems.

(b) The monitoring, measurement, control and other functions of all equipment in the station will be realized by the computer monitoring and control system, which will be of a modular, hierarchical, distributed, and open architecture.

(c) The HVDC control system will be of a hierarchical distributed architecture. The sampling units, data bus, master device to control port, should be fully in duplicated configuration.

(d) The HVDC protection offers protection for pole/two poles, DC switchyard, DC lines and earth electrode lines, which are divided into multiple overlapped protection zones. The protection zones and configuration shall ensure all devices are under comprehensive protection. Triple redundant protection will be used for the HVDC system.

(e) The HVDC protection and control systems will be separate. In function and configuration of control cabinets, the protection systems of the two poles should be completely independent.

(f) HVDC control and protection system is suitable for both rectifier operation, inverter operation can be applied.

(g) In the 500kV AC yard, a relay bay will be provided, and control and protection devices will be provided corresponding to the AC equipment bays. HVDC control and protection cabinets, converter transformer control and protection cabinets will be arranged in in the respective rooms in the control building; the control and protection cabinets of AC filters, capacitors and reactor banks, and AC lines will be arranged in the local AC relay room.

(h) Based on the characteristics of HVDC systems, auxiliary DC power supplies will be provided respectively to DC P I, P II, common equipment of the station and AC local relay room.

(2) Computer monitoring and control system

The Matiari converter station will be designed on a manned basis. The computer monitoring and control system will be of object-oriented design. Through full use of computer technology, modern control technology, network communications technology and graphics technology, an integrated automation system of control, measurement, telecontrol and modern comprehensive management. The computer monitoring and control system will be of modular, hierarchical distributed network architecture. The operators may use the HMI in the control room to monitor, control and record all the equipment in the converter station, and send related information to control centers through remote communications devices.

(3) HVDC control system

In addition to basic control of various operation modes, the HVDC control system includes various basic controllers and limiters, and is capable of maintaining the controlled signals such as DC power, DC current, DC voltage and converter firing angle within the steady state limits of primary DC equipment. The control system also has the ability to suppress transient overcurrent and overvoltage, and to recover steadily within the specified response time after AC or DC system failures.

The HVDC control system will be of a hierarchical distributed architecture. With the purpose of assigning control functions to the lowest possible layer, the HVDC control system is divided into the following by function: double-pole control layer, pole control layer and converter valve control layer.

The sampling units, data bus, master device to control port, should be fully in duplicated configuration.

(4) HVDC protection system

The HVDC protection system is arranged based on protection zones. The protection system of the converter station is divided into the following seven protection zones: AC filter/shunt capacitor protection zone, converter transformer protection zone, converter protection zone, DC line protection zone, DC filter protection zone, DC switchyard protection zone, and DC earth electrode line protection zone. Each protection zone and adjacent protection zone are overlapped to ensure that there is no dead zone. Triple redundant protection will be used for the HVDC system.

Among them, the DC filter protection and converter transformer protection will be provided by the pole protection; three sets of electrical quantity protection and non electrical quantity protection will be provided for each pole; duplicated protection will be provided for the AC filters based.

DC protection of the two poles are completely separate. HVDC protection and DC control systems will be relatively independent, both in redundancy.

(5) Component protection

Duplicated protection will be provided for the main and standby 500/35kV step-down transformers, that is, two sets of independent electrical quantity protection and one set of non electrical quantity protection will be provided in two cabinets. One set of protection in one cabinet will be provided for the auxiliary transformer for external power supply and auxiliary 35kV /11.5kV transformer. One set of protection arranged in corresponding switch cabinet will be provided for the 11 kV/400V transformer.

One circuit breaker protection and one control box will be provided for each 500kV auxiliary transformer circuit breaker, arranged in the 500/35kV step-down transformer protection cabinet.

One line protection cabinet of the same configuration as the opposite side will be provided for the two π connected lines of 132kV. One protection cabinet will be provided for the 132kV bus.

One set of protection will be provided for each 35kV reactor, including current quick break protection, overcurrent protection, and zero sequence overcurrent protection. One cabinet will be provided for protection of two reactors.

(6) Transient fault recorder system

The transient fault recorder system includes AC transient fault and DC transient fault recorders.

DC transient fault recording function is performed by a separate DC transient fault recording panel. Separate DC fault recorders are provided for the DC system based on pole and converter transformer, used to record the DC system valve group pulse sequence, firing angle, extinction angle, power, and current, voltage and protection operations and fault information of the HVDC and converter transformer circuits. Two converter transformer fault recorder panels and two valve group DC fault recorder panels will be provided.

The fault recorders record the current, voltage of AC filter banks in the AC yard, 500kV and 35kV auxiliary transformers and protection operations and fault information of various protection devices. Each bank of AC filter will be provided with one panel; two panels will be provided for all the transformers. Fro AC fault recorders related to system protection, see related chapters in Volume 3. The recorded AC fault information will be sent to the AC fault recorder panel in the relay room.

(7) DC fault location system

Two fault location systems will be provided for the HVDC lines of the project, mainly using double end detection of fault transient state travelling wave for ranging. It uses absolute time difference of the initial travelling wave surge reaching from the location of fault on the line to both ends to calculate the distance of fault to the ends.

(8) Station master clock system

The station will be provided with a clock synchronization system, and the master clock should be able to receive GPS reference time signals. For station control and process control which has high real-time requirements, hard connection will be used for synchronization, such as pulse synchronization and B code synchronization; network synchronization will be used for other devices. The synchronization of station master clock covers the station computer monitoring and control system, DC control and protection system, AC protection system, AC and DC transient fault recorder systems, SCADA and remote system, and electricity billing system.

(9) Valve cooling control and protection system

The valve control and protection system is in redundant configuration for each pole. The scope of redundancy extends from power supply of valve cooling control system to sensors which provide information to the control system; similarly, the digital communications interface with DC control and protection system is also redundant. When the main system fails, it will automatically switch to the backup system.

(10) DC power supply system

Three local relay rooms will be provided for this phase in response to the arrangement of AC yard and AC filters. Three DC power supply systems are considered for the AC yard of this phase: respectively for P I, P II and common devices. Six DC power supply systems will be provided for the station.

The DC power supply systems will be of 220V. Each DC power supply system includes two sets of batteries, three sets of microprocessor-based high-frequency switching power supplies and corresponding DC panels. Sectionalized single-bus configuration will be used for the DC power supply system. Each section of bus will be connected to a battery and a charger; and a common charger will be provided for the two batteries, and can be used as backup for any charger. The battery discharge time is 2 hours, and the loads will be supplied in the form of radiation.

(11) AC UPS

To feed important AC loads such as computer control system, workstations, printers, the control building provides two 15kVA AC UPSs, for redundant backup for the two poles and in parallel operation. Each UPS includes a rectifier, inverter, static transfer switch, and a bypass system. Two UPSs are respectively connected to two 220V batteries, with no dedicated battery. Each UPS has a full capacity. When AC power fails, the UPS can provide emergency power supply for two hours.

AC relay room will be provided with one inverter power supply system to energize the AC loads.

(12) Meter

Electricity meters are provided as follows according to the main electrical connection of the project:

One meter will be provided at 500kV AC filters and LV side of 500kV auxiliary transformer. Separate panels will be provided for the meters in the separate rooms. The meters will communicate with the station computer monitoring and control system through serial ports.

(13) Other auxiliary systems

The station will be provided with a fire alarm and control system. The capacity, performance requirements and corresponding interfaces of fire alarm controllers will be provided according to the scale of this phase. However, the fire alarm system should have extension spaces to meet future needs.

A video surveillance system and security guard system will be provided to prevent unlawful entry.

A full chromatography online insulating oil monitoring system will be provided for the converter transformers and HV transformers; a leakage current online monitoring system will be provided for the valve and DC yard lightning arresters.

(14) Arrangement of control building and protection room

Based on the primary equipment of the converter station, the control building and 500kV AC relay rooms will be arranged as follows:

The control building will contain operator control room, P I control and protection equipment room, P II control and protection equipment room, common and bipolar control and protection equipment room, P I converter transformer and DC yard interface room, P II converter transformer and DC yard interface room, P I valve cooling equipment room, P II valve cooling equipment room, common DC panel room, P I DC panel room, and pole II DC panel room.

The 500kV AC switchyard will be provided with three 500kV local relay rooms, each of which will be provided with two battery rooms;

(a) The secondary devices of #1~#5 500kV series will be arranged in the first 500kV local relay room;

(b) The secondary devices of #6~#10 500kV series will be arranged in second 500kV relay room.

(c) The secondary devices of ACF1-ACF4 will be arranged in the ACF 500kV local relay room;

5.6 Site Planning and General Layout

The overall planning of the station site mainly takes into account the following aspects:

1) To mitigate the noise impact on surrounding residents, the fence of the converter station will be at least 200 m away from the surrounding residential areas, and an area is reserved outside the fence walls to the west for future expansion of 500 kV system.

2) As the receiving-end converter station is located to the northeast, the DC outgoing line shall run towards the northeast direction and the DC yard shall be located in the east or north of the converter station.

3) The outgoing line of 500 kV AC system leads to the south basically and, therefore, the AC switchgear area should be located in the south of the converter station.

Based on the above considerations, the axis of the station area (i.e., centerline of the transport road of converter transformers) is along true south-north direction. The valve hall and converter transformer area will be arranged at the center, the DC yard in the east, the AC filter banks in the north and the 500 kV switchgear area in the south of the station area. A total of 12 outgoing lines are planned, 10 out of which are to be built at this phase. The auxiliary production area is arranged in the northeast of the station area. The land within the boundary of the fence walls is sized 27.716 hectare.

The 100-year flood level at the site is 23.8 m, which is higher than the natural ground level, thus necessitating earth fill at the station site to increase the level to 24.0 m. The earth fill in the station area is about 2 m high on average. An earth volume of 353,000 m^3 is required to be sourced from outside and 105,000 m^3 of planting soil and sludge needs to be discarded outside.

The access road is connected from the national trunk highway N5 to west of the station area. A 1180 m long access road will be newly constructed, which has 6.0 m wide cement concrete pavement, gravel roadbed and 0.5 m wide clay-bound macadam shoulder on either side.

Roads of cement concrete pavement will be used on the station site, and the roadbed will be made of macadam. Main roads (road for transport of converter transformers) on the site will be 6.0m wide. The roads for transport of 500kV HV shunt reactors and smoothing reactors will be 4.5m wide, with a turning radius of 12m. The phase-to-phase road will be 3.0m wide, with a turning radius of 7.0m. The ring roads will be 4.0m wide with a turning radius of 9.0m.

Cable trenches shall be of concrete structure.

Unpaved surface in the station shall be covered with gravel.

5.7 Transport of Large Equipment

5.7.1 Dimensions of Large Equipment

The transport dimensions of large equipment, by referring to experience of similar projects, are given as follows:

	Transportation dimensions (m)	Weight (t)	Quantity
Yy converter transformer	13×4.5×5	350	7
Yd converter transformer	12.5×4.5×4.8	310	7
500/35kV step-down transformer	8.4×3.8×4.3	160	2
500kV HV reactor	3.8×3.5×3	70	18 for the current phase

* The exact transport dimensions will be provided by the manufacturers

5.7.2 Transport Conditions

Chinese equipment will be used for this project. After departure from Chinese manufacturers, the equipment will be shipped by water to a port in Pakistan, then by land to the site. Pakistan is located in South Asia, landlocked on three sides, with the south bordering the Arabian Sea. Pakistan's inland transport relies on road, supplemented by rail, but the railway cannot transport large heavy pieces of cargo. Most of its inland rives are not navigable for large vessels. So the large equipment for this project can be transported by sea and inland road.

5.7.3 Analysis of Transport Plan

According to the transport conditions in Pakistan, large equipment will be transported by manufacturers to Karachi, a port city in south Pakistan. According to site survey, Port Qasim can be used as the receiving port, from where equipment can be transported to the sending and receiving end converter stations by road. The transport route is as follows:

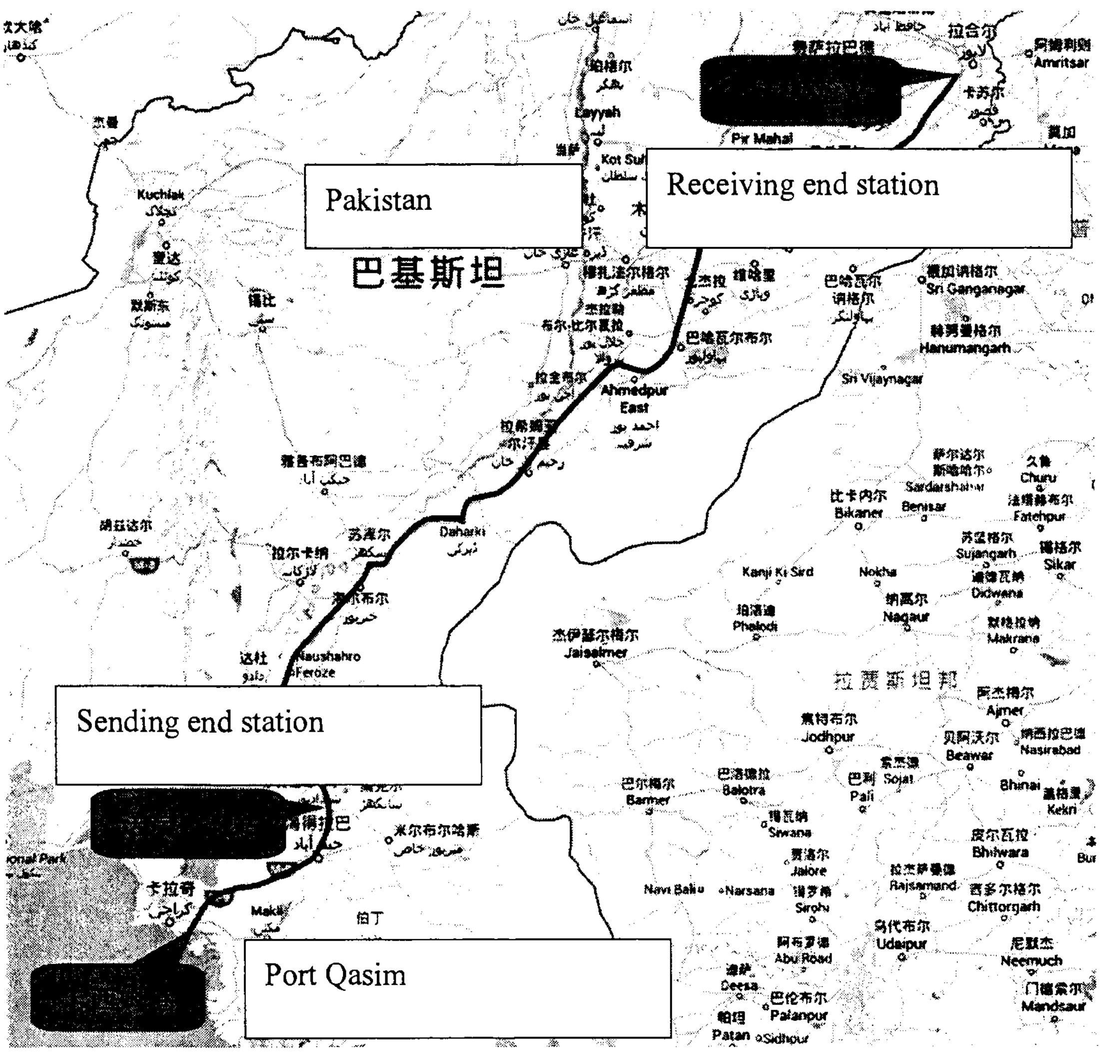


Figure5.7-1: Inland road transport map

Port Qasim is about 200km away from the sending end converter station and the main route will be the N5 highway, which is a main north-south road equivalent to China's national highway. With good roadbed, flat surface, and without high gradients, the road has poor conditions at some locations, but suitable for transport of large vehicles. The problem is that there are many bridges and overhead barriers. The road and bridges should be properly protected during transport.

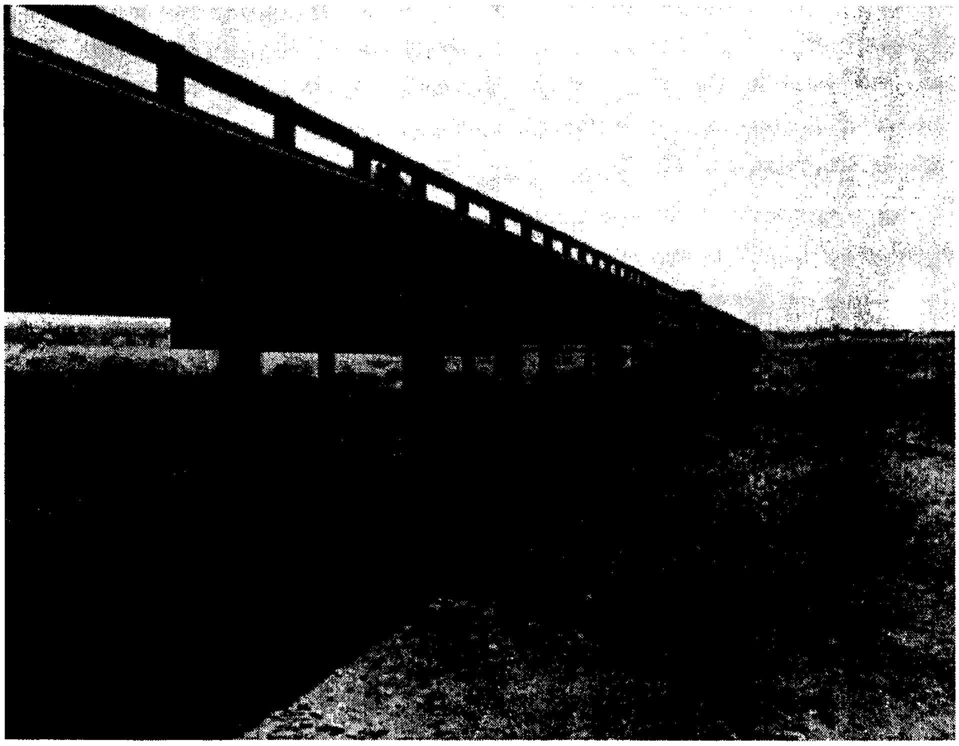


Figure 5.7-2: A large bridge on N5 road

Figure 5.7-3: A typical overhead barrier on N5 road

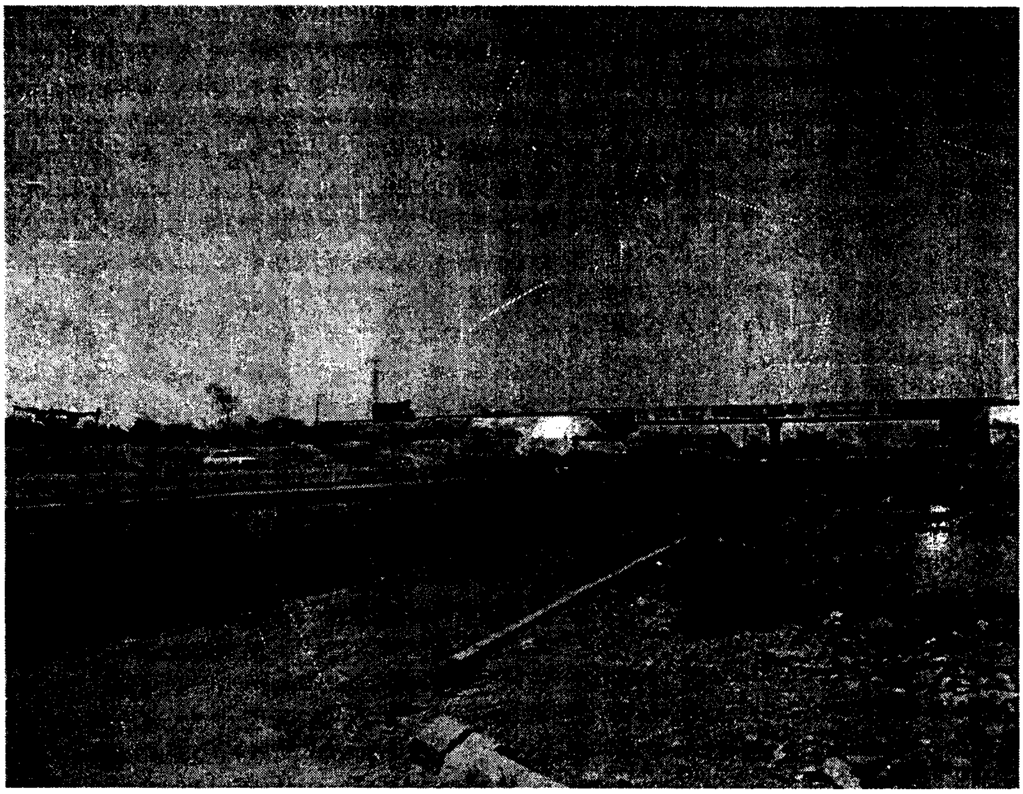


Figure 5.7-4: An overpass on N5 road, the vehicle can get off the bridge through the reverse road

There are approximately 20 bridges on the road, including a large bridge of about 500m. Most local bridges have a box girder structure, offering good bearing capacity. The overhead barriers on the road limit the height to 6m. With proper measures taken, they can meet the passage needs of large equipment for the project.

5.7.4 Conclusions and Recommendations

According to the road conditions found during survey, the large equipment for the project can be shipped to the site after properly planning and safety measures. As informed by the local transport company, equipment heavier than 450t had been transported on the road. But transporting over so long a distance by road will involve high difficulty and unpredictable factors. The owner is advised to engage a qualified transporter to develop a plan for transport of large equipment to the site safely, with minimum costs.

5.8 Auxiliary Power

5.8.1 Introduction of Auxiliary Power Supply

In order to assure the operation reliability of converter station, three circuits of auxiliary power supply are proposed for Matiari converter station; two circuits will be led through 35/11.5kV auxiliary transformers on two 35kV AC buses; the other circuit will be led from the 132kV transmission line near the station. The power supply lines will be finalized by the owner.

5.8.2 Principles of Connection of Auxiliary Power

Two 500/35kV step-down transformers will be provided in the station; two main 500kV buses are connected with the HV side by open AC switchgear; LV side is connected to 35kV system of the station. The two 11kV power supplies are led from the LV side of two 35/11.5kV auxiliary transformers. The station standby power supply is temporarily led from 132kV transmission line near the station in an overhead manner. The owner will finalize the power supply routes.

Single bus connection and open arrangement will be used for 132kV switchgear; 132kV transformer has two outgoing circuits and 132/11.5kV auxiliary transformer has one incoming circuit. Bus PT will be provided.

Single bus in two sections will be used for the 11kV system; each section is supplied by a separate 1-circuit main power supply; besides, one standby section will be provided. Each 11kV working section is connected with two 11/0.4kV, 2500kVA low-voltage auxiliary transformers for valve group's auxiliary load. Besides, each 11kV working section is connected with one 11/0.4kV (2500kVA) low-voltage auxiliary transformer for common load of converter station.

5.8.3 Auxiliary Power Equipment and Arrangement

(1) Selection of auxiliary transformer

The auxiliary transformer includes two 35/11.5kV auxiliary transformers and one 132/11.5kV auxiliary transformer; the low-voltage auxiliary transformer includes six 11/0.4kV auxiliary transformers.

(2) Selection of high/low-voltage distribution panel

1) High-voltage switch cabinet

Trolley or intermediate switch cabinet will be provided as 11kV high-voltage switch cabinet and vacuum circuit breaker will be provided inside.

2) Low-voltage switch cabinet

Drawer type or plug-in intelligent switch cabinet will be provided as 400V low-voltage switch cabinet (PC, MCC and so on). .

5.9 Buildings and Structures

5.9.1 Buildings

±660kV Matiari converter station includes the following buildings: one P I valve hall, one P II valve hall, one control building, one 11kV switch cabinet building, one 400V common switchgear building, three 500kV relay and battery building s (500kV No. 1 relay and battery building, 500kV No. 2 relay and battery building and 500kV No. 3 relay and battery building),one metering building ,one spare parts warehouse, one Specially store, one Spare flat wave reactor chamber ,one integrated water pump house, one dormitory building for chinese ,one refectory for Chinese, one activity building, one dormitory building for Pakistani ,one refectory for Pakistani,one office building for operating crew, three guard buildings and gates, some watchtowers,one office building,one dormitory building for security personnel,one dormitory building for managers,one dormitory building for laborers.

The total building area is about 25781m^2.

List of new buildings in the station

No.	Name of buildings	Building dimensions (m) Length x Width x Height	Classification of fire hazard	Refractory level	Number of floors	Building area (m2)	Qty' (building)
1	P I valve hall	84×35×30 (lower chord of roof truss 24.75)	IV	Level II	Single floor	3075	1
2	P II valve hall	84×35×30 (lower chord of roof truss 24.75)	IV	Level II	Single floor	3075	1
3	Control building	33.6×37.9×18.9	V	Level II	Three floors	3243	1
4	11kV switch cabinet building	15.6×9.6×4.4	V	Level II	Single floor	162	1
5	400V common switchgear building	12×9.6×4.4	V	Level II	Single floor	118	1
6	500kV No. 1 relay and battery building	36.6×9.6×4.2	V	Level II	Single floor	373	1
7	500kV No. 2 relay and batterybuilding	39.8×9.6×4.2	V	Level II	Single floor	405	1
8	500kV No. 3 relay and battery building	36.6×9.6×4.2	V	Level II	Single floor	373	1
9	Maintenance and spare parts warehouse	78×15×13.97	IV	Level II	Single floor	1274	1
10	Integrated water pump house	40×8.5×7.8 (excluding underground part 3m)	V	Level II	Single floor	344	1
11	metering building	9.6×3.4×3.7	V	Level II	Single floor	39	1
12	Specially store	5.1×5.1×3.9	V	Level II	Single floor	29	1
13	Spare flat wave reactor chamber	8.6×8.6×5.9	V	Level II	Single floor	82	1
14	dormitory building for chinese	49.2×9.3×14.4	V	Level II	Four floors (floor height: 3.6m)	1888	1
15	refectory for Chinese	30×9.0×5.4	V	Level II	Single floor	280	1
16	activity building	24×9.3×5.4	V	Level II	Single floor	231	1
17	dormitory building for Pakistani	45.6×8.1×14.4	V	Level II	Four floors (floor height: 3.6m)	1528	1

18	office building for operating crew	38.4×27.6×11.7	V	Level II	three floors (floor height: 3.9m)	2052	1
19	refectory for Pakistani	30×9.0×5.4	V	Level II	Single floor	280	1
20	guard building and gate	5.7×5.1×3.0	V	Level II	Single floor	32	3
21	watchtower	3.0×3.0×7.5	V	Level II	Two floors	22	5
22	dormitory building for security personnel	75.6×7.8×3.6	V	Level II	Single floor	610	1
23	Office building	42×27.3×8.4	V	Level II	Two floors	1424	1
24	dormitory building for managers	72×37.9×3.6	V	Level II	Single floor	1654	1
25	dormitory building for laborers	90.1×30×7.2	V	Level II	Two floors	3036	1
Total		/	/	/	/	25781	31

5.9.2 Structure

5.9.2.1 Design Conditions

Designed wind speed: the owner's recommended maximum instantaneous (3s) wind speed (at an altitude of 10m and frequency of once every 50 years) is 160km/h: 44.4m/s. It is converted into maximum average wind speed (10min) of 31.1m/s.

Basic earthquake intensity: The converter station belongs to 2A area. The peak acceleration of ground motion is 0.14g under 10% frequency of once every 50 years.

5.9.2.2 Design Standards

(1) ASCE 7-10 minimum design loads for buildings and other structures .

(2) ACI 318-11 Building Code Requirements for Structural Concrete and Commentary .

(3) AISC 341-05 seismic provision for structural steel buildings .

(4) ASCE 10-97 Design of Latticed Steel Transmission Structures .

(5) ASCE 113-2008 Substation Structure Design Guide .

(6) ACI 543R-00 Design, Manufacture, and Installation of Concrete Piles .

(7) AISC 360-10 Specification for Structural Steel Buildings.

(8) ACI 530-11 Building Code Requirements for Masonry Structures.

5.9.2.3 Structural Type

Valve hall: It is in single floor; P I valve hall and P II valve hall will be provided. The main structure is steel—reinforcement concrete frame structure; the roof is in the form of trapezoid steel roof truss. The double-layer heat conservation compressive steel sheet will be provided for the roof plate. The fire wall is in the Reinforcement concrete frame structure

Spare flat wave reactor chamber and Maintenance and spare parts warehouse:Steel structure will be adopted.

The integrated water pump house includes above-ground and underground parts. The above-ground part is in the single-floor reinforcement concrete frame structure and underground part will be in the form of pond and is in the cast-in-situ reinforced steel concrete box structure.

All other buildings (Control building, relay and battery building, office buildings , refectories, refectories, Specially store, metering buildings, common switchgear building etc): Reinforcement concrete frame structure will be adopted.

Water related building (structure): The deep well pump house is in the single-floor R.C frame structure. The industrial fire-fighting water pond, spray water pond, sewage adjustment pond and accident oil collection pond are in the reinforced steel concrete box structure. The foundation of embedded sewage treatment unit is made of reinforced steel concrete plate foundation. The rainwater valve foundation is made of reinforced steel concrete plate foundation. The underground water discharge pump station is in the reinforced steel concrete box structure; the bottom of pond has an embedment depth of about -9.10m.

The gantries and equipment supports will be latticed steel structure with cast-in-situ R.C. stepped footing. Connections of members will be bolted. Gantry will be mounted on the foundations by means of anchor bolts embedded in the foundation concrete.

5.9.2.4 Soil and Foundation

Foundation dimensions and buried depth are calculated based on the data available from the geological report. Gantry foundation will be buried to 2.0m~3.5m deep. Equipment support foundation will be buried to 1.5m~2.5m. Foundation shall be placed on undisturbed soil layer, otherwise pile foundation should be adopted。

5.9.2.5 Standard for structural design

A) RC structure

Deflection of members shall be no greater than L/240 (9.5.2.6 of ACI 318, the latest version)

B) Steel structure

Deflection of framework beams shall be no greater than L/300, and deflection of framework columns shall be no greater than H/150.

C) Slenderness Ratio

Table4.1.4-3 Limiting Slenderness Ratio (refer to ASCE 10 part 3.4, the latest version)

Main compression member	150
Secondary members carrying calculated stresses	200
Redundant members without calculated stresses	250
All tension-only members	350

D) Connection of steel structure

Connection method: Factory fabrication -- Bolt connection & welding; On-site-- Bolt connection.

Bolts and nuts: Grade 4.8 6.8 and 8.8 galvanized bolts will be used, with minimum diameter 12mm. All bolts will be completed with galvanized washers. Each bolt will be provided with one flat washer and one spring washer.

Welding: Q235B and Q345B steel electrodes shall use E43 type and E50 type. The welding operation shall be avoided as far as possible for the Q420B high-strength steel. Weld metal shall match the metal material of members to be connected.When steels of different strength are to be connected, the weld material matching the low strength steel way be used.

Table4.1.4-4 Summary of bolt Strength

Material origin	**Grade**	**Yield strength (N/mm^2)**	**Tensile strength (N/mm^2)**
China	4.8	320	400
	6.8	480	600
	8.8	640	800

5.9.2.6 Materials

(1) Steel

Steel Q235B and Q345B will be used as steel for gantry and equipment support. Calculation shall be carried out as per ASCE or ACI standard.

a) Main member angle steel : Q345B

b) Web member angle steel: Q235B

c) Walkway, ladder: Q235B

d) Anchor bolt: Q345B

Table 4.1.4-5 Summary of Steel Strength

Material origin	Brand	Thickness (mm)	Yield strength (N/mm²)	Tensile strength (N/mm²)
China	Q235B	t≤16	235	375
		16<t≤40	225	
	Q345B	t≤16	345	470
		16<t≤35	325	
		35<t≤50	295	

(2) Concrete

Table4.1.4-6 Summary of Concrete Strength

Item	THE SPECIFIED COMPRESSIVE STRENGTH OF CONCRETE, CYLINDRICAL MODEL ON 28-DAY TESTS: fc'
Foundation	28 N/mm²
Beam, column, slab	28 N/mm²
Cable trench	28 N/mm²
Pre-fabricated member	28 N/mm²
bedding course	14 N/mm²
Others	28 N/mm²

(3) Steel bar

Table 4.1.4-7 Summary of Steel Bar Strength

Category	(N/mm²) Yield strength	Remark
Grade 40	280	
Grade 60	420	
Grade 75	520	

(4) Anti-corrosion of steel structure

The steel for gantry and equipment support will be hot-galvanized for corrosion resistance. The steel buildings will be painted for corrosion resistance.And zinc-rich painting will be used at site for local anti-corrosion treatment where the zinc coat is damaged.

5.9.2.7 Noise

According to the Pakistan standard THE GAZETTE OF PAKISTAN, EXTRA, NOVEMBER 26, 2010, the sound environment of various functional areas and related discharge limits are formulated as follows:

National Environmental Quality Standards for Noise

S. No.	Category of Area / Zone	Effective from 1st July, 2010		Effective from 1st July, 2012	
		Limit in dB(A) Leq *			
		Day Time	Night Time	Day Time	Night Time
1.	Residential area (A)	65	50	55	45
2.	Commercial area (B)	70	60	65	55
3.	Industrial area (C)	80	75	75	65
4.	Silence Zone (D)	55	45	50	45

Note: 1. Day time hours: 6.00 a. m to 10.00 p. m.

2. Night time hours: 10.00 p. m. to 6.00 a.m.

3. Silence zone: Zones which are declared as such by the competent authority. An area comprising not less than 100 meters around hospitals, educational institutions and courts.

4. Mixed categories of areas may be declared as one of the four above-mentioned categories by the competent authority.

*dB(A) Leq: Time weighted average of the level of sound in decibels on scale A which is relatable to human hearing.

The noise at the boundary of the converter station is in accordance with Chinese standard (Emission Standard for Industrial Enterprise Noise at Boundary GB12348-2008) 2 level: the daytime noise level is less than 60dB(A) and night noise level is less than 50dB(A). And for area 150 meters far away from the fence of converter station, the noise should be less than 45dB(A) in night time and 55dB(A) in day time.

5.10 Water Systems

5.10.1 Water Supply System for Station Area

The water supply system for station area includes domestic, productive and fire protection water supply systems.

Domestic water supply system includes a 30m^3 stainless steel water tank, domestic water supply unit and domestic water supply pipe network, etc. Variable-frequency constant-voltage water supply is adopted for domestic water supply unit, the designed water supply flow is 25m^3/h and water supply pressure is 45m.

Productive water supply system shall mainly provide make up water for the cooling water system outside the converter valve. That system is composed of a productive water tank and 4 sets of productive water supply pumps (two in use and two standby) as well as its water supply pipeline, etc. The effective water storage volume o productive water tank is the water consumption for five days of production. The make up water of cooling water system outside valve for each pole is an independent water supply system, after is pressurized by one set of working centrifugal pump (the other set of water pump is standby) by the water taken from water tank, it shall be delivered into corresponding cooling water tank outside valve through pipeline.

The fire protection water supply system shall provide fire protection water for indoor and outdoor fire hydrant of building as well as water atomizing extinguishing system of converter transformer. The system adopts independent temporary high-pressure water supply system, and it is composed of fire-water pond, fire supply pump unit and the fire supply pipe network equipped with fire hydrant, etc. In order to avoid deterioration of water quality caused by long-term disuse of water protection water, the measures for ensuring water protection water not to be used for other purpose are taken into consideration, the mode of jointly constructing fire-water pond and productive water tank shall be adopted, and the storage quantity of fire protection water shall be 300 m^3.

5.10.2 Drainage System

Organized split water drainage system shall be adopted for water drainage in the station area, i.e., rainwater and valve cold drainage system, domestic sewage treatment and reuse system as well as emergency oil drainage system.

The rainwater in the station area shall be collected by the storm water inlet on the ground beside road, and it shall be converged to the rainwater pump station through underground water drainage pipe before being pumped to outside the station.

The cooling system outside valve inside station has little water drainage, the water quality is unpolluted, and it shall be considered to be drained to rainwater drainage pipe network through pipe.

Domestic sewage treatment and reuse system shall be responsible for collecting the domestic sewage of comprehensive building, master control building and safeguard doorkeeper's room through pipe, and delivering into the buried integrated sewage treatment device for disposal, then it shall be collected into the wastewater tank through biochemical secondary treatment, so as to be reused for greening in the station.

For the emergency oil drainage of oil-bearing equipment, such as converter transformer and reducing transformer, etc., through collection by the oil pit at the lower position, it shall be converged into the emergency oil collecting basin through underground oil drainage pipe, water shall be drained out into rainwater drainage pipe network after separation of oil and water, and oil shall be stored into the emergency oil collecting basin for recovery.

5.11 Ventilation and Air Conditioning System

(1) General

Air conditioning and/or other environmental control systems will be provided for all buildings and process areas to ensure satisfactory operation of the HVDC system under the range of climatic conditions to which the station may be subjected. These systems will provide for personnel comfort and equipment operational reliability. Areas requiring environment control will at least include:

- Valve hall
- Control room
- Electrical equipment room
- Communication equipment room
- Office, meeting room, documentation room, duty room
- Pump house
- Battery room
- Valve cooling equipment room etc.

List of Indoor Design Criteria for Buildings or Rooms

Room	Temperature		Relative Humidity	
	Summer	Winter	Summer	Winter
Valve Hall	≤50 °C	≥10 °C	20~60%	20~60%
Control Room	24~28°C	16~18°C	50~70%	50~70%
Protection Equipment Room	24~28°C	16~18°C	50~70%	50~70%
Communication Equipment Room	24~28°C	16~18°C	50~70%	50~70%

Valve Cooling Control room	24~28°C	16~18°C	50~70%	50~70%
Office	26~28°C	16~18°C	≤70%	-
Meeting Room	26~28°C	16~18°C	≤70%	-
Documentation Room	26~28°C	16~18°C	≤70%	-
400V Distribution Room	≤35 °C	-	-	-
DC Panel Room	≤30 °C	16~18°C	≤70%	-
Battery Room	≤30 °C	16~18°C	-	-
Valve Cooling Equipment Room	≤35 °C	≥10	-	-
Relay Room	24~28°C	16~18°C	≤70%	-
10kV Power Distribution Room	≤35 °C	-	-	-
Duty Room	24~28°C	16~18°C	≤70%	-
Rest Room	24~28°C	16~18°C	≤70%	-
Canteen	24~28°C	16~18°C	≤70%	

(2) Ventilation for Valve Hall

Each valve hall will be provided with an independent ventilation system by two redundant air handling units with 100% capacity per each, one operation and one standby. to maintain indoor temperature and relative humidity at an acceptable level for normal operation of electrical equipment inside the valve hall. Also a slight overpressure (5~10Pa)will be provided inside the hall to prevent the infiltration of dust through building enclosure.

Air handling unit will be consisted of return fan section, return air and fresh air mixing section, filter section, cooling coil section, auxiliary electric heater section, muffler section and supply fan section etc.

The ventilation system for valve hall will be a closed cycle and the total air volume in the valve hall will be re-circulated through the main filters. Normally in favorite outdoor conditions the air in valve hall will be sucked to AHU, mixed with fresh air up to a maximum of 20% of the total air requirement, then cooled or heated, dehumidified or humidified, filtered and supplied back to the hall via air ducts by supply fan of AHU to maintain the specified conditions inside the valve hall. In hot days in summer, two redundant air cooled water chillers with 100% capacity per each, one operation and one standby, will be provided to supply chilled water (about 7°C) to cooling coil inside the air handling unit for cooling the circulated air.

Overpressure inside valve hall can be realized by adjusting the fresh air damper and exhaust air damper to make the fresh air volume exceed the exhaust air volume plus air leakage volume through valve hall enclosure.

The power for ventilation equipment for valve hall will be cut off by fire alarm signals to prevent the spreading of the fire in the case of fire.

Each valve hall will be served with smoke exhaust fans for smoke evacuation after the fire has been distinguished, if fire occurs inside the hall.

Water chillers and air handling units will be located on the ground outside the valve hall.

(3) Ventilation and Air Conditioning for Control Building

Central air conditioning systems will be provided for control building of which the main equipment will be 2×100% air-cooled water chillers and 2×100% air handling units, one of each equipment will be in operation and another standby.

The air cooled water chiller will produce chilled water in summer and hot water in winter to cooling coil inside AHU, AHU will supply cooled or heated, de-humidified, filtered air via air ducts to the rooms needing air conditioning, and return air will be drafted back to AHU for re-treatment.

Valve cooling equipment room and ventilation plant room will be provided with mechanical exhaust system by axial fans for normal ventilation, the air changes per hour will not be less than 5 times.

Axial fans will be equipped for 400V distribution room for emergency ventilation and air changes per hour will be larger than 12 times per hour.

Battery room will be provided with a mechanical ventilation system by explosion proof & anti-corrosive axial fan to exhaust hydrogen and acid gases to the outside. The air changes will not be less than 3 times per hour.

Toilet will be provided with mechanical exhaust by ceiling type ventilator with air changes per hour not less than 6 times.

If fire occurs at control building, the related ventilation and air conditioning equipment will trip by fire alarm signals to prevent the spreading of the fire.

(4) Ventilation and Air Conditioning for Relay Room

Air cooled split air conditioners will be provided for relay room and battery room to maintain the indoor temperature and relative humidity required for normal operation of electrical panels and battery.

The air conditioner for battery room will be of explosion proof type.

One redundant air conditioner will be provided above the quantity required to achieve the operating indoor environment for rated power.

Battery room will be provided with a mechanical ventilation system by explosion proof & anti-corrosive axial fan to exhaust hydrogen and acid gases to the outside. The air changes will not be less than 3 times per hour.

Axial fans will also be provided for relay room for ventilation during installation and maintenance.

The power for ventilation and air conditioning equipment will be cut off automatically by fire alarm signals to prevent the spreading of the fire in the case of fire.

(5) Ventilation and Air Conditioning for 11 kV Power Distribution Room

Normal and emergency ventilation by axial fans will be provided for 11kV power distribution room and the air changes will be larger than 12 times per hour.

In addition to the ventilation system mentioned above, air cooled split air conditioners will also be provided to maintain the indoor temperature not higher than 35°C to ensure the normal operation of the electrical equipment during hot days in summer.

The air conditioners and fans will be powered off automatically in the fire circumstance.

(6) Ventilation and Air Conditioning for Common 400V Power Distribution Room

Normal and emergency ventilation by axial fans will be provided for common 400V power distribution room and the air changes will be larger than 12 times per hour.

In addition to the ventilation system mentioned above, air cooled split air conditioners will also be provided to maintain the indoor temperature not higher than 35°C to ensure the normal operation of the electrical equipment during hot days in summer.

The air conditioners and fans will be powered off automatically in the fire circumstance.

(7) Ventilation and Air Conditioning for Office Builing and Dormitory

Air cooled split air conditioners will be provided for office, rest room, canteen and meeting room to maintain the indoor temperature for personal comfort.

Normal and emergency ventilation by axial fans will be provided for power distribution room and the air changes will be larger than 12 times per hour.

In addition to the ventilation system mentioned above, air cooled split air conditioners will also be provided for distribution room to maintain the indoor temperature not higher than 35°C to ensure the normal operation of the electrical equipment during hot days in summer.

Each toilet will be served with a toilet ventilator for air changes.

(8) Ventilation for Comprehensive Pump House

A natural inlet and mechanical exhaust ventilation system will be provided for pump house, in which wall-mounted axial fans will be used as exhaust equipment.

(9) Ventilation and Air Conditioning for Guard House

Air cooled split air conditioners will be provided for duty room, bedroom to maintain the indoor temperature at required level. The toilet will be served with a toilet ventilator and the air changes will not be less than 6 times per hour.

5.12 Fire protection

The main protection object of fire protection system in this engineering shall be such buildings as the master control building and valve hall, comprehensive building and overhaul spare articles warehouse, etc., as well as the oil-bearing equipments such as converter transformer, etc.

The fire protection system includes fire water system (which is divided into indoor and outdoor fire hydrant extinguishing system and water spray extinguishing system) and mobile fire extinguisher configuration, etc. Among them, indoor and outdoor fire hydrant shall mainly be adopted for fire protection of building, and it shall be configured with certain quantity of mobile fire extinguishers at the same time. Water spray extinguishing system shall mainly be adopted for the converter transformer, and it shall be configured with certain quantity of mobile fire extinguishers at the same time.

Independent temporary high-pressure fire protection water supply system shall be adopted for the fire water system, and it shall be composed of one 300m^3 fire-water pond, fire service pump, constant-pressure pump, surge tank and fire protection water supply pipe network with fire water facilities (fire hydrant and deluge valve), etc. The 300m^3 fire-water pond and productive water tank shall be jointly constructed, and there shall be protective measure for not using the fire water for other purpose.

The fire protection water supply pipe network shall be circularly arranged around the master control building and valve hall, comprehensive building as well as converter transformer, and the interval for arrangement of outdoor fire hydrant shall not be greater than 120m.

There shall be one set of water spray extinguishing system for each set of converter transformer, including deluge valve unit, signal butterfly valve, discharge nozzle and pipe, etc.

NATIONAL TRANSMISSION & DESPATCH
COMPANY (NTDC) LIMITED PAKISTAN

FEASIBILITY STUDY

FOR

±660kV HVDC PROJECT

FROM MATIARI TO LAHORE IN PAKISTAN

VOLUME Ⅲ-2

LAHORE CONVERTER STATION

Pak Matiari-Lahore Transmission Company(Private) LTD.

January 2017, Beijing, P.R. China

±660kV HVDC PROJECT
FROM MATIARI TO LAHORE IN PAKISTAN
GENERAL LIST OF CONTENTS

TECHNICAL DEFINITIONS

The following technical definitions apply to this Specification:

Purchaser	National Transmission And Despatch Company Limited (NTDC)
Company	The project company for development, investment, construction, operation and maintenance of the ±660kV HVDC project from Matiari to Lahore in Pakistan.
HVDC System	All of the relevant equipments and systems in bipolar operation, including converter transformers, converter valves, DC yard equipment, AC filter, control& protection system, DC transmission line, electrode and electrode line, etc.
HVDC Project	HVDC System and the relevant construction works in this project. the relevant construction works include outlet and inlet line of converter station, buildings and structures, related auxiliary production facilities and living facilities.
M-L T/L	Matiari-Lahore Transmission Line
AC yard	AC switchgear area in converter station
DC yard	DC switchgear area in converter station
Life yard	Living facilities and part of auxiliary production facilities area in converter station
T area	Transformer area
M-E T/L	Matiari Electrode Grounding Transmission Line
M E/G	Matiari Electrode Grounding
L-E T/L	Lahore Electrode Grounding Transmission Line
L E/G	Lahore Electrode Grounding
M C/S	Matiari Converter Station
L C/S	Lahore Converter Station
M AC busbar	Matiari AC busbar
L AC busbar	Lahore AC busbar
M AC system	Matiari AC system

L AC system	Lahore AC system
P I	Pole I
P II	Pole II

The following abbreviations apply to this Specification:

AC	Alternating Current
ACI	American Concrete Institute
A/D	Analog to Digital
AN	Audible Noise
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing Material
BIL	Basic Impulse Insulation Level
BS	British Standard
BSL	Basic Switching Impulse Insulation Level
CB	Control Building
CCITT	International Consultative Committee on Telephone and Telegraph Systems
CT	Current Transformer
CTV	Capacitive Voltage Transformer
D/A	Digital to Analog
DC	Direct Current
DIN	Deutsches Institute fur Normung
EEI	Edison Electric Institute
EIA	Environmental Impact Assessment
ESCR	Effective Short Circuit Ratio
ESDD	Equivalent Salt Deposit Density
FAT	Factory Acceptance Tests
HF	High Frequency
HVDC	High Voltage Direct Current
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
I/O	Input/Output
ISO	International Standards Organization

LED	Light Emitting Diode
MMI	Man Machine Interface
MVU	Multiple Valve Unit
NFPA	National Fire Protection Association
OPGW	Optical Fiber Composite Overhead Ground Wire
P&C	Protection and Control
PLC	Power-line Carrier
PT	Potential Transformer
RF	Radio Frequency
RI	Radio Interference
RIV	Radio Interference Voltage
RTU	Remote Terminal Unit
RPC	Reactive Power Controls
SCADA	Supervisory Control and Data Acquisition
SER	Sequence of Events Recorder
SLG	Single Line to Ground Fault
SMC	Station Master Clock
SPC	Software Production Control
SWC	Surge Withstand Capability
TFR	Transient Fault Recorder
UPS	Uninterruptible Power Supply
VDT	Video Display Terminal
VDU	Video Display Unit
VF	Voice Frequency
VT	Voltage Transformer

VOLUME Ⅲ-2 CONTENTS

1. Overview of Project

1.1 Design Basis

(1) *National Power System Expansion Plan 2011-2030, Main Report*, Canada SNC-Lavalin International Corporation, Pakistan National Technology Service Company, 2011

(2) *State of Industry Report 2013*, Pakistan National Electric Power Regulatory Authority (NEPRA)

(3) Parts of *Feasibility Study of HVDC/HVAC 1300km Long Transmission Line from Karachi to Up-country for Dispersal of 2500-3000MW Power from Imported Coal Based Power Project*, Canada SNC-Lavalin International Corporation, Pakistan National Technology Service Company, 2013

(4) NEPRA *Grid Code*

(5) *Transmission Services Agreement*

(6) Minutes of meeting signed between China and Pakistan

(7) Supporting documents for this project (environmental assessment and social stability reports)

(8) Laws, regulations, specifications and codes of Pakistan

1.2 Scope of Design

It includes the design of converter station, grounding electrodes, DC transmission line and grounding electrode lines, and the preparation of technical equipment specifications and investment estimation.

1.3 Major Design Principles

(1) The works in this stage is done according to *Regulations on Contents Depth of Feasibility Studies of Transmission and Distribution Projects* (DL/T 5448-2012);

(2) The design and construction experience of the ±660kV DC project from Ningdong to Shandong in China is fully absorbed to optimize the main design scheme and improve design quality;

(3) The DC transmission voltage rating shall be considered as 660 kV, transmission capacity as 4000 MW and transmission size as one circuit;

(4) The number and locations of AC outgoing circuits of the converter station are subject to the minutes of meeting signed between China and Pakistan in March;

(5) The feasibility of station site shall be demonstrated from station water source, station power supply, transportation, land nature and grounding electrodes. Geological stability assessment is made for the site scheme through exploration and survey. If there is any unfavorable geological condition in the station and surrounding areas, judgment shall be made for its hazardous degree and development trend, and prevention and control measures shall be proposed;

(6) In design, proper design measures need to be taken by combining the domestic situations of Pakistan. In addition, local laws, regulations and standards of Pakistan need to be strictly followed and local customs need to be considered for the design of public and auxiliary facilities.

1.4 Overview of Site Selection

From August 24 to 30 in 2014, China Electric Power Equipment and Technology Co., Ltd. (CET) carried out site survey for the converter station site and transmission line corridor and made further communication with the related personnel from Pakistan on the specific matters about this project. In this survey, 3 sites were respectively selected for the converter stations at both ends and were compared in the preliminary feasibility study report.

From March 15 to 26 in 2015, 15 persons from CET carried out investigation and site survey for the DC transmission line from Matiari to Lahore in Pakistan. The persons from NTDC had made full preparation before this and suggested several station sites and grounding electrode fields based on their actual local situations to the persons from CET. In this survey, the persons from CET determined project scale and grid connection scheme, defined the suggested station sites as the candidates for feasibility study, and carried out on-the-spot investigation for sensitive and key points of the transmission line.

1.5 Overview of Grid Connection

The AC side of the DC receiving-end converter station, with the voltage of 500kV, is π-connected to the dual-circuit 500kV line from Lahore to Lahore South. Lahore North 500 kV substation, and a dual-circuit 500 kV line, the converter station at receiving end–Lahore North–Gakkhar will be constructed. The converter station at receiving end has 6 circuits of outgoing lines, 2 to Lahore Substation, 2 to Lahore South Substation and 2 to Lahore North Substation. The grid connection scheme for the receiving-end converter station is shown in Figure 1.5-1.

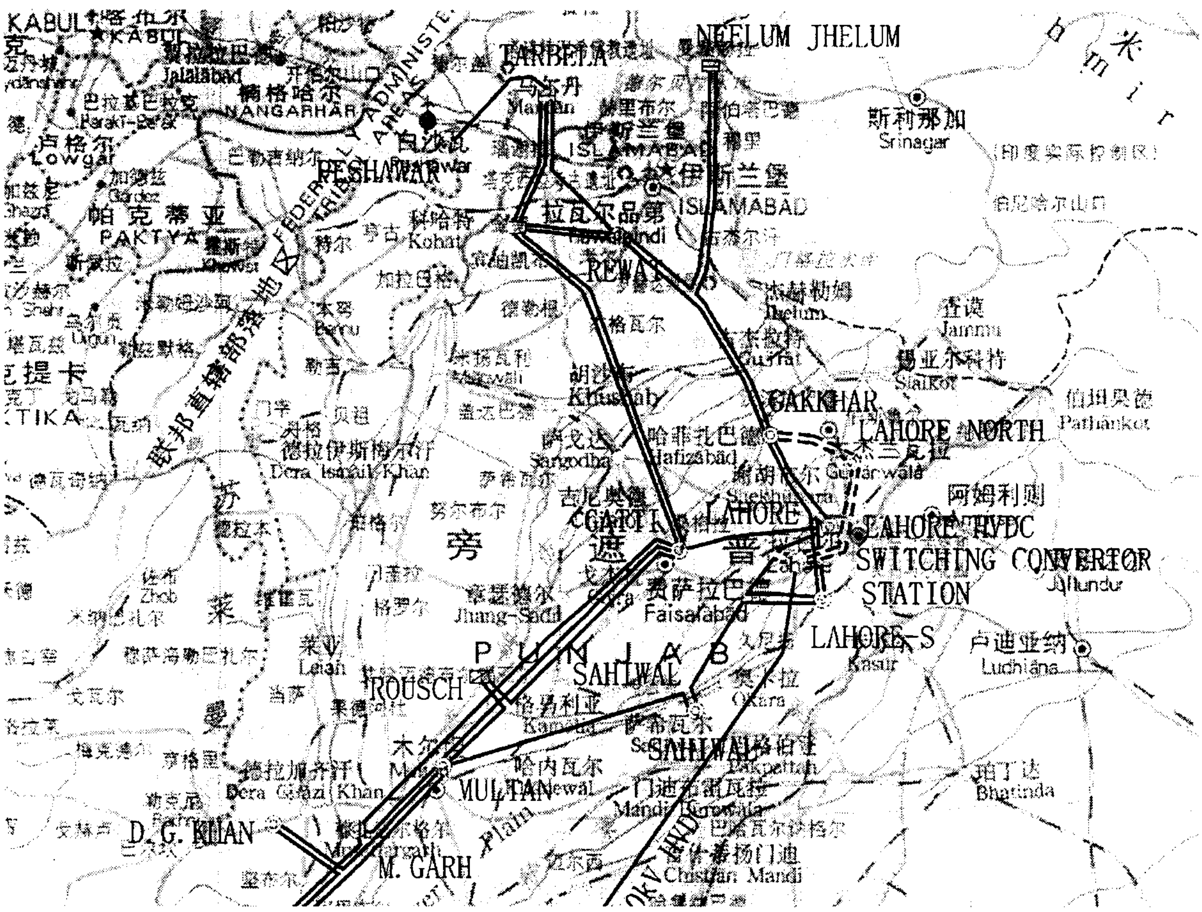


Figure 1.5-1: Grid connection scheme for receiving-end converter station

1.6 Main Technical Schemes

Table 1.6-1 Main Technical Schemes

No.	Item	Technical Scheme
1	Main connection scheme	
	Connection of converter valve bank and DC side	The converter valve banks are wired in series by using one 12-pulse converter group for either pole and there are two 12-pulse converter groups in total. Typical bipolar DC connection is used for DC yard and smoothing reactors, DC passive filters, DC voltage measurement devices, DC current measurement devices, DC isolating switches, high-speed change-over switches, neutral point equipment, DC carrier communication equipment and overvoltage protection devices are symmetrically provided on either pole.

No.	Item	Technical Scheme
	Connection on the 500kV AC side	The 3/2 circuit breaker connection method is used for 500kV AC yard. The long-term targets of this converter station are the same as this phase. In this phase, there are 6 outgoing lines, 4 AC filter(hereinafter referred to as 'ACF') banks and 2 converter transformer banks. There are 12 elements, which form 6 complete strings. It is provisionally assumed that the incoming lines of converter transformers are provided with AC PLCs.
	Connection of 500kV AC filter field	AC filters are connected in series by using ACF banks. The 500kV ACF banks are wired by using single bus. In the whole station there are 16 sub-banks of ACFs and parallel capacitors, which form 4 banks, with 4 sub-banks each.
	Connection of 500kV step-down transformers	The 500kV side of the two 500/35kV step-down transformers is respectively connected to two 500kV bus.
	Connection of 35kV AC area	Connection is made by using single bus and switchgear units are arranged in an outdoor and open manner. In the whole station there are two 35kV buses, three 60 Mvar low-voltage reactor banks and two 35/11.5kV transformers.
	Connection of the external power supply of converter station	The external power supply of converter station is introduced from 132kV transmission line nearby or the 132 kV bay within the SARFRAZ NAGAR 220kV substation, and is connected to the high-voltage side of one 132/11.5 kV station transformer.
2	Distribution unit and general electric arrangement	
	Arrangement of valve hall and converter transformer	6 banks of double converter valves are provided for each pole, and installed in a suspension manner. 6 single-phase two-winding converter transformers are arranged in a line on the AC incoming line side of valve hall to match up with arrangement of the two valve halls. The bushings of converter transformer on valve side are inserted into the valve hall and connected to 12-pulse converter valve bank after the Y/Δ connection in valve hall.
	Arrangement of switchgear at DC switch field	Outdoor DC yard scheme is used for DC yard. The DC yard equipment is installed on the both poles in symmetric manner, DC neutral bus equipment is located in the center of DC yard, pole bus equipment is arranged on both sides and 2 DC filter banks are provided between the DC neutral bus and the pole bus. DC filters and pole bus dry-type smoothing reactors are arranged at low height with fences around. Consideration is made to properly heighten the equipment foundation. The capacitors for DC filters are installed with supporting arrangement scheme.

No.	Item	Technical Scheme
	Arrangement of 500kV AC switchgear	The 3/2 circuit breaker connection method is used for the connection on 500kV AC switchgear, which is arranged in three rows. Two banks of converter transformers are directly connected at elevated places respectively and the ACF banks #1, #2, #3 and #4 are connected through overhead lines.
	Arrangement of 500kV AC filters	String connection method for ACF banks is used for connection of AC filters. In this phase there are 16 sub-banks, including 8 sub-banks with the capacity of 150 Mvar and 8 sub-banks with the capacity of 160 Mvar, which are divided into 4 banks. The ACF banks are arranged in a line.
	Arrangement of 500kV step-down transformers	Two step-down transformers are respectively connected to two 500kV main buses through the open-type AC switchgear.
	Arrangement of 35kV switchgear	The connection is made by using single bus and the switchgear are arranged in an outdoor in an open manner. Low-voltage reactors and station transformers are respectively located on both sides of bus.
	Arrangement of switchgear for connecting external power supplies	132kV switchgear in the station are wired with single bus and arranged in an open manner. The 132kV external power supplies are introduced via overhead lines, which is connected to the 132/11.5kV station transformer and provided with bus PT.
3	Electrical secondary equipment	
	DC control system	High voltage DC control system is of layered and distributed structure. Configuration is made from sampling unit, data transmission bus and primary device to control outlet based on the principle of full duplication.
	DC Protection System	High-voltage DC protection and control systems are separated and independent and the protection systems for two poles on functions and panels are completely independent. High-voltage DC protection is provided based on protected areas, the protection system of this converter station is divided into the following 7 protected areas and redundancy configuration is made based on the triple principle.
	Computer monitoring system	The converter station is designed as attended one. The compute monitoring system is a comprehensive automation system integrated with control, measurement, telecontrol and modern comprehensive management. Modularized, layered and distributed network structure is used for the compute monitoring system, so the operators can monitor and record the equipment in the whole converter station through human-machine interface in the master control room and send relevant information to the dispatching centers at all levels through telecontrol communication devices.

No.	Item	Technical Scheme
4	Station power supply	three power supply lines are provided. one power supply line is connected from the outside and the other two are connected from 35kV station transformers in the station.
5	Water source	Underground water is used.

2. Site Conditions

2.1 Overview of Station Sites

The site (center coordinate:N 31°15'35",E 73°49'54") is located at about 65km southwest of Lahore city and on the west side of Bhai Pheru-Mor Khunda highway. The site with flat terrain has a natural ground level of about 190 m to 191 m (geoidal surface is EGM2008, the same below). Wheat is planted on most of the site. The access road is connected from the Bhai Pheru-Mor Khunda highway, which is paved with bituminous surface, has a good condition and a width of about 7 m, and can meet the requirements for project construction and transportation of large equipment.

2.2 Hydro-meteorological conditions

2.2.1 Flood

The site where this converter station is located is flat and about 190 m to 191 m. The rainfall in Lahore is rich and most concentrates in July and August. According to the site investigation, in case of rainstorm in summer, the poor discharge conditions may result in the short-period water logging with the water level of 191.8 m and the about 0.5 m-deep ponding, which can be discharged in 2-3 days.

According to the measured data at the Balloki Barrage, the highest flood level was 192.3 m in history, happening in 1988, and the site was also flooded. According to the feedback from the residents near the site, the flood level in 1998 was about 192.4 m, and the flood lasted for about 1 week. Based on the largest flood data in history, the P-III frequency is calculated, and the 100-year flood level is calculated to be 193.23 m.

Fig. 2.2-1 Actual Situation of Receiving-side Converter Station

2.2.2 Meteorological conditions

In general, Pakistan has a subtropical monsoon climate. Traditionally, the climate of Pakistan is divided into four seasons: from March to April is spring and in this period the weather is not very hot or cold, but is warm and dry; from May to August is summer, and the temperature in June is highest and may be up to 45℃; the weather is rainy in July and August so this period is called as rainy season; from September to October is autumn; from November to next February is winter.

The receiving-side converter station is about 65.0 km to the southwest of Lahore city. The site has the similar landform with the Weather Station of Lahore City, and they are in the same climate region so the meteorological data shall refer to the data of the Lahore Weather Station located at N31°33′ and E74°20′ and with elevation of 214 m.

2.2.2.1 General meteorological conditions

The general meteorological data of the Lahore Weather Station are listed below (the data was collected from 1980 to 2010 except for partial data):

Annual mean air temperature	23.9℃
Extreme maximum air temperature	48.0℃ (June 10, 2007)
Extreme minimum air temperature	-2.2℃ (January 22, 2008)
Annual mean atmospheric pressure	983.1 hPa
Mean rainfall	679.7 mm
Maximum rainfall in 24 hours	274 mm (September 6, 2014)
Annual mean evaporation capacity	1,623.6 mm
Annual mean relative humidity	57%
Annual mean wind speed	1.6 m/s
Measured maximum wind speed	40.7 m/s (3 s instant)
Prevailing wind direction	NW

2.2.2.2 Designed wind speed and icing

Based on the building load regulations of Pakistan, the basic wind speed is not lower than 120 km/h and that in the coastal region is not lower than 130 km/h. According to the minutes of the meeting held before, the design wind speed for this project is taken as 160 km/h (corresponding to about 31.1 m/s), and the design icing thickness is taken as 0 mm.

2.3 Engineering geology and hydrogeology conditions

All the information in this section is just for reference because the detailed soil investigation is not completed for Lahore station.

2.3.1Regional geology and earthquakes

2.3.1.1 Overview of regional landforms and regional geologys

Pakistan is located in northwest of South Asia, and Arabian Sea is in the south. The main mountains include Karakoram Mountains, Himalayas Mountains, Hindu Kush Mountains and Soliman Mountains.The longest river—the Indus River almost runs through the whole Pakistan from north to south, which has four main branches: Hydaspes River, Azeri Sinise River, Ravi River and Sattler Season River, and are called as the "Punjab"; Traditionally, the Khyber Pass and Bolan Pass at western border is the only way connecting Central Asia and South Asia. Indus River Plain is the most wealthy agriculture region in Pakistan, where there is the most developed irrigation network in the world. KutchWetland approaching the sea level is the lowest point of the land, and the Chogori at the border of China and Pakistan whose altitude is 8611m is the highest point; The high-low difference in terrain causes the climate's diversity.

Because Pakistan is located at the combining site of Eurasian Plate and India Plate, it is affected by striking of the two plates, therefore, Pakistan become the frequently occurred region of earthquakes. The Punjab and Sindh in northwest are located the northwest corner of India Plate; the western Balochistan and the North-West frontier are located at Eurasian Plate, that's the east edge of Iranian plateau crossing the Middle East and Central Asia; the northern region of northeast and Azad Kashmir are located at the edge of India Plate, in geology, they belong to the Central Asia in geology, this region becomes the frequently occurred region of earthquakes because of striking of the two plates. The project to be constructed is located at the northwest corner of India Plate. According to the geologic structure map of Pakistan (see Fig. 2.3-1), there is Kirthar fault taking near north-south trend at about 60Km on west side of the route, and at about 100KM on the south side, there is Naga Parga fault taking west-east trend, and there isn't large new fault near the route, the distance requirements can be met.

2.3.1.2 Earthquakes

The striking of the Eurasian Plate and India Plate has caused rising of Himalayas Mountains, therefore, Pakistan frequently occurs earthquakes, among them, Kashmir and Kida are the frequently occurred regions of earthquakes. In 1931, the strong earthquake occurred there, and then, in 1935, the earthquake level was higher, the whole small city of Kida was almost destroyed, the military station nearby suffered heavy casualties, 0.2million people died at least. In addition, in 1965, an earthquake that the epicenter was in Kohistan of North-West Frontier occurred, and that earthquake also caused serious casualties. The earthquake occurred in 1991 almost destroyed all the villages of North-West Frontier, but the number of casualties was much less than that in 1935. The recent earthquake was Kashmir earthquake occurred on October 8, 2005, the number of casualties was up to 73 thousands in the control region of Pakistan. Where there has been no earthquake of above level-6 occurred in recent years.

According to Building Code of Pakistan (2007) FIG.2.1 (SEISMIC ZONING MAP OF PAKISTAN) and FIG.A-1 (Peak Ground Acceleration (g) with 10% Probability of Exceedance in 50 years), the two converter stations are mainly located in ZONE 2A, the Peak Ground Acceleration (g) with 10% Probability of Exceedance in 50 years is 0.14g (see Fig. 2.3-2, Fig. 2.3-3), the corresponding basic earthquake intensity is 7 degree.

In conclusion, the earth's crust where the project is located is relatively stable; the terrain is suitable for construction of the converter station.

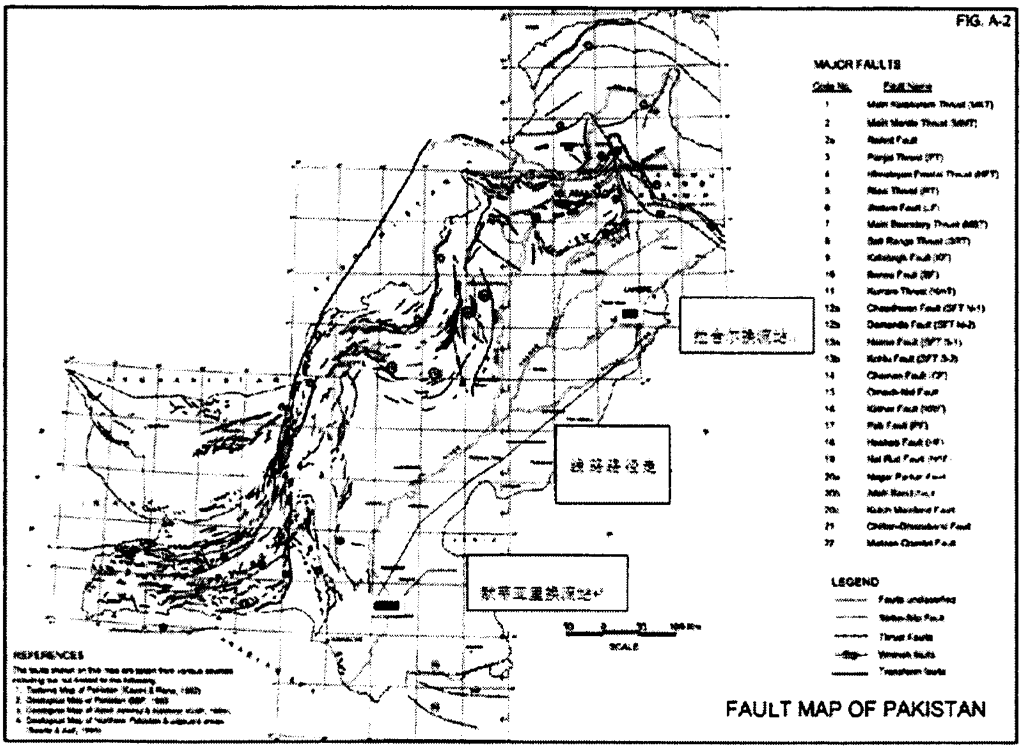


Fig. 2.3-1 Geologic structure map of Pakistan

[illegible]	Lahore converter station
[illegible]	Route path orientation
[illegible]	Matiari Converter Station

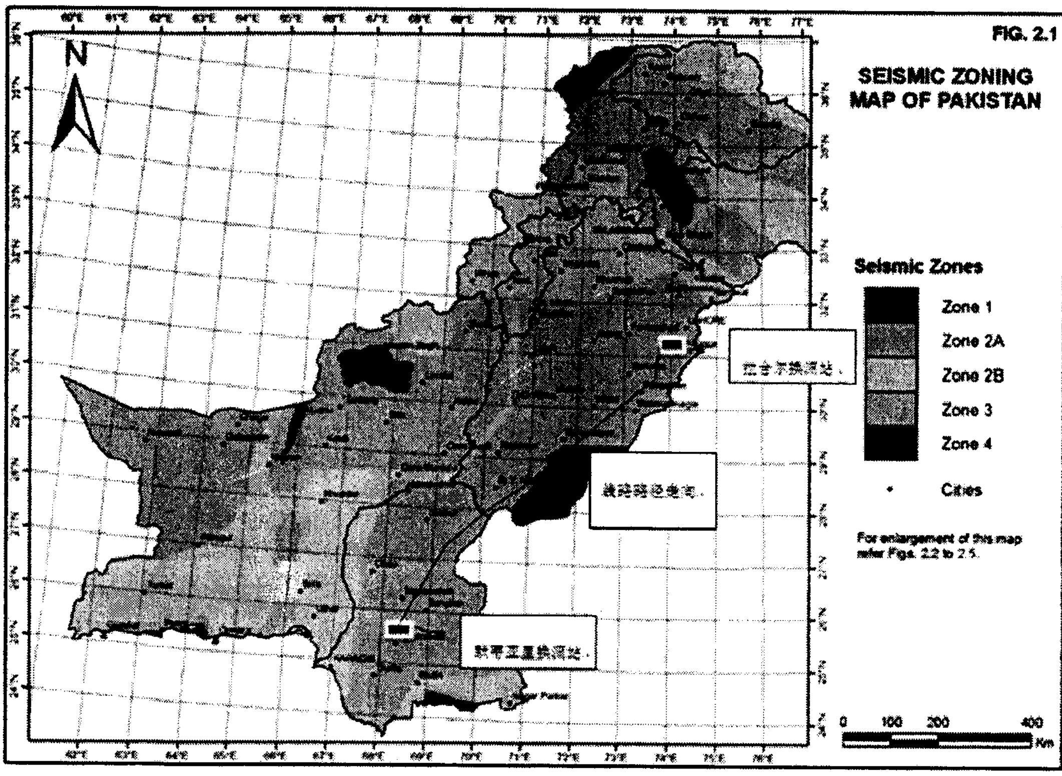


Fig. 2.3-2 Earthquake partition map of Pakistan

拉合尔换流站	Lahore Converter station
线路路径走向	Route path orientation
默蒂亚里换流站	Matiari Converter Station

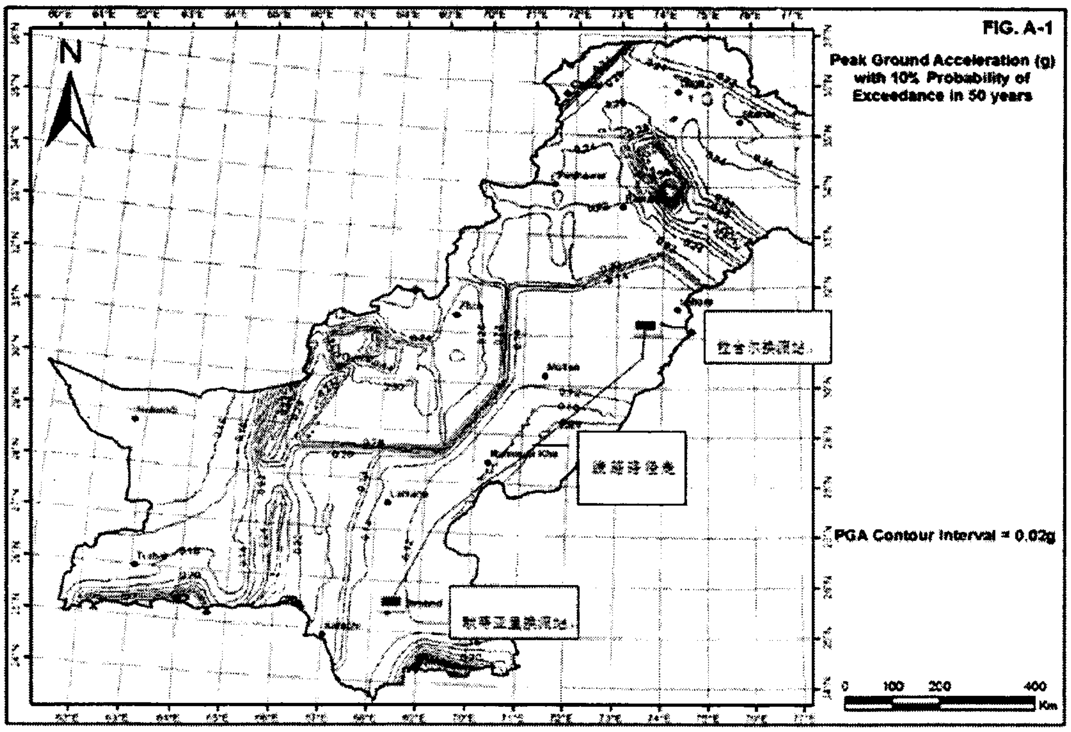


Fig. 2.3-3 Isoline map of the ground acceleration

[illegible]	Lahore Converter station
[illegible]	Route path orientation
[illegible]	Matiari Converter Station

2.3.2 Geotechnical engineering conditions and evaluation of Lahore Converter station

2.3.2.1 Landform

Terrain of the region where the Converter station to be constructed is located is flat alluvial plain (Fig. 2.3-4), the region mainly plants wheat, the southeast side mainly plants fruit trees, Indus River runs through this region, about 6km far from the station.

Ground elevation of the Converter station to be constructed is about 191-192m, the relative height difference is about 1m, and the terrain is flat. There isn't unstable side slope in range of the Converter station, no unfavorable geologic process such as ground settlement and collapse etc. The region of the station is mainly the cultivated land, with a few trees.

Fig. 2.3-4 Landform of the station region

2.3.2.2 Lithology of the formation(just for reference)

ver alluvium plain, and within the range of exploration depth, the stratum structure of the whole site mainly consists of the quaternary Holocene series ($Q4^{al}$) alluvial deposit which is composed of upper silty clay, lower silty-fine sand and local sandwiched silt.

The foundation rock-soil layer can be described from up to down as follows:

Lay (1): Silty clay, yellowish-brown, brown, slight wet, mainly take on pluripotent state. The horizon of this layer is relatively stable, which is widely distributed in the whole site, with the thickness of 2.8~5.5m.

Layer (2): Silty-fine sand, gray, cinerous, saturated, with a few mica plate and local gravels, as well as a little of silt and medium sand, this layer can be divided four sub-layers: (2-1), (2-2), (2-3) and (2-4). Among them, layer (2-1) is loose silty-fine sand, locally distributed; layer (2-2) is slightly dense silty-fine sand, it is widely distributed in the site region, its thickness is 2.0~8.7m; layer (2-3) is silty-fine sand with medium density, it is distributed in the whole site region, in this exploration, this layer was not exposed; and layer (2-4) is close-grained silty-fine sand, this layer is widely distributed in the whole site, in this exploration, this layer was also not exposed.

Layer (3): Silt, gray, grayish yellow, saturated, medium dense state, local dense, with silty clay and a little silty-fine sand. The layer is discontinuously distributed in the whole site, the thickness is 2.0~2.5m.

2.3.2.3 Hydrogeology

According to the analysis to formation of the site, the underground water in the site region is dive, and the basal water is fine-silty, with better water-bearing capacity, and strong penetration, the supply source is mainly precipitation, channels near the site, while, the main discharge channels are atmospheric evaporation and lateral discharge to rivers. In the period of exploration, the stable buried depth of underground water in the drilling hole is 3.3~5.5m. According to the engineering experience, the underground water can meet water demands of the Converter station. We suggest conducting water-supplying hydrogeololgy exploration to the site in advance at the next stage.

According to the evaluation of the environment type, the underground water has sight corrosivity to the concrete structures; according to the evaluation of stratum permeability, the underground water has sight corrosivity to the concrete structures, and the comprehensive evaluation indicates that the underground water has sight corrosivity to the concrete structures; and which has also sight corrosivity to steel bars inside the concrete structures.

According to the evaluation of environment type, the site soil has sight corrosivity to the concrete structures; according to the evaluation of stratum permeability, the site soil has sight corrosivity to the concrete structures, and the comprehensive evaluation indicates that the site soil has sight corrosivity to the concrete structures; and which has also sight corrosivity to steel bars inside the concrete structures; the site soil has medium corrosivity to steel structures (reference to the soil resistivity).

2.3.2.4 Unfavorable geologic process

There isn't unfavorable geologic process in the Converter station region, such as landslide, collapse, mud-rock flow and ground settlement etc.

2.3.2.5 Mineral products and historical relics

There isn't distribution of mineral resources with explored reserves; the project doesn't cover mineral resources and historical relics

2.3.2.6 Evaluation of geotechnical engineering

2.3.2.6.1 Classification of the construction site

Terrain of the construction site is flat, the largest height difference is about 1m, the main formation in the depth range of 30m underground is Quaternary plastic silty clay, loose, slightly dense, medium-dense and close-grained silty-fine sand and medium-dense silt. According to *Earthquake Resistant Design Code of Buildings* (GB50011-2010), the site soils shall be soft medium-soft soil layers, and according to the preliminary determination, type of the construction site shall be class-III, which is the general section of earthquake-resistant construction site.

2.3.2.6.2 Mechanical property of the subsoil

Layer (1) silty clay: Plastic state, the physical property of this layer is general, and this layer can be treated as the natural foundation supporting course of general buildings (structures)

Layer (2-1) silty-fine sand: Loose, the physical property of this layer is worse, it can't be treated as the natural foundation supporting course of buildings (structures) without being treated

Layer (2-2) silty-fine sand: Slightly dense, the mechanical property is general, this layer can be treated as the natural foundation supporting course of buildings (structures).

Layer (2-3) silty-fine sand: Medium dense, the mechanical property is better, this layer can be treated as the natural foundation supporting course of buildings (structures).

Layer (2-4) sitly-fine sand: Dense, with good mechanical property, this layer can be treated as the pile foundation supporting course of buildings (structures).

Layer (3) silt: Medium-dense, local compact, the physical and mechanical property is better, which can be treated as substratum of the building (structure) foundation.

2.3.2.6.3 Sandy soil liquefaction

The converter station is located in the section of alluvial plain; there is saturated sand, with the risk of sandy soil liquefaction. The determination of this sandy soil liquefaction adopts American-standard of seed method (SPT) and the liquefaction results see Table 3-3, the calculation results indicate there is little sandy soil liquefaction in this site in this design stag, and need to be confirmed in next design stage.

2.3.2.6.4 Type of the foundations

Mechanical property of the loose silty-fine sand is worse, it can't be treated as the foundation supporting course directly without being treated. The mechanical property of dense silty-fine sand and plastic silty clay is general, which can be directly treated as foundation supporting course of general buildings (structures). Mechanical property of the medium-dense and close-grained silty-fine is better, which can be directly treated as the foundation supporting course of important buildings (structures). The sections of important buildings (structures) where the distribution of loose and close-grained silty-find sand is thick shall adopt pile foundations, adopting cast-in-situ bored piles, with medium-dense or close-grained silty-fine sand as the bearing stratum of pile foundations.

2.4 Water Supply Sources and Drainage Conditions

2.4.1 Sources of Water Supply

(1) Water demand

The water demands of the converter station mainly consist of domestic water, process water and fire-protection water. Process water is mainly used to provide water for the external cooling system of converter valve. The water consumption varies with the cooling mode. The water consumption for the complete water cooling mode is about 600 m^3/d and that for mixed air/water cooling mode is about 300 m^3/d. The consumption of domestic water and fire-protection water is considered as 250 m^3/d. So the total water consumption is about 850 m^3/d when the complete water cooling mode is used, and it is about 550 m^3/d when the mixed air/water cooling mode is used.

(2) Surface water source

Surface water nearby the site is available from Ravi river. The hydro-junction of Ravi river is located at about 4.5 km to the southeast of the station site. According to the Indus Waters Treaty, the Ravi's water source is under the jurisdiction of India. Pakistan built diversion canal in the last century, inducing water from Chenab river to the Balloki Barrage hydro-junction. However, after years, the diversion canal slits heavily and is incapable of supplying water. Now, the Pakistani government has no desilting plan. This means that the Balloki Barrage hydro-junction only relies on the upstream Ravi river.

The Ravi River is relatively wide and shallow. Its current deviates to the right. The station site is at the left bank, which is unfavorable for water intake. Therefore, the Ravi River is not suitable to be used as a water source for the converter station because its water supply is not reliable.

(3) Underground water

According to the site survey data, underground water can be used as the water source for Lahore converter station.

To sum up, underground water is used as a water source for the site. A deep well is dug within the station and the water is supplied to the process and fire-protection pools and domestic water tanks through pressurization by submerged pumps. It is suggested to carry out a special hydrogeological exploration in the next stage to verify burial and distribution, yield and quality of underground water and to provide a basis for water source design.

2.4.2 Drainage Conditions

The site with flat terrain has the natural terrain elevation of about 190 to 191.4 m. The level of 100-year flood is 193.23 m and the level of waterlogging is 191.8 m. The rainwater shall be collected by the storm water inlet on the ground beside road. Waste Drainage pipe can be used to run off the rainwater or it can be directly drained out the station to nearby land if available. Waste Drainage System will be connected to existing drainage of locality or may arrange its own collecting tank or making of soakage pit provided that a water treatment plant should be installed before soakage pit for purification of waste water according to the waste-discharge standards of EPA of Pakistan which should be provided by NTDC.

The waste water of valve cooling system should first be treated to meet the waste-discharge standards of Pakistan, and then it can be drained out to the waste drainage pipe of station.

2.5 Construction Conditions

All the information in this section is just for reference.

2.5.1 Site Construction Conditions

The site (center coordinate:N 31°15'35",E 73°49'54") is located at about 65km southwest of Lahore city and on the west side of Bhai Pheru-Mor Khunda highway. The site with flat terrain has a natural ground level of about 190 m to 191 m (geoidal surface is EGM2008, the same below). Wheat is planted on most of the site. The access road is connected from the Bhai Pheru-Mor Khunda highway, which is paved with bituminous surface, has a good condition and a width of about 7 m, and can meet the requirements for project construction and transportation of large equipment.

2.5.2 Supply of construction energy

2.5.2.1 Water source for construction

The maximum water consumption is about 20t/h during the construction. The permanent water source for the converter station is from a well dug within the station based on local situations. Considering the big water consumption of permanent water source within the station, a provisional well can be dug during construction to meet the demand for digging permanent water well and the water demands during construction. It is suggested to solve the problem of construction water of this project by digging a well within the station.

2.5.2.2 Power supply for construction

The maximum electricity consumption is about 1600 kVA during construction. The scheme combining permanent and provisional electricity supplies are used for construction, production and living to save project investment. According to the electrical design scheme, it is planned to introduce one 132kV transmission line from the 132kV transmission line nearby or from SARFRAZ NAGAR 220kV substation to the converter station, serving as an external power supply. It is suggested to connect and erect lines and facilities outside the station area in advance, which are provided with step-down transformers to be used during construction. They are delivered for production after the project is put into production. In addition, by considering the unstable domestic power grid of Pakistan, we suggest the constructer use diesel generators for unexpected needs.

2.5.2.3 Communication during construction

To facilitate external contact during construction and ensure reliability of communication, it is planned to connect one communication optical cable from the communication line outside the station to the station, which may be applied to the local communication authority together with permanent communication lines. The communication during construction is achieved by fixed telephone, mobile phone and radio equipment on the construction site.

2.6 External Station Power Supplies

Three station power supply lines will be used for Lahore Converter Station. Two of them are connected from two 35kV AC buses by using two 35/11.5kV station transformers respectively. The remaining one is connected from 132kV transmission line nearby or from the 132kV bay at the SARFRAZ NAGAR 220kV substation.

2.7 Planning of Incoming and Outgoing Line Corridors

According to the line route that was planned by NESPAK and us on May 20, the current outgoing lines of Lahore converter station are as follows: DC outgoing lines go toward the west direction; All six AC outgoing lines go toward the north direction, which are, from west to east, Lahore South 1,Lahore 1, Lahore 2 ,Lahore North 1, Lahore North 2 and Lahore South 2 respectively. The DC lines go toward the west direction. Generally speaking, the terrain along these AC and DC outgoing lines is flat, and there is no scissors crossing in the vicinity of Lahore converter station.

3. Selection of Main Electrical Connection and Equipment

3.1 Main Electrical Connection of Converter Station

3.1.1 Main Electric Connection on AC side

The 500 kV AC side adopts 3/2 circuit breaker connection mode, which is characterized by simple function, high reliability and safety. The connection and string configuration of AC distribution devices are designed in accordance with the following principles:

1) The lines with the same name shall not be in the same string and should not be connected into the same bus as practical as possible;

2) The power supply lines should be in the same string with load lines as practical as possible;

3) All AC and DC lines shall not cross with each other as practical as possible;

4) Each converter transformer bank is provided with one AC PLC filter bank at the line incoming point provisionally;

5) According to the requirements of communication discipline personnel, all lines shall be provided with wave trapper on their outgoing line side;

6) Future expansion should be considered.

The long-term targets for Lahore converter station are the same as the current target.

In the current phase, 6 outgoing lines (2 to Lahore North Substation, 2 to Lahore South Substation, and 2 to Lahore Substation), 4 banks of ACFs, and 2 banks of converter transformers will be built. A total of 12 elements will be incorporated into the strings, constituting 6 complete strings. Each of the two buses will be connected with one 500/35 kV step-down transformer. All the incoming and outgoing lines will be provided with outgoing disconnectors. The converter transformers are provided with AC PLC at their line incoming points provisionally.

The string configuration is as shown in the following table:

Table 3.1.1-1: String configuration of 500 kV AC yard

String No.	Line on 1M Side	Line on 2M Side
Bus connection	#1 500/35 kV step-down transformer	#2 500/35 kV step-down transformer
#1 string	Converter transformer of P I	#1 bank of AC filters
#2 string	Lahore South 1	#2 bank of AC filters
#3 string	Lahore 1	Converter transformer of P II
#4 string	Lahore 2	Lahore North 1
#5 string	Lahore North 2	#3 bank of AC filters
#6 string	Lahore South 2	#4 bank of AC filters

The 35 kV AC switchgear employs single-bus connection mode. The equipments are arranged outdoor. The Lahore converter station has two 35 kV buses, 3 banks of 60Mvar low-voltage reactors, and two 35/11.5 kV auxiliary transformers.

3.1.2 Main Electrical Connection on DC Side

It is recommended to use the bipolar DC connection mode on the DC side, which is a typical connection mode for 500 kV DC transimission project. On the DC side of converter station, smoothing reactors, DC passive filters, DC voltage measuring devices, DC current measuring devices, DC disconnectors, high-speed transfer switches, neutral point equipment, DC carrier communication equipment, overvoltage protection equipment, etc. are all installed symmetrically on both poles.

The main connection schemes for valve bank, converter transformer, and the DC side is recommended as follows:

1) Converter valve: one 12-pulse valve bank for each pole

2) Converter transformer: single-phase two-winding connection mode. In the current phase, a total of 12+2 single-phase two-winding converter transformers will be installed at the Lahore converter station, the three-phase connection groups are YNy0 and YNd11 respectively.

3) The DC switchyard uses the same connection mode as the ±500kV DC bipolar line.

3.1.3 Connection of Valve Bank

The long-term construction target of this project is one ±660 kV/4000 MW DC line, which will be constructed in the current phase. The AC side of converter transformer is connected to the AC 500 kV bus via the equipment within the strings of AC 500 kV switchgear. This project adopts two poles, with each of them provided with one 12-pulse valve bank, the same as routine ±500 kV DC project.

The connection of DC side and valve bank is as shown in the following figure:

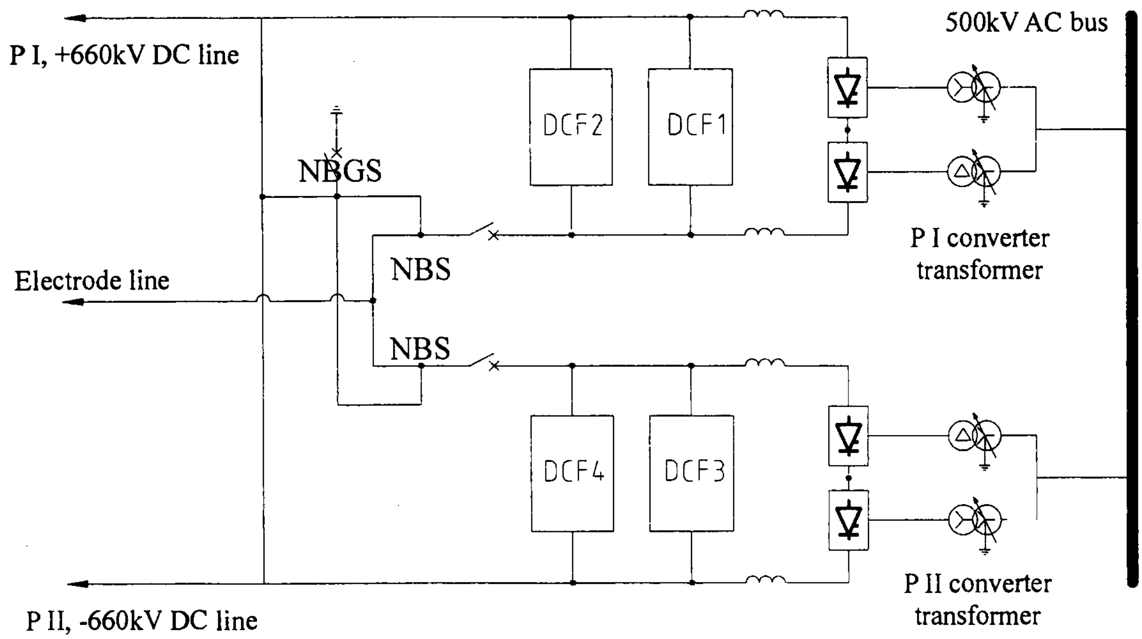


Figure 3.1.3-1: Connection of DC side and valve bank of Lahore converter station

3.2 Preliminary Determination of Converter Valve

3.2.1 Type of Converter Valve

The typical type of converter valve is thyristor converter valve. According to the existing manufacturing capability and the previous operation experience, the type and parameters of converter valves used in this project are provisionally determined as follows:

Table 3.2.1-1: Type of converter valve

	Type of Converter Valve
Converter valve	Double valve type
Mounting mode	Suspension type
Insulation type	Air insulation
Cooling method	Water-cooling (internal-cooling)

According to the experience of other projects, the protective margin of voltage withstand level for the converter valves is provisionally determined as follow:

(1) A 10% margin over the arrester protective level for switching impulses.

(2) A 10% margin over the arrester protective level for lightning impulses.

(3) A 15% margin over the arrester protective level for steep-front impulses.

The converter valves should be capable of withstanding the rated current, overload current and various transient current. With respect to the transient overcurrent due to faults, the valves shall have the following capabilities:

(1) Short-circuit current withstanding capability with subsequent blocking;

(2) Short-circuit current withstand capability without subsequent blocking;

(3) Additional short-circuit current withstanding capability.

3.2.2 Main Parameters of Converter Valve

It is recommended to use 7.2kV/3030A 5-inch thyristor element. The height of converter valve tower is expected to be about 13 m. The rated DC current and voltage of thyristor valve are 3030A and 660kV respectively. It is recommended to use indoor air-insulated water-cooling type thyristor valve, with ETT or LTT valve.

3.2.3 Valve Cooling System

Internal cooing of valve will be realized by water, and external cooling will be realized in two ways: 1) water cooling, outdoor heat exchangers will be of closed evaporative cooling tower, spray water will be produced from reverse osmosis and dosing. 2) Air cooling in serial connection with water cooling, mainly relies on air coolers; in hot seasons when the air coolers are insufficient, the closed cooling water will take over.

The final plan will be determined in next phase.

3.3 Preliminary Determination of Converter Transformer

3.3.1 Short-circuit Impedance

The determination of short-circuit impedance of converter transformer shall be in accordance with the following factors:

a) Restrict short-circuit current;

b) Minimize the harmonic components;

c) Optimizing the design of converter valve, filter, and other converter-related equipment.

Furthermore, the determination of short-circuit impedance may directly affect the weight, size, and cost of transformer. If the short-circuit impedance is large, the following effects will arise:

a) The spacing and width of windings increase, and the width of converter transformer increases while the height of that decreases;

b) Higher rated power;

c) The reactive power loss during operation of converter increases;

d) The harmonic components generated by converter decrease;

e) The short-circuit current on valve side lowers;

f) No-load DC voltage rises, and the number of valve discs and the insulation level of converter valve increases accordingly.

Therefore, the determination of short-circuit impedance is an optimizing process, i.e., a process of seeking balance among the above indicators. According to the previous engineering experience, it is recommended that the short-circuit impedance of converter transformer be 18% in the current phase.

3.3.2 Rated Voltage, Type, and Capacity of Converter Transformer

The connection mode of converter transformer is one 12-pulse valve bank for each pole. Considering the manufacturing, transportation and other related factors, it is recommended that 14 single-phase two-winding converter transformers with a capacity of 401 MVA which is as same as the sending end converter station should be used, with 2 of them serving as standby.

3.3.3 Voltage Regulating Mode and Tapping Range

(1) Determination of regulating mode of on-load tap

The on-load tap of converter transformer is mainly regulated in the following two modes:

a) Keep the no-load voltage on the valve side of converter transformer unchanged;

b) Keep the control angle (firing angle or turn-off angel) within a required range.

The main differences between the above two modes are described as follows:

The tapping regulation of converter transformer in the first mode is mainly used to accommodate the variation of the valve-side no-load voltage caused by the inherent voltage fluctuation of the AC grid. Such variation is generally small, so the tapping range is relatively small. The DC voltage variation caused by DC loads is supplemented by adjusting control angle. The tapping operations using this regulation mode are not frequent, so the tap switches have a longer service life.

In the second regulating mode, the converter normally operates within a small range of control angle, and the variation of DC voltage is mainly regulated and supplemented by the tap of converter transformer. This mode is characterized by low absorption of reactive power, low operation cost, low valve stress, low valve damping circuit loss, and small AC and DC harmonic components. So the operational performance of DC system in this regulating mode is good. But this regulating mode requires frequent tapping operations and a larger tapping range.

Among the long-distance HVDC transmission projects constructed in the recent years in China, 90% of them use the second regulating mode, i.e., regulating the DC operating voltage through tap while keeping the control angle within a required range. In this report, the second regulating mode is recommended. The final scheme shall be determined by the manufacturer after optimization of equipment.

(2) Determination of spacing of tapping positions

The spacing of tapping positions is related to the variation range of firing angle required for angle control, the permitted fluctuation rang of DC voltage during normal operation, the maximum measurement errors of DC operating parameters, etc. If the spacing of tapping positions is too small, more tapping positions are required, the requirement on the fluctuation of the bus steady-state voltage of converter station may be affected, the capacity of filter sub-bank is reduced, and thus the project investment will be increased. If the spacing of tapping positions is too large, a greater angle control range and a larger total amount of reactive power compensation are required, which are not cost-effective as well. According to the previous engineering experience, in the current phase, the spacing of converter transformer tapping positions is determined as 1.25% provisionally.

3.4 Preliminary Determination of Smoothing Reactor

The most important parameter of smoothing reactor is inductance, which should be optimized in accordance with the following conditions:

(1) The rise rate of fault current should be limited;

(2) The current interruption during low current load should be prevented;

(3) The DC current ripples should be restrained;

(4) Techno-economic comparison should be made among the proposed configurations of smoothing reactor and DC filter;

(5) The inductance of smoothing reactor should not lead to resonance at 50 Hz and 100 Hz with DC filter, DC line, converter transformer, capacitor at neutral point and other related equipment.

The inductance of smoothing reactors for either pole is taken as 300 mH provisionally. Dry-type smoothing reactor is used provisionally. Four smoothing reactors are provided for each pole, each reactor with an inductance of 75 mH. Throughout the converter station, there are 8 operating smoothing reactors and 1 standby reactor in total. The smoothing reactors are installed on pole bus and neutral bus separately.

3.5 Preliminary Determination of Equipment at AC Yard and AC Filter Yard

The main AC equipment used in this project is summarized as follows:

Table 3.5-1: Selection of main AC equipment

No.	Equipment Description	Main Parameters and Type Selection
I	500 kV AC switchgear	
1	Circuit breaker	550kV 4000A 63kA(3s) 160kA, with closing resistor[1]
2	Current transformer	500kV 2x2000/1A
3	500kV vertical break disconnector with single earth switch	550kV 3150A 63kA(3s) 160kA
4	500kV disconnector, with single stationary contact and single earth switch	550kV 3150A 63kA(3s) 160kA, dual-column, horizontal type
5	500kV disconnector, with double stationary contacts and triple earth switches	550kV 3150A 63kA(3s) 160kA , three-column, horizontal type
6	Maintenance earth switch	550kV 63kA(3s) 160kA
7	500kV capacitive voltage transformer	500/ √3/0.1/ √3/0.1/ √3/0.1/ √3/0.1kV
8	500kV metal-oxide surge arrester	Y20W
II	AC filter switchgear	
1	500kV AC filter/capacitor bank	Rated capacity: 150Mvar Rated capacity: 160Mvar
2	Porcelain knob type circuit breaker for the incoming line of capacitor bank	550kV 3150A 63kA/3s 160kA , Dual-break
3	Current transformer for the incoming line of capacitor bank	500kV 1000/1A
4	Vertical break disconnector for the incoming line of capacitor bank	550kV 3150A 63kA/3s 160kA, with single earth switch

No.	Equipment Description	Main Parameters and Type Selection
5	Earth switch for the incoming line of capacitor bank	550kV 63kA/3s 160kA
6	500kV metal oxide surge arrester	Y20W
7	500kV capacitive voltage transformer	500/√3/0.1/√3/0.1/√3/0.1/√3/0.1kV
8	Earth switch for 500kV bus	550kV 63kA/3s 160kA
III	Station service system	
1	500kV three-phase oil-immersed transformer	SFP-130000/500 510±2×2.5%/35kV, non-exciting regulation
2	132kV three-phase oil-immersed transformer	8MVA 132±2×2.5%/11.5kV ONAN , non-exciting regulation
3	132kV SF_6 circuit breaker	145kV 1600A 40kA 100kA
4	500kV circuit breaker	550kV 4000A 63kA/3s 160kA
5	500kV horizontal break disconnector with single earth switch	550kV 3150A 63kA/3s 160kA
6	132kV disconnector	145kV 3150A 40kA 100kA, dual-column, horizontally opening, single earth switch
7	500kV earth switch	500kV 63kA/3s 160kA
8	132kV disconnector	145kV 1600A 40kA 100kA,dual-column, horizontally opening, double earth switches
9	500kV current transformer	500kV 2x2000/1A
10	132kV current transformer	132kV 800/1A
11	500kV metal oxide surge arrester	Y20W
12	132kV surge arrester	132kV
13	132kV capacitive voltage transformer	132/√3/0.1/√3/0.1/√3/0.1/√3/0.1kV
14	35kV three-phase two-winding non-exiting regulation transformer	8MVA 35/11.5kV
15	40.5kV circuit breaker	40.5kV 2000A 40kA 100kA
16	35kV current transformer	35kV, routine outdoor type
17	35kV voltage transformer	35/√3/0.1/√3/0.1/√3/0.1/√3/0.1kV
18	Dual-column horizontally-rotation disconnector	(1) 40.5kV, 2000A; 40kA; 100kA;with double earth switches; (2) 40.5kV, 2000A; 40kA; 100kA; with single earth switch

Note: 1. whether the resistor is need depends on the conclusion of over voltage research.

3.6 Preliminary Determination of Equipment at DC Yard

The main DC equipment used in this project is summarized as follows:

Table 3.6-1: Selection of main DC equipment

No.	Equipment Description	Main Parameters and Type Selection
1	Dry-type smoothing reactor for pole line	680kV, 3030A, 75mH
2	Dry-type smoothing reactor for neutral line	150kV,3030A, 75mH
3	680kV DC disconnector	3030A
4	DC high-speed switch NBGS	3030A, including circuit breaker, capacitor bank, reactor, and arrester
5	DC high-speed switch NBS	3030A, including circuit breaker, capacitor bank, reactor, and arrester
6	DC current measuring devices	680kV ,Optical current transformer, with optical connectors and photoelectron equipment
7	DC voltage measuring devices	680kV
8	DC pole bus arrester	680kV
9	Smoothing reactor arrester	680kV
10	$12^{th}/24^{th}$ DC filter	Including C1-high-voltage capacitor, high-voltage capacitor imbalance CT, L1-high-voltage reactor, L2-neutral point reactor, T3-reactor L2 branch CT, T4-CT on the neutral point side, F3-arresters on both ends of L1, F1-arrester on the high-voltage end of L1, C2 low-voltage capacitor, F2-arresters on both ends of L2, etc.
11	$6^{th}/42^{th}$ DC filter	Including C1-high-voltage capacitor, high-voltage capacitor imbalance CT, L1-high-voltage reactor, L2-neutral point reactor, T3-reactor L2 branch CT, T4-CT on the neutral point side, F3-arresters on both ends of L1, F1-arrester on the high-voltage end of L1, C2 low-voltage capacitor, F2-arresters on both ends of L2, etc.
12	Other equipment on DC side	Including high-voltage and low-voltage post insulators, low-voltage disconnector/earth switch, low-voltage current/voltage measure device, DC neutral bus impulse capacitor, PLC reactor, capacitor, power line carrier equipment,etc.

4. Study on Reactive Power Compensation of Converter Station

All the information in this section is just for reference.

4.1 Basic Study Principles

(1) The reactive power compensation levels and zones should be balanced locally without long-distance transmission.

(2) The total reactive power compensation capacity of converter station is generally calculated according to the reactive power consumption of DC system when transmitting rated power in rated voltage. Since there may be large fossil-fired power plants in the vicinity that the converter station serves, the reactive power provided by such power plants should be considered, provided that the system voltage regulation requirement and generator's operation requirements can be met.

The additional reactive power compensation capacity required for DC overload is balanced by the capacity of the standby compensation bank at converter station.

(3) The reactive power capacity installed at substation, in principle, is only used to compensate the reactive power loss of the main transformer of the same substation and the half of that of the outgoing lines at various voltage ratings. For the incoming lines from nearby power sources, they shall be permitted to supply more reactive power, but the voltage drop between the two ends of the line should not exceed 10%. The reactive power compensation in the existing grid and that which has been definitely planned should be simulated according to the actual condition and the planning respectively.

(4) Voltage control of AC system: According to the related code, for hub substation, the operating voltage of the bus on the LV side should be controlled to 1.0~1.1 times the rated voltage of grid in normal condition, and should not be lower than 0.95 times the rated voltage of grid after incident.

The operating voltage at any point of grid shall in no case be higher than the maximum operating voltage of grid. In normal conditions, it shall not be lower than 0.95 to 1.00 times the grid rated voltage (for the substations at the receiving end of grid, take the lowest value).

In addition, the system voltage regulation mainly relies on the adjustment of generator excitation, while using switchable, controlled reactor and capacitor as supplementary means.

(5) The power factor of maximum reactive output of generator should not be lower than the rated power factor. The power factor of minimum reactive output

should be not be higher than 0.95 for steam turbine generator, and should be controlled to prevent phase advance for hydro-generator. The voltage level at the generator end should be limited to 1.05 to 0.95 times the rated voltage.

(6) The reactive power compensation devices installed at converter station are generally considered together with AC filters. In the minimum operating mode, to meet the filtering requirement, a number of filters should be put into operation to make the capacitive reactive power of converter station surplus. Therefore, the AC system or converter station should be able to absorb some capacitive reactive power.

4.2 Calculation of Reactive Consumption of Converter Station

4.2.1 Calculation of Reactive Power Consumption of DC system

The converter station consumes a large amount of capacitive reactive power when it works. The reactive power consumption of converter station shall be calculated taking into account the various AC and DC operating modes. The reactive power consumption of converter station is related to the transmission of DC power, DC voltage, DC current, commutation angle, commutation reactance, and other factors. Calculate the reactive power consumption of the 500kV side of converter station under various operating conditions in accordance with the above-mentioned reactive power control principles. The DC steady operating voltage of converter station is controlled using the fixed firing angle (a=15°) method. The short-circuit impedance of converter transformer is taken as 18% provisionally. According to the Ningdong-Shandong ±660kV HVDC transmission project and based on the principle of not increasing the budget for commutation equipment, the 2-hour overload capacity of DC system is taken as 1.1 times the rated transmitted capacity.

The tolerance for the impedance of converter transformer is taken as ±5%. In the high reactive power operating condition, the commutation impedance tolerance of +5% should be taken; in the low reactive power operating condition, -5% should be taken. DC line resistance is a parameter affecting the reactive power consumption of converter. For the high reactive power mode, use the minimum possible resistance; for low reactive power mode, use the maximum possible resistance. The rated firing angle of rectifier it taken as 15°, while the rated turn-off angle of inverter is taken as 17°.

4.3 Reactive Power Support Capacity of AC System

4.3.1 Reactive Power Supply Capability of AC System

The converter station at the receiving end is an inverter station. The installed reactive power capacity of the 500 kV substations in Punjab province and Islamabad, in principle, is locally balanced in a layered and zoned manner, and is only used to compensate the reactive power loss of main transformer. Long-distance transmission of reactive power from the 500 kV AC system is not considered. Therefore, it is believed that the 500 kV AC system in Punjab province and Islamabad is incapable of providing capacitive reactive power to the converter station at the receiving end.

A part of the additional reactive power compensation capacity required for DC overload operation is balanced by the capacity of the standby compensation sub-bank provided at the converter station; the other part may be provided by the AC system.

4.3.2 Reactive Power Absorption Capacity of AC System

Considering that the auxiliary AC projects in the vicinity of the converter stations at the sending and receiving ends have not yet been provided with appropriate reactive power absorption measures, it is provisionally assumed that the AC system in the vicinity of the converter stations at the sending and receiving ends is incapable of reactive power absorption, and the inductive reactive power should be compensated locally at the converter stations.

4.4 Reactive Power Compensation Configuration of Converter Station

According to calculations, the total capacity of capacitive reactive power compensation of Lahore converter station is taken as 2480 Mvar provisionally. The reactive power compensation capacitors are divided into 4 banks and subdivided into 16 sub-banks. Each sub-bank has a capacity of 150 Mvar to 160 Mvar (there are two sub-bank sizes: the low capacity size is 150 Mvar, and the high capacity size is not greater than 160 Mvar).

The final division of sub-banks should be determined by further studies according to the actual conditions including switching level, system harmonics, and the arrangement of converter station.

As for inductive reactive power compensation, in this phase, 3 banks of low-voltage reactors are provided on the 35 kV low-voltage side of Lahore converter station preliminarily, each bank with a capacity of 60 Mvar and each phase with a capacity of 20 Mvar. These reactors should be of outdoor dry-type air-core design. In the actual engineering design, the configuration of low-voltage reactors should be further optimized according to the actual condition of the low-voltage bus of converter station.

5. Project Planning

5.1 DC System Operation Modes

This project is a typical DC transmission project of bipolar neutral grounding at two terminals. Conventionally, its basic operation modes should include bipolar operation, monopolar ground return operation, and monopolar metallic return operation.

By referring to experience with Ningdong-Shandong ± 660kV DC transmission project, a 12-pulse converter valve group is considered for each pole. The main operation modes of the Matiari-Lahore ±660kV DC transmission project are as follows:

1) Bipolar full voltage operation;
2) Monopolar metallic return operation;
3) Monopolar ground return operation;
4) Reverse power operation;
5) Reduced voltage operation;
6) Additional control functionality required for DC system.

To improve the AC system performance, the DC system should have the following control and auxiliary control functions according to experience:

1) Power swing damping in the case of major accident on the AC system;
2) Reactive power control of the converter station which is transmitting power;
3) Emergency active power support or flow reversal;
4) Control of AC system frequency;
5) Control of AC bus voltage in converter station;
6) Suppression of sub-synchronous oscillation of AC system.

5.2 Main performance Requirements for DC System

5.2.1 DC System Ratings

With the DC system operating continuously under ratings and the Matiari converter station sending power to Lahore converter station, the following continuously operation ratings should be available on the DC line side of the converter station's smoothing reactor:

Rated power: Bipolar 4000MW, monopolar 2000MW

Rated voltage: ± 660kV

Rated current: 3030A

5.2.2 Minimum Transmission Power of the DC System

According to engineering experience, the minimum DC current of the project is tentatively taken as 10% of the rated DC current, that is, the minimum transmission power of the DC system is 10% of the rated power.

5.2.3 Reduced Voltage Operation Capability of the DC System

Based on practical experience and capacity of related equipment, the minimum voltage of the Matiari-Lahore HVDC project is tentatively considered to be 70% of the rated voltage. For 70%~100% of the rating, the transmitted power of the DC system will be 70%~100% of the rated power.

5.2.4 Power Reversal Capability of the DC System

The sending-end of the project has no special requirements for power reversal, that is, the inherent capability of the DC equipment will be used and no additional equipment will be purchased.

5.2.5 AC System Operating Voltage and Frequency

According to the conclusions of flow and stability calculation, the operating voltage and frequency range of the AC bus of Lahore converter station is tentatively determined as follows:

(1) Operating voltage

With generators running at a reasonable power factor and an appropriate low voltage reactive compensation capacity for the 500kV substation in the receiving end, the 500kV bus voltage in the Lahore converter station can be maintained in a reasonable range.

For the recommended connection scheme, according to the flow calculation results of various modes, the normal voltage at the receiving end converter station for 500kV is taken as 475-530kV, the rated voltage of the 500kV bus on the converter AC side is taken as 490-510 kV, and the post-accident voltage is taken as 450-550kV.

(2) System frequency

According to the actual operation of the system, the normal fluctuation of the receiving end converter station bus frequency is 50 ± 0.2Hz. In the case of a fault, the system frequency range is tentatively taken as 49.0-51.0Hz.

5.2.6 Overload Requirements for the DC System

HVDC systems generally run with continuous rated power, but considering the design margin of equipment, environmental temperature changes and other factors, the DC system should have a certain overload capability. The overload capability can be divided into transient overload and short-term overload capability based on the duration of overload.

A stronger transient overload capacity will help improve the system transient stability. The short-term overload capacity is mainly intended to send more power and reduce the impact on grid operation when the AC and DC equipment is out of service for some reasons.

For this project there are no special requirements for DC overload capacity. By referring to overload capacity of HVDC projects in China and other countries, the 2-hour overload capacity of the DC system is tentatively considered to be 1.1 times the rating without costs for additional equipment.

The values of the overload capacity of the Matiari-Lahore DC system should be determined based on R&D progress of equipment, without causing additional costs or difficulty in construction.

5.3 Requirements for the Main Technical Parameters of the DC System

5.3.1 Requirements of the Grid for Electrical Connections in Converter Stations

A 12-pulse valve group is recommended for each pole. A converter station will be provided with a 500kV bus, with3/2 breaker connection. The receiving end converter station is planned to have 12 500kV bays, 6 system connection lines(2 to Lahore substation, 2 to Lahore North substation, 2 to Lahore South substation), 4 banks of capacitors and filters, and 2 converter transformer incoming lines.

5.3.2 Requirements of the Grid for Converter Transformer Parameters

(1) The parameters of converter transformer in the Lahore (the receiving end) converter station are as follows:

Short-circuit impedance percentage Uk is tentatively considered as 18%, which will be further optimized based on equipment manufacturing capability and transportation;

Type of converter transformer: single-phase two-winding transformer, in Y0/Δ and Y0/Y connection;

Configuration of converter transformer: 12 + 2;

Single-phase two-winding capacity: 401MVA;

Tap range on the HV side of converter transformer: Uk = 18%, -7-+23.

5.4 Primary Electrical Design of Converter Station

5.4.1 Valve Hall and converter Transformer Arrangement

Valve hall and converter transformer area are the core area of a converter station. The delivery power of the converter station is 4000MW. In addition, the costs of converter transformer and valve hall account for a large part of the total investment of the converter station, therefore, the primary consideration in arranging the valve hall and converter transformer will be their operational safety, and investment will be considered as well.

Based on the design of one 12-pulse valve group for each pole, double valve will be used.

In the case of double valve, the valve tower will be about 13m high. Each valve hall will have six valve towers. With single-phase two-winding converter transformer and double valve arrangement, the 6 converter transformers of each pole will be arranged in a line on the AC incoming line side of the valve hall. The 12 valve side bushings of the converter transformers will be led into the valve hall, then connected to the 12-pulse valve group after a Y/Δ connection in the valve hall. The converter valves in the valve hall will be double valves, six groups per pole, suspended.

5.4.2 DC Switchgear Type and Layout

Outdoor DC yard will be used.

In the DC yard, the equipment will be arranged symmetrically for the two poles. The DC neutral bus equipment will be arranged in the center of the field, the line bus equipment on two sides, and two DC filter banks will be arranged between the DC neutral bus and the pole bus. The DC filters and pole bus smoothing reactors are arranged in low locations, surrounded by security fencing. The DC filter capacitors are installed with supports.

5.4.3 500kV AC Power Switchgear

1) 500kV AC switchgear

   3/2 circuit breaker connection will be used on the 500kV AC side, in three rows. Two converter transformers are directly elevated to a series. The #1, #2, #3 and #4 AC filter banks will be led to the string through overhead line.

2) Equipment on the step-down transformer circuit

   The two step-down transformers will be led to the two 500kV main buses respectively through open AC switchgear.

5.4.4 AC Filter Arrangement

AC filters are connected in series in the form of banks. For this phase 16sub-banks are considered, with 8 being 150Mvar, and 8 being 160Mvar. All AC filter banks will be arranged in a line. All AC filters of the converter station will be centralized for clearing demarcation of zone and use of noise reduction measures.

5.4.5 35kV Switchgear Arrangement

35kV AC switchgear will be connected with a single bus, with the switchgear arranged outdoor. Two 35kV buses will be provided, in which one is connected with two 60Mvar LV reactors and one 35/11.5kV auxiliary transformer, while the other one is connected with one 60Mvar LV reactors and one 35/11.5kV auxiliary transformer.

5.4.6 Electrical General Layout Plan

The electrical general layout plan will be determined as follows:

1) The direction of ± 660kV DC and 500kV AC outgoing lines should meet the requirements of AC and DC line corridor, minimize angle towers, and avoid line crossover.

2) 3/2 circuit breaker connection will be used for the AC 500kV switchgear, connection of AC filters will be considered based on use of live tank circuit-breaker.

3) Four banks of AC filters are proposed.

4) Double valve arrangement is tentatively proposed for valve hall.

5) Outdoor DC yard is considered.

In response to the main electrical connection, the electrical general layout plan of the Lahore converter station is as follows:

The control building, valve hall, converter transformers and 35kV switchgear are arranged in the center of the station area, the DC yard in the west, and ± 660kV DC transmission lines are led to the west. The 500kV AC switchgear will be arranged in the east of the station area. All the six 500kV AC lines will be led to the north. All the four AC filters will be arranged in the south. Spaces will be reserved for additional main transformers, 500kV and 220kV lines.

5.4.7 Lightning Protection

"Ground wire " will be used as lightning protection measures for this project: ground wires will be used for the valve hall, converter transformers and 500kV AC filters,500kV switchgear area protection. Roof lightning strip will be used for buildings which cannot be protected by ground wires (such as auxiliary building, integrated pump house, garage and other buildings)..

Given that copper ground wires are used in most recent converter stations in China, copper conductors are considered for the earth grid.

5.5 Secondary Electrical Design of Converter Station

(1) Design principles

(a) The converter station will be designed on a manned basis. An integrated computer monitoring and control system will be built for the AC and DC systems.

(b) The monitoring, measurement, control and other functions of all equipment in the station will be realized by the computer monitoring and control system, which will be of a modular, hierarchical, distributed, and open architecture.

(c) The HVDC control system will be of a hierarchical distributed architecture. The sampling units, data bus, master device to control port, should be fully in duplicated configuration.

(d) The HVDC protection offers protection for pole/two poles, DC switchyard, DC lines and earth electrode lines, which are divided into multiple overlapped protection zones. The protection zones and configuration shall ensure all devices are under comprehensive protection. Triple redundant protection will be used for the HVDC system.

(e) The HVDC protection and control systems will be separate. In function and configuration of control cabinets, the protection systems of the two poles should be completely independent.

(f) HVDC control and protection system is suitable for both rectifier operation, inverter operation can be applied.

(g) In the 500kV AC yard, a relay bay will be provided, and control and protection devices will be provided corresponding to the AC equipment bays. HVDC control and protection cabinets, converter transformer control and protection cabinets will be arranged in in the respective rooms in the control building; the control and protection cabinets of AC filters, capacitors and reactor banks, and AC lines will be arranged in the local AC relay room.

(h) Based on the characteristics of HVDC systems, auxiliary DC power supplies will be provided respectively to DC P I, P II, common equipment of the station and AC local relay room.

(2) Computer monitoring and control system

The Lahore converter station will be designed on a manned basis. The computer monitoring and control system will be of object-oriented design. Through full use of computer technology, modern control technology, network communications technology and graphics technology, an integrated automation system of control, measurement, telecontrol and modern comprehensive management. The computer monitoring and control system will be of modular, hierarchical distributed network architecture. The operators may use the HMI in the control room to monitor, control and record all the equipment in the converter station, and send related information to control centers through remote communications devices.

(3) HVDC control system

In addition to basic control of various operation modes, the HVDC control system includes various basic controllers and limiters, and is capable of maintaining the controlled signals such as DC power, DC current, DC voltage and converter firing angle within the steady state limits of primary DC equipment. The control system also has the ability to suppress transient overcurrent and overvoltage, and to recover steadily within the specified response time after AC or DC system failures.

The HVDC control system will be of a hierarchical distributed architecture. With the purpose of assigning control functions to the lowest possible layer, the HVDC control system is divided into the following by function: double-pole control layer, pole control layer and converter valve control layer.

The sampling units, data bus, master device to control port, should be fully in duplicated configuration.

(4) HVDC protection system

The HVDC protection system is arranged based on protection zones. The protection system of the converter station is divided into the following seven protection zones: AC filter/shunt capacitor protection zone, converter transformer protection zone, converter protection zone, DC line protection zone, DC filter protection zone, DC switchyard protection zone, and DC earth electrode line protection zone. Each protection zone and adjacent protection zone are overlapped to ensure that there is no dead zone. Triple redundant protection will be used for the HVDC system.

Among them, the DC filter protection and converter transformer protection will be provided by the pole protection; three sets of electrical quantity protection and non electrical quantity protection will be provided for each pole;

duplicated protection will be provided for the AC filters.

DC protection of the two poles are completely separate. HVDC protection and DC control systems will be relatively independent, both in redundancy.

(5) Component protection

Duplicated protection will be provided for the main and standby 500/35kV step-down transformers, that is, two sets of independent electrical quantity protection and one set of non electrical quantity protection will be provided in two cabinets. One set of protection in one cabinet will be provided for the auxiliary transformer for external power supply and auxiliary 35kV /11.5kV transformer. One set of protection arranged in corresponding switch cabinet will be provided for the 11.5 kV/400V transformer.

One circuit breaker protection and one control box will be provided for each 500kV auxiliary transformer circuit breaker, arranged in the 500/35kV step-down transformer protection cabinet.

One set of protection will be provided for each 35kV reactor, including current quick break protection, overcurrent protection, and zero sequence overcurrent protection. One cabinet will be provided for protection of two reactors.

(6) Transient fault recorder system

The transient fault recorder system includes AC transient fault and DC transient fault recorders.

DC transient fault recording function is performed by a separate DC transient fault recording panel. Separate DC fault recorders are provided for the DC system based on pole and converter transformer, used to record the DC system valve group pulse sequence, firing angle, extinction angle, power, and current, voltage and protection operations and fault information of the HVDC and converter transformer circuits. Two converter transformer fault recorder panels and two valve group DC fault recorder panels will be provided.

The fault recorders record the current, voltage of AC filter banks in the AC yard, 500kV and 35kV auxiliary transformers and protection operations and fault information of various protection devices. Each bank of AC filter will be provided with one panel; two panels will be provided for all the transformers. Fro AC fault recorders related to system protection, see related chapters in Volume 3. The recorded AC fault information will be sent to the AC fault recorder panel in the relay room.

(7) DC fault location system

Two fault location systems will be provided for the HVDC lines of the project, mainly using double end detection of fault transient state travelling wave for ranging. It uses absolute time difference of the initial travelling wave surge reaching from the location of fault on the line to both ends to calculate the distance of fault to the ends.

(8) Station master clock system

The station will be provided with a clock synchronization system, and the master clock should be able to receive GPS reference time signals. For station control and process control which has high real-time requirements, hard connection will be used for synchronization, such as pulse synchronization and B code synchronization; network synchronization will be used for other devices. The synchronization of station master clock covers the station computer monitoring and control system, DC control and protection system, AC protection system, AC and DC transient fault recorder systems, SCADA and remote system, and electricity billing system.

(9) Valve cooling control and protection system

The valve control and protection system is in redundant configuration for each pole. The scope of redundancy extends from power supply of valve cooling control system to sensors which provide information to the control system; similarly, the digital communications interface with DC control and protection system is also redundant. When the main system fails, it will automatically switch to the backup system.

(10) DC power supply system

Three local relay rooms will be provided for this phase in response to the arrangement of AC yard and AC filters. Two DC power supply systems are considered for the AC yard of this phase: respectively for P I, P II and common devices. Five DC power supply systems will be provided for the station.

The DC power supply systems will be of 220V. Each DC power supply system includes two sets of batteries, three sets of microprocessor-based high-frequency switching power supplies and corresponding DC panels. Sectionalized single-bus configuration will be used for the DC power supply system. Each section of bus will be connected to a battery and a charger; and a common charger will be provided for the two batteries, and can be used as backup for any charger. The battery discharge time is 2 hours, and the loads will be supplied in the form of radiation.

(11) AC UPS

To feed important AC loads such as computer control system, workstations, printers, the control building provides two 15kVA AC UPSs, for redundant backup for the two poles and in parallel operation. Each UPS includes a rectifier, inverter, static transfer switch, and a bypass system. Two UPSs are respectively connected to two 220V batteries, with no dedicated battery. Each UPS has a full capacity. When AC power fails, the UPS can provide emergency power supply for two hours.

Each AC relay room will be provided with one inverter power supply system to energize the AC loads.

(12) Meter

Electricity meters are provided as follows according to the main electrical connection of the project:

One meter will be provided at 500kV AC filter bank and LV side of 500kV step-down transformer. Separate panels will be provided for the meters in the separate rooms. The meters will communicate with the station computer monitoring and control system through serial ports.

(13) Other auxiliary systems

The station will be provided with a fire alarm and control system. The capacity, performance requirements and corresponding interfaces of fire alarm controllers will be provided according to the scale of this phase. However, the fire alarm system should have extension spaces to meet future needs.

A video surveillance system and security guard system will be provided to prevent unlawful entry.

A full chromatography online insulating oil monitoring system will be provided for the converter transformers and HV transformers; a leakage current online monitoring system will be provided for the valve and DC yard lightning arresters.

(14) Arrangement of control building and protection room

Based on the primary equipment of the converter station, the control building and 500kV AC relay rooms will be arranged as follows:

The control building will contain operator control room, P I control and protection equipment room, P II control and protection equipment room, common and bipolar control and protection equipment room, P I converter transformer and DC yard interface room, P II converter transformer and DC yard interface room, P I valve cooling equipment room, P II valve cooling equipment room, common DC panel room, P I DC panel room, and pole DC panel room.

The 500kV AC switchyard will be provided with three 500kV local relay rooms, each of which will be provided with two battery rooms;

(a) The secondary devicesof ACF1-ACF4 will be arranged in the first 500kV local relay room;

(b) The secondary devices of #1~#3 500kV series will be arranged in the second 500kV local relay room;

(c) The secondary devices of #4~#6 500kV series will be arranged in third 500kV relay room.

5.6 Transport of Large Equipment

5.6.1 Dimensions of Large Equipment

The transport dimensions of large equipment, by referring to experience of similar projects, are given as follows:

Table 5.6-1 Transportation dimensions and weight of large equipment

	Transportation dimensions (m)	Weight (t)	Quantity
Yy converter transformer	13×4.5×5	350	7
Yd converter transformer	12.5×4.5×4.8	310	7
500/35kV step-down transformer	8.4×3.8×4.3	160	2

* The exact transport dimensions will be provided by the manufacturers

5.6.2 Transport Conditions

Chinese equipment will be used for this project. After departure from Chinese manufacturers, the equipment will be shipped to a port in Pakistan, then by land to the site. Pakistan is located in South Asia, landlocked on three sides, with the south bordering the Arabian Sea. Pakistan's inland transport relies on road, supplemented by rail, but the railway cannot transport large heavy pieces of cargo. Most of its inland rives are not navigable for large vessels. So the large equipment for this project can be transported by sea and inland road.

5.6.3 Analysis of Transport Plan

According to the transport conditions in Pakistan, large equipment will be transported by manufacturers to Karachi, a port city in south Pakistan. According to site survey, Port Qasim can be used as the receiving port, from where equipment can be transported to the sending and receiving end converter stations by road. The transport route is as follows:

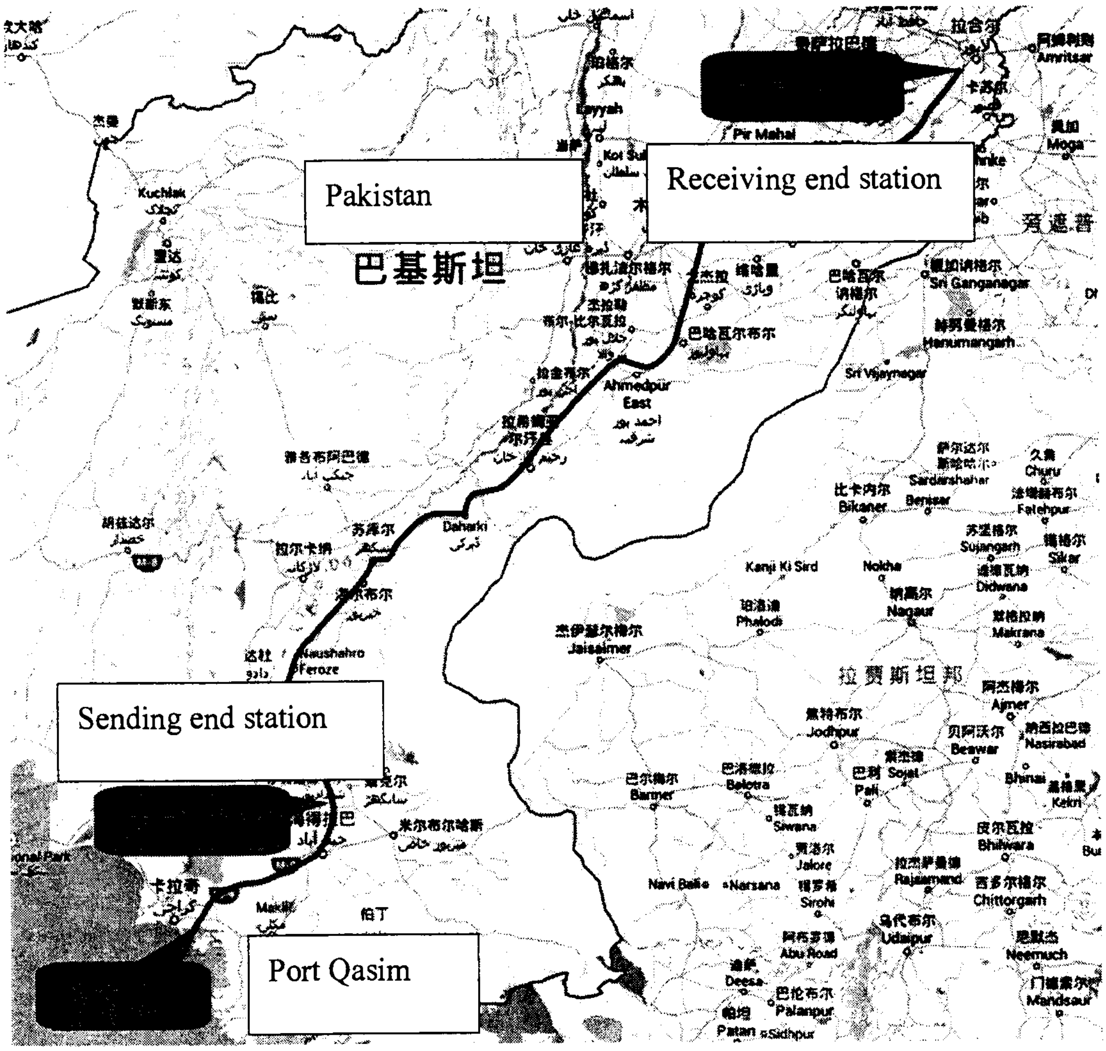


Figure 5.6-1: Inland road transport map

Port Qasim is about 1200km away from the receiving end converter station and the main route will be the N5 highway, which is a main north-south road equivalent to China's national highway. With good roadbed, flat surface, and without high gradients, the road has poor conditions at some locations, but suitable for transport of large vehicles. The problem is that there are many bridges and overhead barriers. The road and bridges should be properly protected during transport.

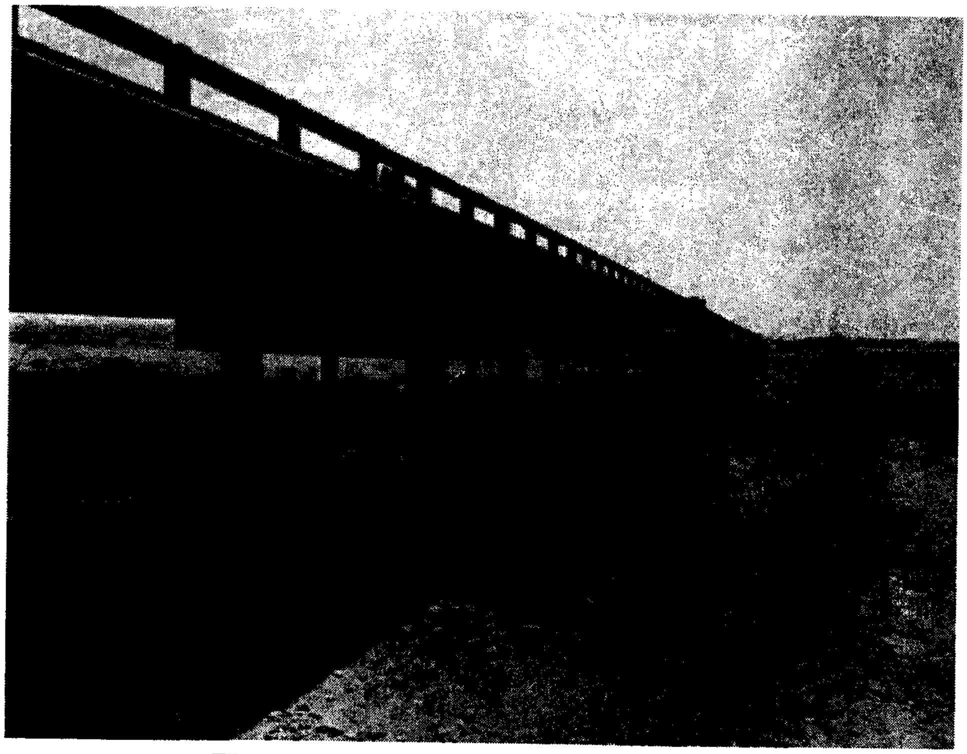


Figure 5.6-2: A large bridge on N5 road

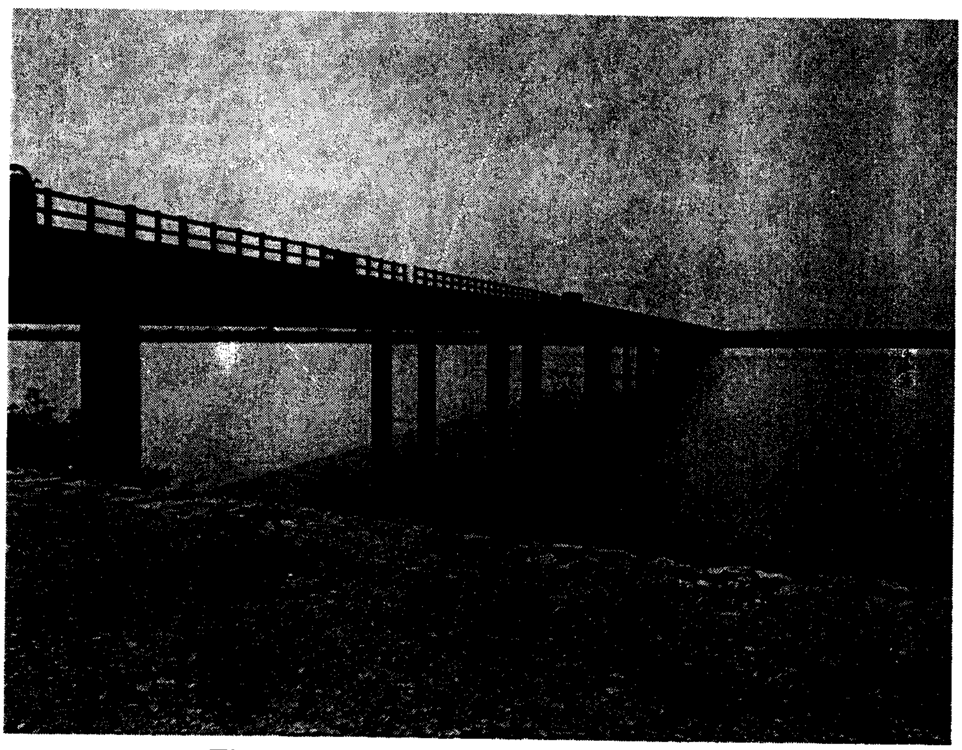


Figure 5.6-3: A large bridge on N5 road

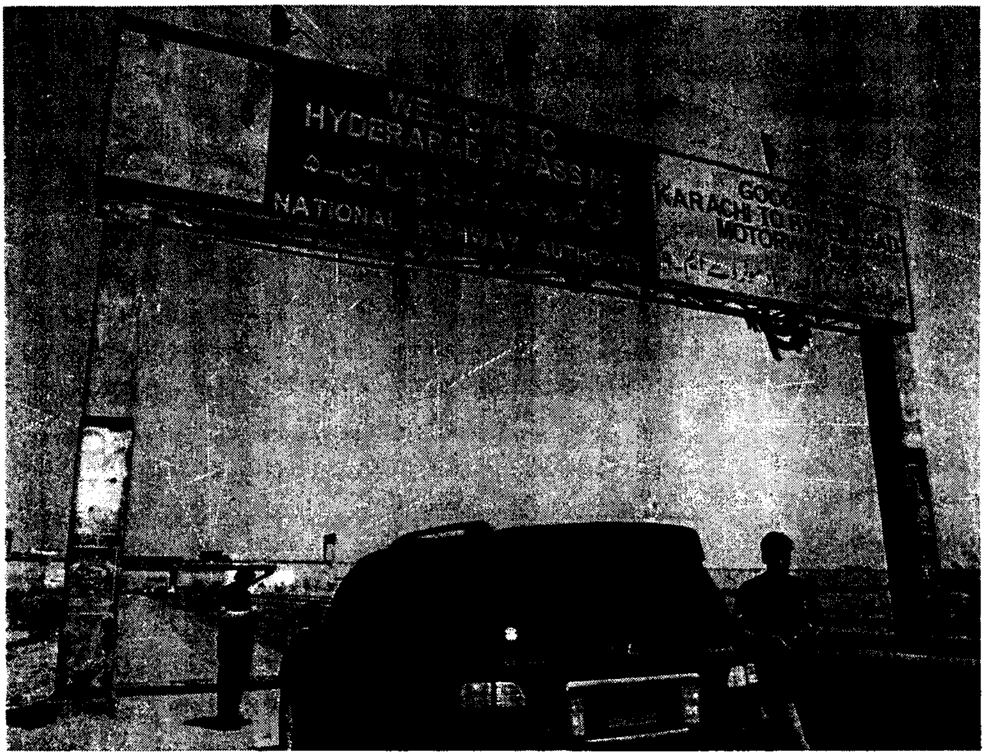


Figure 5.6-4: A typical overhead barrier on N5 road

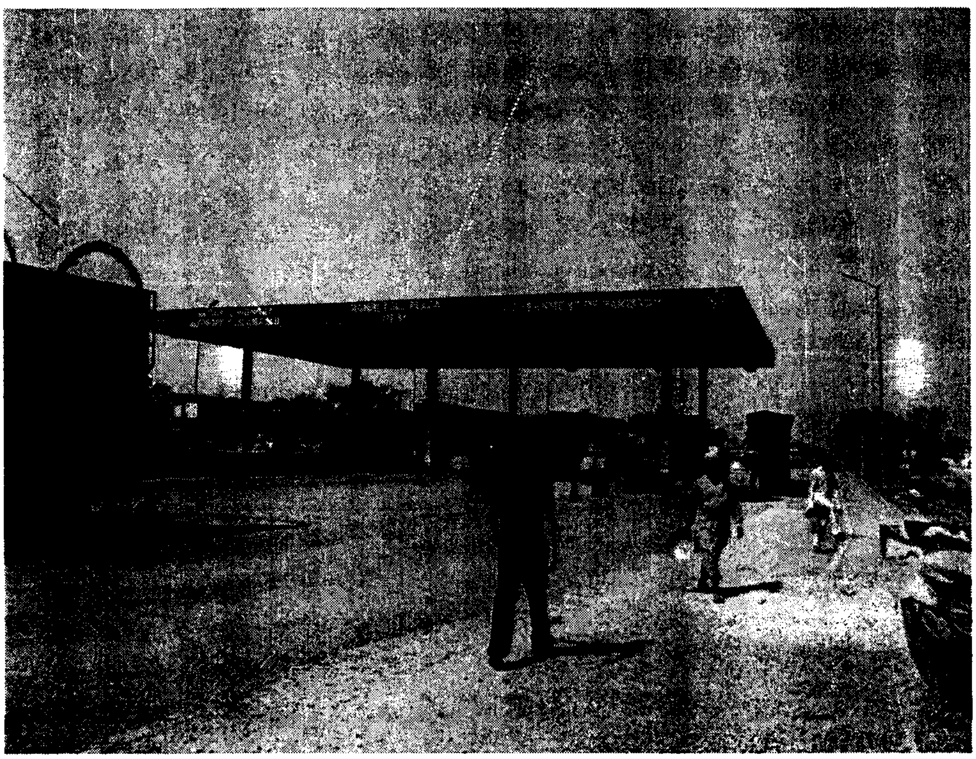


Figure 5.6-5: Toll gate on N5 road

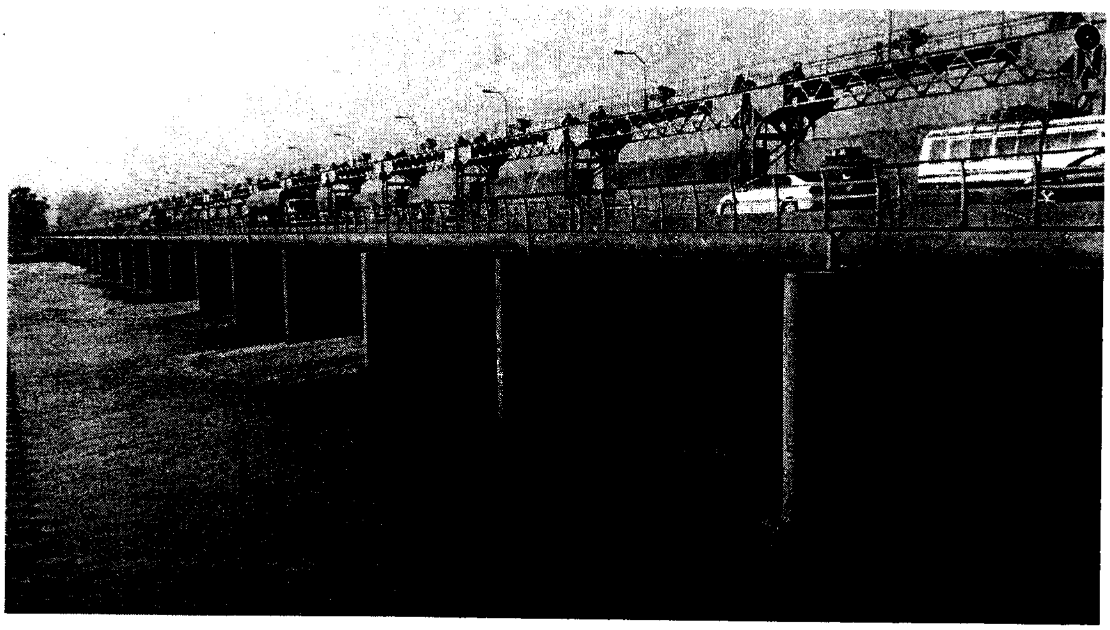


Figure 5.6-6: Large reservoir along the access road

There are approximately 100 bridges on the road, including large bridges of above 500m. Most local bridges have a box girder structure, offering good bearing capacity. The overhead barriers on the road limit the height to 6m. With proper measures taken, they can meet the passage needs of large equipment for the project.

5.6.4 Conclusions and Recommendations

According to the road conditions found during survey, the large equipment for the project can be shipped to the site after properly planning and safety measures. As informed by the local transport company, equipment heavier than 450t had been transported on the road. But transporting over so long a distance by road will involve high difficulty and unpredictable factors. The owner is advised to engage a qualified transporter to develop a plan for transport of large equipment to the site safely, with minimum costs.

5.7 Auxiliary Power

5.7.1 Introduction of Auxiliary Power Supply

In order to assure the operation reliability of converter station, three circuits of auxiliary power supply are proposed for Lahore converter station; two circuits will be led through 35/11.5kV auxiliary transformers on two 35kV AC buses; the other circuit will be led from 132kV transmission line nearby or from the 132kV bay in the SARFRAZ NAGAR 220kV substation.

5.7.2 Principles of Connection of Auxiliary Power

Two 500/35kV step-down transformers will be provided in the station; two main 500kV buses are connected with the HV side by open AC switchgear; LV side is connected to 35kV system of the station. The two 11.5kV power supplies are led from the LV side of two 35/11.5kV auxiliary transformers. The station standby power supply is temporarily led from 132kV transmission line nearby or 132kV bay in the SARFRAZ NAGAR 220kV substation. Single bus connection and open arrangement will be used for 132kV switchgear; 132kV transformer has two outgoing circuits and 132/11.5kV auxiliary transformer has one incoming circuit. Bus PT will be provided.

Single bus in two sections will be used for the 11.5kV system; each section is supplied by a separate 1-circuit main power supply; besides, one standby section will be provided. Each 11.5kV working section is connected with two 11.5/0.4kV, 2500kVA low-voltage auxiliary transformers for valve group's auxiliary load. Besides, each 11.5kV working section is connected with one 11.5/0.4kV (2500kVA) low-voltage auxiliary transformer for common load of converter station.

5.7.3 Auxiliary power equipment and arrangement

(1) Selection of auxiliary transformer

The auxiliary transformer includes two 35/11.5kV auxiliary transformers and one 132/11.5kV auxiliary transformer; the low-voltage auxiliary transformer includes six 11.5/0.4kV auxiliary transformers.

(2) Selection of high/low-voltage distribution panel

1) High-voltage switch cabinet

Trolley or intermediate switch cabinet will be provided as 11.5kV high-voltage switch cabinet and vacuum circuit breaker will be provided inside.

2) Low-voltage switch cabinet

Drawer type or plug-in intelligent switch cabinet will be provided as 400V low-voltage switch cabinet (PC, MCC and so on).

5.8 Buildings and structures

5.8.1 Buildings

±660kV Lahore converter station includes the following buildings: PI valve hall, P II valve hall, one control building, 500kV No. 1 relay (with battery room) and 11.5kV switch cabinet room, 500kV No. 2 relay (with battery room) and measuring room, 500kV No. 3 relay(with battery room), 400V common switchgear room, integrated water pump house, deep well pump house, four deluge valve rooms, spare smoothing reactor room, special materials storage, maintenance workshop & spare parts storage, Chinese dining room, Chinese dormitory, activityroom, Pakistan'sdining room, Pakistan's dormitory, two office building, management staffdormitory, workers' dormitory, security rooms, watch tower, Pakistan's security staffdormitory.

The total building area is about 26500m^2.

Table 5.8-1 List of buildings and structures in the station

No.	Name of buildings	Building dimensions (m) L x W x H	Number of floors	Building area (m^2)	Qty
1	P I valve hall	84×35×30 (lower chord of roof truss 24.75)	Single floor	3243	1
2	P II valve hall	84×35×30 (lower chord of roof truss 24.75)	Single floor	3075	1
3	Control building	33.6×37.9×18.9	Three floors	3075	1
4	500kV No. 1 relay (with battery room) and 11.5kV switch cabinet room	46×9.6×5.65	Single floor	455	1
5	500kV No. 2 relay (with battery room) and measuring room	34.4×9.6×5.65	Single floor	341	1
6	500kV No. 3 relay (with battery room)	31×9.6×5.65	Single floor	308	1
7	400V common switchgear room	12.6×9.6×5.65	Single floor	126	1
8	integrated water pump house	30.5×10×11.55	Single floor	315	1
9	deep well pump house	22.3×10×9.85	Single floor	231	1
10	deluge valve room	6×3.6×5.35	Single floor	24	4
11	spare smoothing reactor room	8.6×8.6×6.95	Single floor	80	1
12	special materials storage	5.1×5.1×5.35	Single floor	29	1
13	maintenance workshop & spare parts storage		Single floor	1274	1
14	Chinese dining room		Single floor	280	1
15	Chinese dormitory		Four floor	1888	1
16	activity room		Single floor	232	1
17	Pakistan'sdining room		Single floor	280	1
18	Pakistan's dormitory		Four floor	1532	1
19	office building		Three floor	2052	1
20	office building (operational area)		Three floor	1483	1
21	managementstaffdormito		Two floor	1946	1

	ry				
22	workers'dormitory		Three floor	3103	1
23	security room		Single floor	32	2
24	watchtower		Two floor	22	4
25	Pakistan'ssecuritystaff dormitory		Two floor	904	1
Total		/	/	26468	32

5.8.2 Structure

5.8.2.1 Design scope

The structural design scope includes the upper structure, foundation and subgrade treatment of all the buildings (structures) in the enclosure wall of Lahore converter station. The main buildings (structures) include (but not limited to): buildings (structures) of converter area (P I valve hall, P II valve hall, control building, converter transformer foundation and fire wall, transportation road and converter transformer's incoming line structure), buildings (structures) of 500kV AC yard and AC filter yard, buildings (structures) of DC filter yard, buildings (structures) of auxiliary transformer and 132kV switchgear area, water related buildings (structures) of station and administrative buildings (structures).

5.8.2.2 Design conditions

Designed wind speed: the owner's recommended maximum instantaneous (3s) wind speed (at an altitude of 10m and frequency of once every 50 years) is 160km/h: 44.4m/s. It is converted into maximum average wind speed (10min) of 31.1 m/s.

Basic earthquake intensity: The converter station belongs to 2A area. The peak acceleration of ground motion is 0.14g under 10% frequency of once every 50 years; the basic earthquake intensity is 7°.

5.8.2.3 Design Standards

(1) ASCE 7-10 minimum design loads for buildings and other structures .

(2) ACI 318-11 Building Code Requirements for Structural Concrete and Commentary .

(3) AISC 341-05 seismic provision for structural steel buildings .

(4) ASCE 10-97 Design of Latticed Steel Transmission Structures .

(5) ASCE 113-2008 Substation Structure Design Guide .

(6) ACI 543R-00 Design, Manufacture, and Installation of Concrete Piles .

(7) AISC 360-10 Specification for Structural Steel Buildings.

(8) ACI 530-11 Building Code Requirements for Masonry Structures.

5.8.2.4 Structural Type

Valve hall: It is in single floor; P I valve hall and P II valve hall will be provided. The main structure is steel—reinforcement concrete frame structure; the roof is in the form of trapezoid steel roof truss. The double-layer heat conservation compressive steel sheet will be provided for the roof plate. The fire wall is in the Reinforcement concrete frame structure

Spare flat wave reactor chamber and Maintenance and spare parts warehouse:Steel structure will be adopted.

The integrated water pump house includes above-ground and underground parts. The above-ground part is in the single-floor reinforcement concrete frame structure and underground part will be in the form of pond and is in the cast-in-situ reinforced steel concrete box structure.

All other buildings (Control building, relay and battery building, office buildings , refectories, refectories, Specially store, metering buildings, common switchgear building etc): Reinforcement concrete frame structure will be adopted.

Water related building (structure): The industrial fire-fighting water pond, spray water pond, sewage adjustment pond and accident oil collection pond are in the reinforced steel concrete box structure. The foundation of embedded sewage treatment unit is made of reinforced steel concrete plate foundation. The rainwater valve foundation is made of reinforced steel concrete plate foundation. The underground water discharge pump station is in the reinforced steel concrete box structure.

The gantries and equipment supports will be latticed steel structure with cast-in-situ R.C. stepped footing. Connections of members will be bolted. Gantry will be mounted on the foundations by means of anchor bolts embedded in the foundation concrete.

5.8.2. 5 Subgrade and foundation

Foundation dimensions and buried depth are calculated based on the data available from the geological report. Gantry foundation will be buried to 2.0m~3.5m deep. Equipment support foundation will be buried to 1.5m~2.5m. Foundation shall be placed on undisturbed soil layer, otherwise pile foundation should be adopted.

5.8.2.6 Standard for structural design

A) RC structure

Deflection of members shall be no greater than L/240 (9.5.2.6 of ACI 318, the latest version)

B) Steel structure

Deflection of framework beams shall be no greater than L/300, and deflection of framework columns shall be no greater than H/150.

C) Slenderness Ratio

Table5.1.4-3 Limiting Slenderness Ratio (refer to ASCE 10 part 3.4, the latest version)

Main compression member	150
Secondary members carrying calculated stresses	200
Redundant members without calculated stresses	250
All tension-only members	350

D) Connection of steel structure

Connection method: Factory fabrication -- Bolt connection & welding; On-site-- Bolt connection.

Bolt: Grade 5.8 6.8 and 8.8 galvanized bolts will be used, with minimum diameter 12mm. All bolts will be completed with galvanized washers. Each bolt will be provided with one flat washer and one spring washer.

Welding: Q235B and Q345B steel electrodes shall use E43 type and E50 type. The welding operation shall be avoided as far as possible for the Q420B high-strength steel. Weld metal shall match the metal material of members to be connected.When steels of different strength are to be connected, the weld material matching the low strength steel way be used.

Table5.1.4-4 Summary of bolt Strength

Material origin	**Grade**	**Yield strength (N/mm^2)**	**Tensile strength (N/mm^2)**
China	5.8	320	400
	6.8	480	600
	8.8	640	800

(3) Materials

A) Steel

Steel Q235B and Q345B will be used as steel for gantry and equipment support. Calculation shall be carried out as AISC standard.

Main member angle steel : Q345B

Web member angle steel: Q235B

Walkway, ladder: Q235B

Anchor bolt: Q345B

Table 5.1.4-5 Summary of Steel Strength

Material origin	Brand	Thickness (mm)	Yield strength (N/mm^2)	Tensile strength (N/mm^2)
China	Q235B	t≤16	235	375
		16<t≤40	225	
	Q345B	t≤16	345	470
		16<t≤35	325	
		35<t≤50	295	

B) Concrete

Table5.1.4-6 Summary of Concrete Strength

Item	THE SPECIFIED COMPRESSIVE STRENGTH OF CONCRETE, CYLINDRICAL MODEL ON 28-DAY TESTS: fc'
Foundation	28 N/mm^2
Beam, column, slab	28 N/mm^2
Cable trench	28 N/mm^2
Pre-fabricated member	28 N/mm^2
bedding course	14 N/mm^2
Others	28 N/mm^2

C) Steel bar

Table 5.1.4-7 Summary of Steel Bar Strength

Category	(N/mm^2) Yield strength	Remark
Grade 40	280	
Grade 60	420	
Grade 75	520	

(4) Anti-corrosion of steel structure

The steel for gantry and equipment support will be hot-galvanized for corrosion resistance. The steel buildings will be painted for corrosion resistance.And zinc-rich painting will be used at site for local anti-corrosion treatment where the zinc coat is damaged.

5.8.2.7 Noise

According to the Pakistan standard THE GAZETTE OF PAKISTAN, EXTRA, NOVEMBER 26, 2010, the sound environment of various functional areas and related discharge limits are formulated as follows:

Table 5.8-2

National Environmental Quality Standards for Noise

S. No.	Category of Area / Zone	Effective from 1st July, 2010		Effective from 1st July, 2012	
		Limit in dB(A) Leq *			
		Day Time	Night Time	Day Time	Night Time
1.	Residential area (A)	65	50	55	45
2.	Commercial area (B)	70	60	65	55
3.	Industrial area (C)	80	75	75	65
4.	Silence Zone (D)	55	45	50	45

Note: 1. Day time hours: 6.00 a. m to 10.00 p. m.

2. Night time hours: 10.00 p. m. to 6.00 a.m.

3. Silence zone: Zones which are declared as such by the competent authority. An area comprising not less than 100 meters around hospitals, educational instiutions and courts.

4. Mixed categories of areas may be declared as one of the four above-mentioned categories by the competent authority.

*dB(A) Leq: Time weighted average of the level of sound in decibels on scale A which is relatable to human hearing.

The noise at the boundary of the converter station is in accordance with Chinese standard (Emission Standard for Industrial Enterprise Noise at Boundary GB12348-2008) 2 level: the daytime noise level is less than 60dB(A) and night noise level is less than 50dB(A). And for area 150 meters far away from the fence of the converter station, the noise should be less than 45dB(A) in night time and 50dB(A) in day time.

5.9 Water Systems

5.9.1 Water Supply System for Converter Station

The water supply system for converter station includes domestic, productive and fire protection water supply systems.

Domestic water supply system includes a $15m^3$ stainless steel water tank, domestic water supply unit and domestic water supply pipe network, etc. Variable-frequency constant-voltage water supply is adopted for domestic water supply unit, the designed water supply flow is $15m^3/h$ and water supply pressure is 60m.

Productive water supply system shall mainly provide make up water for the cooling water system outside the converter valve. That system is composed of a productive water tank and 4 sets of productive water supply pumps (two in use and two standby) as well as its water supply pipeline, etc. The effective water storage volume productive water tank is the water consumption for five days of production. The makeup water of cooling water system outside valve for each pole is an independent water supply system, after pressurized by one set of working centrifugal pump (the other set of water pump is standby) by the water taken from water tank, it shall be delivered into corresponding cooling water tank outside valve through pipeline.

The fire protection water supply system shall provide fire protection water for indoor and outdoor fire hydrant of building as well as water atomizing extinguishing system of converter transformer. The system adopts independent temporary high-pressure water supply system, and it is composed of fire-water pond, fire supply pump unit and the fire supply pipe network equipped with fire hydrant, etc. In order to avoid deterioration of water quality caused by long-term disuse of water protection water, the measures for ensuring water protection water not to be used for other purpose are taken into consideration, the mode of jointly constructing fire-water pond and productive water tank shall be adopted, and the storage quantity of fire protection water shall be about 400-500 m^3.

5.9.2 Drainage System

Organized split water drainage system shall be adopted for water drainage in the station area, i.e., rainwater and valve cold drainage system, domestic sewage treatment and reuse system as well as emergency oil drainage system.

The rainwater in the station area shall be collected by the storm water inlet on the ground beside road. And it shall be converged to the rainwater pump station through underground water drainage pipe before being pumped to outside the station.

The cooling system outside valve inside station has little water drainage, the water quality is unpolluted, and it shall be considered to be drained to rainwater drainage pipe network through pipe.

Domestic sewage treatment and reuse system shall be responsible for collecting the domestic sewage of comprehensive building, master control building and safeguard doorkeeper's room through pipe, and delivering into the buried integrated sewage treatment device for disposal, then it shall be collected into the wastewater tank through biochemical secondary treatment, so as to be reused for greening in the station.

For the emergency oil drainage of oil-bearing equipment, such as converter transformer and reducing transformer, etc., through collection by the oil pit at the lower position, it shall be converged into the emergency oil collecting basin through underground oil drainage pipe, water shall be drained out into rainwater drainage pipe network after separation of oil and water, and oil shall be stored into the emergency oil collecting basin for recovery.

5.10 Ventilation and Air Conditioning System

(1) General

Air conditioning and/or other environmental control systems will be provided for all buildings, and process areas to ensure satisfactory operation of the HVDC system under the range of climatic conditions to which the station may be subjected. These systems will provide for personnel comfort and equipment operational reliability. Areas requiring environment control will at least include:

- Valve hall
- Control room
- Electrical equipment room
- Communication equipment room
- Office, meeting room, documentation room, duty room
- Pump house
- Battery room
- Valve cooling equipment room etc.

Table 5.10-1 List of Indoor Design Criteria for Buildings or Rooms

Room	Temperature		Relative Humidity	
	Summer	Winter	Summer	Winter
Valve Hall	≤50 °C	≥10	20~60%	20~60%
Control Room	24~28°C	16~18°C	50~70%	50~70%
Protection Equipment Room	24~28°C	16~18°C	50~70%	50~70%
Communication Equipment Room	24~28°C	16~18°C	50~70%	50~70%
Valve Cooling Control room	24~28°C	16~18°C	50~70%	50~70%
Office	26~28°C	16~18°C	≤70%	-
Meeting Room	26~28°C	16~18°C	≤70%	-
Documentation Room	26~28°C	16~18°C	≤70%	-
400V Distribution Room	35 °C	-	-	-
DC Panel Room	≤30 °C	16~18°C	≤70%	-

Battery Room	≤30 °C	16~18°C	-	-
Valve Cooling Equipment Room	≤35 °C	≥10	-	-
Relay Room	24~28°C	16~18°C	≤70%	-
11kV Power Distribution Room	≤35 °C	-	-	-
Duty Room	24~28°C	16~18°C	≤70%	-
Rest Room	24~28°C	16~18°C	≤70%	-
Canteen	24~28°C	16~18°C	≤70%	

(2) Ventilation for Valve Hall

Each valve hall will be provided with an independent ventilation system by two redundant air handling units with 100% capacity per each, one operation and one standby, to maintain indoor temperature and relative humidity at an acceptable level for normal operation of electrical equipment inside the valve hall. Also a slight overpressure (5~10Pa) will be provided inside the hall to prevent the infiltration of dust through building enclosure.

Air handling unit will be consisted of return fan section, return air and fresh air mixing section, filter section, cooling coil section, auxiliary electric heater section, muffler section and supply fan section etc.

The ventilation system for valve hall will be a closed cycle and the total air volume in the valve hall will be re-circulated through the main filters. Normally in favorite outdoor conditions the air in valve hall will be sucked to AHU, mixed with fresh air up to a maximum of 20% of the total air requirement, then cooled or heated, dehumidified or humidified, filtered and supplied back to the hall via air ducts by supply fan of AHU to maintain the specified conditions inside the valve hall. In hot days in summer, two redundant air cooled water chillers with 100% capacity per each, one operation and one standby, will be provided to supply chilled water (about 7°C) to cooling coil inside the air handling unit for cooling the circulated air.

Overpressure inside valve hall can be realized by adjusting the fresh air damper and exhaust air damper to make the fresh air volume exceed the exhaust air volume plus air leakage volume through valve hall enclosure.

The power for ventilation equipment for valve hall will be cut off by fire alarm signals to prevent the spreading of the fire in the case of fire.

Each valve hall will be served with smoke exhaust fans for smoke evacuation after the fire has been distinguished, if fire occurs inside the hall.

Water chillers and air handling units will be located on the ground outside the valve hall.

(3) Ventilation and Air Conditioning for Control Building

Central air conditioning systems will be provided for control building of which the main equipment will be 2x100% air-cooled water chillers and 2x100% air handling units, one of each equipment will be in operation and another standby.

The air cooled water chiller will produce chilled water in summer and hot water in winter to cooling coil inside AHU, AHU will supply cooled or heated, de-humidified, filtered air via air ducts to the rooms needing air conditioning, and return air will be drafted back to AHU for re-treatment.

Valve cooling equipment room and ventilation plant room will be provided with mechanical exhaust system by axial fans for normal ventilation, the air changes per hour will not be less than 5 times.

Axial fans will be equipped for 400V distribution room for emergency ventilation and air changes per hour will be larger than 12 times per hour.

Battery room will be provided with a mechanical ventilation system by explosion proof & anti-corrosive axial fan to exhaust hydrogen and acid gases to the outside. The air changes will not be less than 3 times per hour.

Toilet will be provided with mechanical exhaust by ceiling type ventilator with air changes per hour not less than 6 times.

If fire occurs at control building, the related ventilation and air conditioning equipment will trip by fire alarm signals to prevent the spreading of the fire.

(4) Ventilation and Air Conditioning for Relay Room

Air cooled split air conditioners will be provided for relay room and battery room to maintain the indoor temperature and relative humidity required for normal operation of electrical panels and battery.

The air conditioner for battery room will be of explosion proof type.

One redundant air conditioner will be provided above the quantity required to achieve the operating indoor environment for rated power.

Battery room will be provided with a mechanical ventilation system by explosion proof & anti-corrosive axial fan to exhaust hydrogen and acid gases to the outside. The air changes will not be less than 3 times per hour.

Axial fans will also be provided for relay room for ventilation during installation and maintenance.

The power for ventilation and air conditioning equipment will be cut off automatically by fire alarm signals to prevent the spreading of the fire in the case of fire.

(5) Ventilation and Air Conditioning for 11kV Power Distribution Room

Normal and emergency ventilation by axial fans will be provided for 11kV power distribution room and the air changes will be larger than 12 times per hour.

In addition to the ventilation system mentioned above, air cooled split air conditioners will also be provided to maintain the indoor temperature not higher than 35℃ to ensure the normal operation of the electrical equipment during hot days in summer.

The air conditioners and fans will be powered off automatically in the fire circumstance.

(6) Ventilation and Air Conditioning for Common 400V Power Distribution Room

Normal and emergency ventilation by axial fans will be provided for common 400V power distribution room and the air changes will be larger than 12 times per hour.

In addition to the ventilation system mentioned above, air cooled split air conditioners will also be provided to maintain the indoor temperature not higher than 35℃ to ensure the normal operation of the electrical equipment during hot days in summer.

The air conditioners and fans will be powered off automatically in the fire circumstance.

(7) Ventilation and Air Conditioning for Office Builing and Dormitory

Air cooled split air conditioners will be provided for office, rest room, canteen and meeting room to maintain the indoor temperature for personal comfort.

Normal and emergency ventilation by axial fans will be provided for power distribution room and the air changes will be larger than 12 times per hour.

In addition to the ventilation system mentioned above, air cooled split air conditioners will also be provided for distribution room to maintain the indoor temperature not higher than 35℃ to ensure the normal operation of the electrical equipment during hot days in summer.

Each toilet will be served with a toilet ventilator for air changes.

(8) Ventilation for Comprehensive Pump House

A natural inlet and mechanical exhaust ventilation system will be provided for pump house, in which wall-mounted axial fans will be used as exhaust equipment.

(9) Ventilation and Air Conditioning for Guard House

Air cooled split air conditioners will be provided for duty room, bedroom to maintain the indoor temperature at required level. The toilet will be served with a toilet ventilator and the air changes will not be less than 6 times per hour.

5.11 Fire protection

The main protection object of fire protection system in this engineering shall be such buildings as the master control building and valve hall, comprehensive building and overhaul spare articles warehouse, etc., as well as the oil-bearing equipments such as converter transformer, etc.

The fire protection system includes fire water system (which is divided into indoor and outdoor fire hydrant extinguishing system and water spray extinguishing system) and mobile fire extinguisher configuration, etc. Among them, indoor and outdoor fire hydrant shall mainly be adopted for fire protection of building, and it shall be configured with certain quantity of mobile fire extinguishers at the same time. Water spray extinguishing system shall mainly be adopted for the converter transformer, and it shall be configured with certain quantity of mobile fire extinguishers at the same time.

Independent temporary high-pressure fire protection water supply system shall be adopted for the fire water system, and it shall be composed of one 400m^3 fire-water pond, fire service pump, constant-pressure pump, surge tank and fire protection water supply pipe network with fire water facilities (fire hydrant and deluge valve), etc. The 400-500m^3 fire-water pond and productive water tank shall be jointly constructed, and there shall be protective measure for not using the fire water for other purpose.

The fire protection water supply pipe network shall be circularly arranged around the master control building and valve hall, comprehensive building as well as converter transformer, and the interval for arrangement of outdoor fire hydrant shall not be greater than 120m.

There shall be one set of water spray extinguishing system for each set of converter transformer, including deluge valve unit, signal butterfly valve, discharge nozzle and pipe, etc.

NATIONAL TRANSMISSION & DESPATCH
COMPANY (NTDC) LIMITED PAKISTAN

FEASIBILITY STUDY

FOR

±660kVHVDC PROJECT

FROM MATIARI TO LAHORE IN PAKISTAN

VOLUME Ⅳ

HVDC TRANSMISSION LINE

PAK MATIARI-LAHORE TRANSMISSION COMPANY(PRIVATE) LIMITED.

January 2017,Beijing, P.R. China

±660kV HVDC PROJECT

FROM MATIARI TO LAHORE IN PAKISTAN

GENERAL LIST OF CONTENTS

TECHNICAL DEFINITIONS

The following technical definitions apply tothis Specification:

Purchaser	National Transmission And Despatch Company Limited (NTDC)
Company	The project company for development, investment, construction, operation and maintenance of the ±660kV HVDC project from Matiari to Lahore in Pakistan.
HVDC System	All of the relevant equipment and systems in bipolar operation, including converter transformers, convertor valves, DC yard equipment, AC filter, control& protection system, DC transmission line, electrode and electrode line, etc.
HVDC Project	HVDC System and the relevant construction works in this project. the relevant construction works including outlet and inlet line of converter station, buildings and structures, related auxiliary production facilities and living facilities.
M-L T/L	Matiari-Lahore Transmission Line
AC yard	AC switchgear area in converter station
DC yard	DC switchgear area in converter station
Life yard	Living facilities and part of auxiliary production facilities area in converter station
T area	Transformer area
M-E T/L	Matiari Electrode Grouding Transmission Line
M E/G	Matiari Electrode Grouding
L-E T/L	Lahore Electrode Grouding Transmission Line
L E/G	Lahore Electrode Grouding
M C/S	Matiari Converter Station
L C/S	Lahore Converter Station
M AC busbar	Matiari AC busbar
L AC busbar	Lahore AC busbar
M AC system	Matiari AC system

L AC system	Lahore AC system
P I	Pole I
P II	Pole II

The following abbreviations apply to this Specification:

AC	Alternating Current
ACI	American Concrete Institute
A/D	Analog to Digital
AN	Audible Noise
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing Material
BIL	Basic Impulse Insulation Level
BS	British Standard
BSL	Basic Switching Impulse Insulation Level
CB	Control Building
CCITT	International Consultative Committee on Telephone and Telegraph Systems
CT	Current Transformer
CTV	Capacitive Voltage Transformer
D/A	Digital to Analog
DC	Direct Current
DIN	Deutsches Institute fur Normung
EEI	Edison Electric Institute
EIA	Environmental Impact Assessment
ESCR	Effective Short Circuit Ratio
ESDD	Equivalent Salt Deposit Density
FAT	Factory Acceptance Tests
HF	High Frequency
HVDC	High Voltage Direct Current

IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
I/O	Input/Output
ISO	International Standards Organization
LED	Light Emitting Diode
MMI	Man Machine Interface
MVU	Multiple Valve Unit
NFPA	National Fire Protection Association
OPGW	Optical Fiber Composite Overhead GroundWire
P&C	Protection and Control
PLC	Power-line Carrier
PT	Potential Transformer
RF	Radio Frequency
RI	Radio Interference
RIV	Radio Interference Voltage
RTU	Remote Terminal Unit
RPC	Reactive Power Controls
SCADA	Supervisory Control and Data Acquisition
SER	Sequence of Events Recorder
SLG	Single Line to Ground Fault
SMC	Station Master Clock
SPC	Software Production Control
SWC	Surge Withstand Capability
TFR	Transient Fault Recorder
UPS	Uninterruptible Power Supply
VDT	Video Display Terminal
VDU	Video Display Unit
VF	Voice Frequency
VT	Voltage Transformer

VOLUME Ⅳ CONTENTS

1 Project Overview

1.1 General

The Matiari-Lahore ± 660kV HVDC transmission line starts at Matiari converter station about 38km northeast to Hyderabad and ends at Lahore converter station approximately 40km southwest of Lahore. The line goes from southwest to northeast and crosses Sindh and Punjab, measuring 810km in aviation line. The length determined at feasibility study stage (the recommended route) is 878km, with a buckling factor of 1.08. The altitude ranges from 20 to 200m along the line.

The line corridor is mainly flat terrain, including flat ground of 342km (38.9%), and desert of 496km (56.5%), swamp of 40km(4.6%). The highest temperature is 52.5°C, the lowest temperature -5°C, the 3-sec gust wind speed at 10m above ground is 160km/h(44.44m/s), the corresponding 10-minute average wind speed at 10 meters above ground is 31.1m/s.The corridor goes through ice-free areas.

According to the feasibility study, the following are recommended: conductor uses 4×JL1/G3A-1250/70 and 4×JL1/LHA1-800/550;both2 shield wires use 24-fiber OPGW-120;towers use lattice steel self-supported type (1977 towers, 2.25 towers/km), including 257 tension towers (13%), 1720 suspension towers (87 %).

1.2 Main Design Basis

(1) LAVALIN feasibility study report provided by NTDC

(2) NTDC Draft Reply on Queries from CET - Gadani HVDC Transmission Project (Transmission Lines Part)

(3) "Minutes of meeting of Pakistan HVDC transmission project feasibility study" China Power Equipment Co., Ltd., July 14, 2014

(4) Minutes of Meeting Held on Dated 04.03.2015 In WAPADA House, Lahore HVDC Project (Spip)

(5) Minutes of Meetings for HVDC Transmission Line Project from Matiari to LahoreHeld on March16-25, 2015 at NTDCL Head Office Wapda House, Lahore, Meeting Minutes March 25, 2015

(6) Minutes of Meetings for HVDC Transmission Line Project from Matiari to LahoreHeld on May 20, 2015 at GM Planning (Power), PIA Building, Lahore, Meeting Minutes May 20, 2015

(7) May 4, 2015 NTDC's reply to route recommendation by our company, Preliminary Route alignment / coordination from MATIARI-LAHORE HVDC transmission line

(8) Evironmental Impanct Assessment（EIA）Report by NESPAK ,July 2015

(9) Technical Issue List for Discussion of TSA Technical Specification ,Volume Ⅳ HVDC Transmission Line on Oct 14,in WAPADA House

(10) General Critical Issues for TSA of 660kV HVDC BOOT Project (Matiari-Lahore), Oct 31, Islamabad

1.3 Standards and Specifications

According to the main design principles agreed with NTDC, the engineering, construction, operation and maintenance of the HVDC transmission project will be performed according to the IEC, IEEE or the Chinese Standards for the DC portion of the HVDC Transmission Project. The following standards and specifications will be used at the current stage:

(1) Electrical design and material standards and specifications

DL 5497-2015:Technical code for design of HVDC overhead transmission line

IEEE 142-2007 Grounding of industrial and commercial power system

CIGRE 388 Impacts of HVDC Lines on the Economics of HVDC Projects

IEC 61089 Round wire concentric lay overhead electrical stranded conductors

IEC 60794-1-1,2001 Optical fibre cables-Part 1-1:general specification –general

IEC 61396 Electrical mechanical and physical requirements and test methods of Optical ground wire

IEC 61284 Overhead lines-requirements and tests for fittings

IEC 61325-1995 Ceramic or glass insulator units for d.c. systems- definitions,test methods and acceptance criteria

(2) Structural design and material standards and specifications

ASCE 74-2009:Guidelines for Electrical Transmission Line Structural Loading

IEC 60826:Design criteria of overhead transmission lines

ASCE 10-97 :Design of latticed steel transmission structures

ACI318:American concrete institutes

IEEE Std 691-2001:IEEE Guide for Transmission Structure Foundation Design and Testing

ASCE 74-2009:Guidelines for Electrical Transmission Line Structural Loading

IEC 60826: Design criteria of overhead transmission lines

ASCE 10-97 : Design of latticed steel transmission structures

GB/T 3098.1 :Mechanical Properties of Fasteners—Bolts, Screws and Studs,

GB/T 3098.2 :Mechanical Properties of Fasteners—Nuts-Coarse Thread

GB/T 5117 :Covered Electrodes for Manual Metal Arc Welding of Non-alloy and FineGrain Steels

GB/T 5118 :Covered Electrodes for Manual Metal Arc Welding of Creep-resisting Steels.

GB 50661:Code for Welding of Steel Structures.

GB/T 1591 :High Strength Low Alloy Structural Steels

GB/T 700 :Carbon Structural Steel.

GB 50017 :Code for Design of Steel Structures .etc, and/or other approved standard.

GB 50010 :Code for Design of Concrete structures

GB1499.1:Steel for the reinforcement of concrete: Hot rolled plain bars

GB1499.2 :Steel for the reinforcement of concrete: Ribbed bars

JGJ 18 :Specification for welding and acceptance of reinforcing steel bars.etc, and/or other approved standard.

2 Route

2.1 Route plan

The TL project starts at Matiari converter station in Hyderabad, Sindh, and ends at Lahore converter station, Lahore, Punjab. The overall direction is from southwest to northeast, passing through the Sindh and Punjab provinces. The route length in the recommended plan is 878km. Figure2-1 shows the overview of line route.

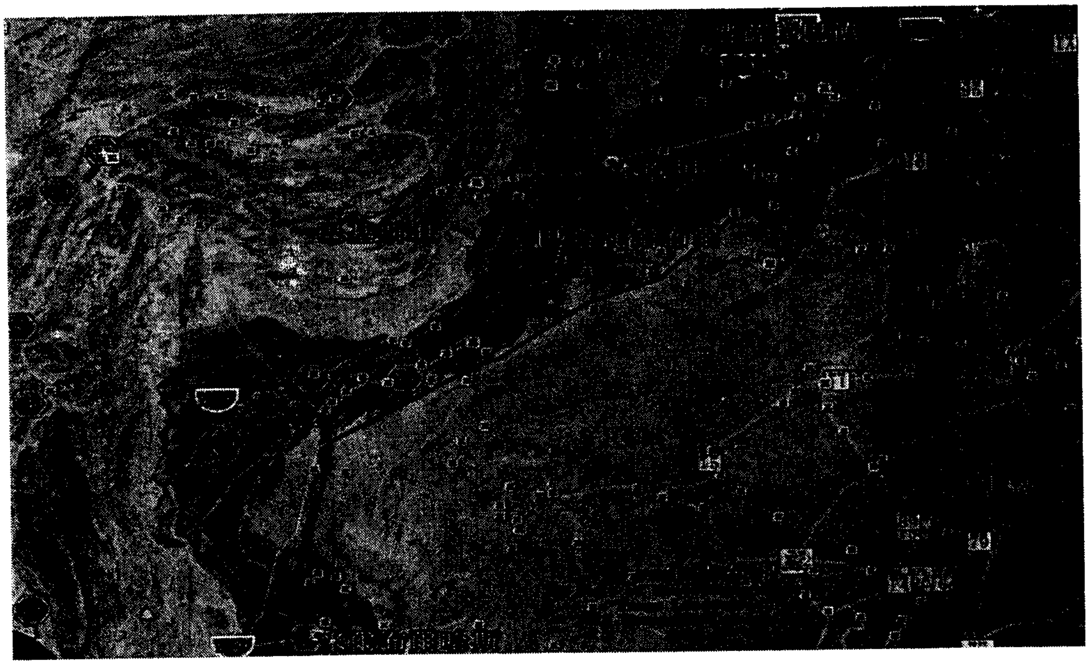


Figure2-1 HVDC Transmission Line Route

2.2 Engineering Geology and Hydro Geological Conditions

2.2.1 Regional Geology and Earthquake

Regional Geomorphology and Regional Geology Overview: According to the Pakistani geological map, the 60km west of line has north southward Kirthar fault, and 100km south of line has east western Naga Parga fault, the nearby place has no new active fault, satisfying the distance requirement.

Earthquake: This earth crust of proposed area is relatively stable, which is suitable for construction of converter station and transmission lines.

2.2.2 Geotechnical Engineering Condition and Assessment

2.2.2.1 Geotechnical Engineering Conditions of Northern Plains

2.2.2.1.1Topography

The line passes alluvial plain from Bhai phero of Lahore to Hasilpur, a total of about 240 kilometers. The terrain undulating is small with small dune distributed, elevation is about 140-200m, height difference is about 60m, the plain area is farmland.

2.2.2.1.2Lithology

According to this reconnaissance and reference from geotechnical engineering investigation report of Canada's SNC-LAVALIN, the liner formation is as follows:

Clay fine sand soil: variegated, saturated - dry, loose - dense.

Fine sand: variegated, mainly saturated, loose - dense.

Clay: black, yellow, etc., wet - little wet, fabricable - hard fabricable state based.

Silt: variegated, mainly saturated, usually little dense –middle solid.

2.2.2.1.3Hydro Geological Conditions

Groundwater of this section is quaternary phreatic or perched water with partial load bearing capacity; the burial depth of water (or load bearing water head) is about 2.00m-12.00m, annual change amplitude of groundwater level is 1.00m - 2.50m.

2.2.2.1.4Adverse Geological Processes.

There is no landslide, avalanches, landslides, ground collapse or other adverse geological process.

2.2.2.1.5Minerals and Artifacts.

There is no mineral reserve, overlaid historical relics or monuments.

2.2.2.2 Geotechnical Engineering Conditions of Desert Section

(1) Topography

This line section passes desert, covering from Hasilpur city to Sanghar city, and a total of about 600 kilometers. The liner terrain is relatively flat with sparse vegetation or no vegetation, elevation is about 40-140m, height is about 100m.

(2) Lithology

According to this reconnaissance up capital, and with reference to Canada's SNC-LAVALIN geotechnical survey report, formations along the line as follows:

Fine sand: yellow, pale yellow, dry - slightly wet, loose - dense.

Silt: pale yellow, slightly wet, loose – dense.

(3) Hydro geological conditions

This section has no groundwater impacting tower foundation.

(4) Adverse geological process

There is no landslide, avalanches, landslides, ground collapse or other adverse geological process.

(5) Mineral heritage

There is no mineral reserve, overlaid historical relics or monuments.

2.2.2.3 Geotechnical Engineering Conditions of Southern Plain

(1) Topography

The route covers from Sanghar City to Matiari converter station of Hyderabad City, a total of about 90 km. Liner terrain is with small undulating, about 24-40m of elevation, 16m of differential height. The land is mainly arable land for wheat and other crops growing.

(2) Lithology

According to this reconnaissance up capital, and with reference to Canada's SNC-LAVALIN geotechnical survey report, formations along the line as follows:

Silt, gray, grey yellow, saturated - dry, slightly dense - dense

Fine sand: gray, grey yellow, saturated - dry, loose - dense.

Clay: dark gray, gray, wet - slightly wet, soft fabricable - hard fabricable.

(3) Hydro geological conditions

Groundwater of this section is quaternary phreatic or perched water with partial load bearing capacity; the burial depth of water (or load bearing water head) is about 1.00m-8.00m, annual change amplitude of groundwater level is 1.00m – 3.00m.

(4) Adverse geological processes.

There is no landslide, avalanches, landslides, ground collapse or other adverse geological process.

(5) Mineral artifacts.

There is no mineral reserve, overlaid historical relics or monuments.

2.3 Hydrological Condition along the Line

2.3.1 Nara Canal

Nara Canal is an important waterway in Sindh province, Pakistan. It is formed by excavation of excising river course of Nara River. As the longest canal in Pakistan, it origins at Sukkur Barrage in the north of Rohri, flows southward via Khairpur, Sanghar and Tharparkar to Jamrao Canal, and finally joins the old river course of India River, through which it continuously flows southward and joins the ocean via Kutch swamp. Nara Canal is 364km long, with the design water volume 385.2m^3/s and the actual water amount 400.5m^3/s, covering an irrigated area of 8,100km^2.

The line strides across a tributary of Nara Canal in the north of Sanghar. The terrain of crossing segment area is flat, and the river course is winding. There are a lot of reeds around the river course, forming many pondings. According to the field investigation, the historical maximum flood in the crossing segment area took place in the summer of 1992, with the submerged depth ranged in 1.5-2.0m and the duration exceeding one month. The crossing segment area is easily subject to waterlogging after rainstorms in summer, when the submerged depth can reach over 0.5m and the submerged duration may last for one month. It's suggested to further assess the impact of flood in the next stage based on the placement of tower position.

2.3.2 Sutlej River

Sutlej River is one of the main tributaries of Indus River. It starts from Lake Rakshastal in the territory of China, where it is named as Xiangquan River. It flows westward via Himachal province of India, enters the territory of Pakistan in the northeast of Kasur in Punjab Province, then keeping basically parallel to Ravi River, flows southwest and connects to Chenab River, and finally joins Indus River. It is approximately 1450km long and covering a catchment area about 39.5$\times$104km^2.

At approximately 0.5km upstream of Arifwala-Sahiwal Rd Bridge, the line strides across Sutlej River. The crossing segment is a wandering reach, where the cross section is wide and shallow, the height difference of swale is small, shoals are densely covered and branches are intertwined, so that water flows are scattered and the main stream is swinging and unstable. According to the flood data provided by NTDC, the area belongs to a flood prone area, where the maximum submerged depth is ranged in 18-23ft, and the submerged duration may last for one month. It's suggested to further assess the impact of flood in the next stage based on the placement of tower position.

There is a 132kV line built at approximately 300m upstream of Arifwala-Sahiwal Rd Bridge, and the base is heightened by about 3m.

2.3.3 Ravi River

Ravi River is one of the main tributaries of Indus River. It starts from Himalaya Mountains of Chamba District, Himachal Province, India. As a transboundary river between India and Pakistan, it flows through the northwest of India and the east of Pakistan. Ravi River enters the territory of Pakistan in the northeast of Punjab province, flows southwestward via Lahore, Kasur, Okara, Sahiwal and Khanewaletc., connects to Chenab River and finally joins Indus River. It is approximately 725km long and covering a catchment area about 11,600km^2.

The line strands across Ravi River at approximately 2km downstream of Balloki Barrage. In the crossing segment, the river course is winding, the river surface is wide and shallow, there are a lot of river branches, and it is a mobile bed stream. According to the data on the historical maximum flood level of Balloki Barrage, the 100-year flood level for the crossing segment of the line is predicted to be about 194.2m. It's suggested to further assess the impact of flood in the next stage based on the placement of tower position.

There is a 500kV line built at approximately 300m downstream of Balloki Barrage, and the base is heightened by about 3m.

3 Meteorological

The main meteorological elements in the project is shown as below in the following table.

Table 3-1 main meteorological elements

Meteorological element	Temperature (°C)	Wind Speed (m/s)	Ice Thickness (mm)
Minimum temperature	-5	0	0
Annual average temperature	25	0	0
Maximum wind speed	15	44.44(31.1)	0
Icing conditions	/	/	/
Maximum temperature	52.5	0	0
Failure	-1.1	0	0
Thunderstorm Days	32/year		

Note: The reference wind speed is the 3-sec gust wind speed at 10m above ground, the corresponding 10-min average wind speed at 10 meters above ground is in the following bracket.

4 Selection of Conductor and Earth Wire

4.1 Selection of Conductor

4.1.1 Principles for Selection of Conductor

According to the characteristics of DC transmission line, as selecting conductors, comprehensive consideration shall be given to the following factors in term of electrical characteristics, mechanical properties and economic efficiency:

(1) Current density;

(2) Current carrying capacity;

(3) Radio interference level (RI);

(4) Corona audible noise (AN);

(5) Electric power losses

(6) Mechanical properties;

(7) Annual cost;

(8) Others (impacts on tower weight, insulators, fittings and foundation; and manufacturing and construction conditions, operational experience and so on).

4.1.2 Condition for Selection of Conductor

(1) Power system conditions

The power system boundary condition for selection of conductor is shown in Table 4.1-1.

Table 4.1-1 Powers System Boundary Condition for Selection of Conductor

Operating voltage (kV)	±660
Transmission capacity (MW)	4000
Rated current (A)	3030
Overload current(A)	3333
Annual maximum load loss hours (hours)	6200
Electricity price ($)	$0.0838 (¥0.5)
Operation period (year)	30
Discount rate	10%

(2) Electromagnetic environmental requirements for selection of conductor

There are no relevant standards available in Pakistan, so China's standard DL 5497-2015:*Technical code for design of HVDC overhead transmission line* will apply, which specifies that:

For an area at an altitude of 1000m or below, the radio interference limit shall not exceed 58 dB (μV/m) at 20m from the projection at the ground of the positive polarity conductor of DC overhead transmission line, at 80% time, 80% confidence degree, and 0.5MHz frequency.

For an area at an altitude above 1000m, the audible noise limit (L50) caused by corona at 20m from the projection at the ground of the positive polarity conductor of DC overhead transmission line in a sunny day shall not exceed 45dB (A); in the case of the above sea level above 1000m and the line is passing through a non-residential area, it shall be controlled below 50dB (A).

4.1.3 Selection of Conductor

When selecting the type of Conductor, 13 schemes of conductor are compared. They are respectively:

4×JL/G3A-900/40,4×JL/G3A-1000/45,4×JL/G1A-1120/90,4×JL1/G3A-1250/70,4×JL1/G2A-1520/125;

6×JL/G1A-630/45,6×JL/G2A-720/50,6×JL/G1A-800/555,6×JL/G3A-900/40,6×JL/G3A-1000/45,6×JL/G1A-1120/90,6×JL1/G3A-1250/70,6×JL1/G2A-1520/125.

Taking current-carrying capacity, electromagnetic environment, mechanical properties, tower load, economical efficiency, conductor manufacture, stringing construction, operation, maintenance and various other factors into comprehensive consideration, and integrating the actual situation of natural conditions in the work, aluminum conductor steel reinforced 4×JL1/G3A—1250/70 is the optimal scheme for this HVDC line project. The sub-conductor is square arrangement with the spacing of 500mm.Pole spacing for 4×JL1/G3A—1250/70 will be 17m.

Considering the Matiari converter station is about 170km north to the coastline, and the HVDC goes north to Lahore which will be further away from the coastline, aluminum alloy-core aluminum stranded conductor will used for about 214km from Matiari converter station

Refer to Table 4.1-2 for the technical parameters of conductors.

Table 4.1-2 Technical parameters of conductors

Item \ Conductor type		JL1/G3A—1250/70	JL1/LHA1-800/550-54/37
Structural strands/diameter, mm	Outer layers	Aluminum 76/4.58	High Conductivity Aluminum 54/4.35
	Core	Steel 7/3.57	Aluminum Alloy37/4.35
Cross section, mm^2	Outer layers	Aluminum 1252.09	High Conductivity Aluminum802.53
	Core	Steel 70.07	Aluminum Alloy 549.88
	Total	Total cross section 1322.16	Total cross section 1352.41

Item \ Conductor type	JL1/G3A－1250/70	JL1/LHA1-800/550-54/37
Diameter, mm	47.35	47.85
Elastic modulus, N/mm^2	62200	55000
Coefficient of thermal expansion, 1/°C×10-6	21.1	23.00
Calculated weight, kg/km	4011.1	3744.5
Calculated tensile strength, kN	294.23	292.96
DC resistance of conductor at 20°C (Ω/km)	0.02291	0.02260

4.2 Selection of Earth Wire

The earth wires use 2 OPGW cables by the requirement of communication. The cross-section of OPGW for this project shall apply 120mm^2, and the diameter shall be about 14mm. In this stage the provisionally applied OPGW model is OPGW-15-120-2 (24-fiber), for which the main technical parameters are given in the below table.

Table 4.2-3 Summary of OPGW parameters in the project

Item	OPGW-15-120-2
Calculated sectional area (mm^2)	121.1
Calculated outside diameter (mm)	15.2
Calculated weight (kg/m)	0.711
Calculated tensile strength (N)	101300
Elastic modulus (N/mm^2)	132000
Coefficient of thermal expansion(1/°C)	13.8×10^{-6}
Breaking stress (N/ mm^2)	836.00

4.3 Safety factor for Conductor and Earth Wire

The safety factor of conductor and earth wire should be no less than 2.5.The everyday tension of conductor and earth wire should be not more than 25%. The sag of earth wire should be not more than the sag of conductor.

4.4 Anti-Vibration solutions for Conductor and Earth Wire

4.4.1 Vibration Dampers for Conductor

Refer to Table 4.3-1 for the installed quantity of vibration dampers for conductors.

Table 4.3-1 Installed quantity of vibration dampers on conductor

Span range (m)	Installed Quantity (pieces) (one sub-conductor, one side)
500m and below	0
500-800	1

800-1200	2
1200-1500	3

4.4.2 Spacers for Conductor

It's proposed in the project to apply four-bundle conductor, arranged as a normal quadrilateral, with a sub-conductor spacing of 500mm. Space dampers for four-bundle conductor are recommended for the project. The space damper shall be installed un-equidistantly. The average sub-span is 55m.

5 Insulation Coordination

5.1 Pollution

According to the investigations made on the insulation configuration of existing lines along the line to be built in the project, on the basis of the analysis on the general situation with respect to meteorology, environment and pollution of the areas that the line corridor pass-through, and as well as our operational experience in electric power system, the length of segments partitioned on the basis of pollution area throughout the line and the salt deposit density are recommended in Table 5.1-1.

Table 5.1-1 Partition of pollution area throughout the line

Pollution area	Equivalent salt deposit density (mg/cm^2)	Non soluble deposit density (mg/cm^2)	Length of line segment (km)
Light pollution area	0.05	0.30	0
Medium pollution area	0.08	0.48	221
Heavy pollution area	0.15	0.90	657

5.2 Type and Parameter of Insulator

Synthetic insulator can be adopted for suspension string, and porcelain insulator for tension string in the project.

Outside dimensions and technical parameters of DC porcelain insulators shall be selected as per Table 5.2-1.

Table 5.2-1 Outside dimensions and technical parameters of DC porcelain insulator

Insulator Model	Ratedelectro mechanical failure load kN	Structural height mm	Nominal diameter of insulator mm	Creepage distance mm	Flashover voltage kV				Ball&Socket Size	Single insulator weight kg
					DC flashover voltage		50% lightning impulse flashover voltage			
					Dry	Wet	Positive polarity	Negative polarity		
XZP-420	420	205	400	650	150	60	150	160	28	24.0
XZP-210	210	170	320	545	140	55	140	150	20	13.6

5.3 Number of Disk Insulator and Length of Synthetic Insulator

Refer to Table 5.3-1 and Table 5.3-2 for the selected number of disk insulators and the length of synthetic insulator for this project.

Table 5.3-1 Insulation Configuration of Tension Insulator String

Pollution area	**Light pollution area ($0.05mg/cm^2$)**	**Medium pollution area ($0.08mg/cm^2$)**	**Heavy pollution area ($0.15mg/cm^2$)**
Number of Insulators	56	73	81

Table 5.3-2 Insulation Configuration of Synthetic Insulator

Pollution area	**Light pollution area ($0.05mg/cm^2$)**	**Medium pollution area ($0.08mg/cm^2$)**	**Heavy pollution area ($0.15mg/cm^2$)**
Length of synthetic insulator string (m) /Creepage distance (m)	8.5/33.4	8.5/33.4	9.2/38.4

5.4 Clearance

Refer to Table 5.4-1 for the clearance of tower recommended for the project.

Table 5.4-1 Clearance at tower head for ±660kVDC line (m)

Above sea level (m)	500
Operating voltage clearance(m)	1.70
Switching overvoltage clearance (m)	4.40

Note: The maximum switching overvoltage ratio throughout the line is provisionally taken as 1.82pu

6 Insulator String and Hardware

6.1 Value of Safety Factor

In reference to the stipulations in 6.0.1 of "Technical regulations on design of HVDC overhead transmission line", combined with the experience in construction and operation of Ningdong-Shandong ±660kV HVDC lines and other ±500kV HVDC lines, the safety factor adopted for the hardware in this project is shown in Table 6.1-1.

Table 6.1-1 List of safety factor for hardware

Condition	Maximum load	Maintenance	Line breakage	String breakage
Safety factor	2.5	1.5	1.5	1.5

The safety factor adopted for the insulator in this project is shown in Table 6.1-2.

Table6.1-2 Safety factor of insulator's mechanical strength

Condition	**Maximum working load**		**Normal load**	**Break**	**Disconnection**
	Disc insulator	**Rod insulator**			
Safety factor	2.7	3	4	1.8	1.5

6.2 Suspension String of Conductor

In general, it is recommended to use V type string for the suspension insulator string in this project. Refer to the following drawing for the pattern of arrangement.

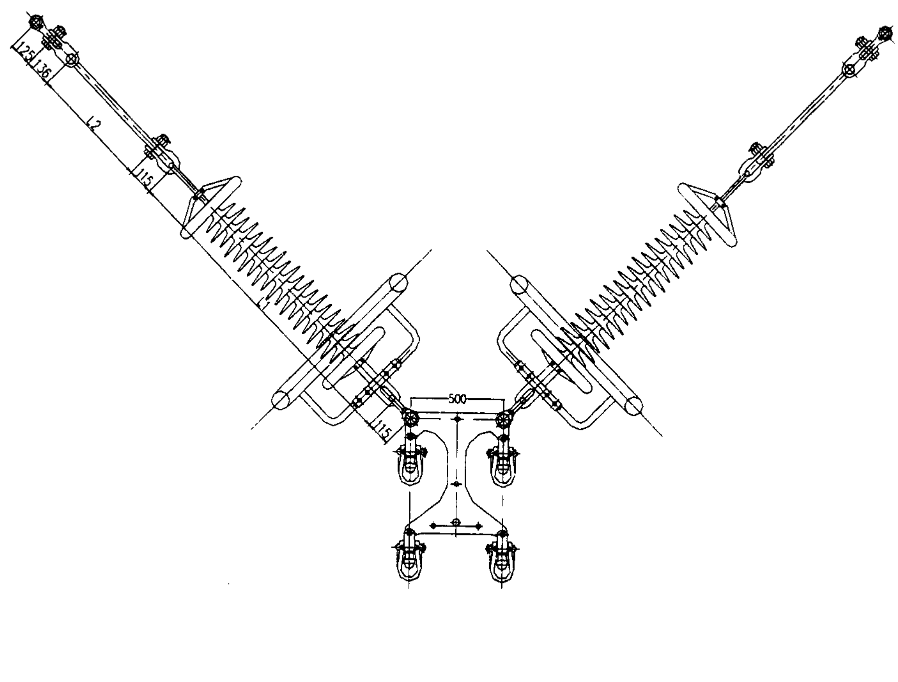


Figure 6.2-1(a) Schematic diagram for arrangement of V type single string

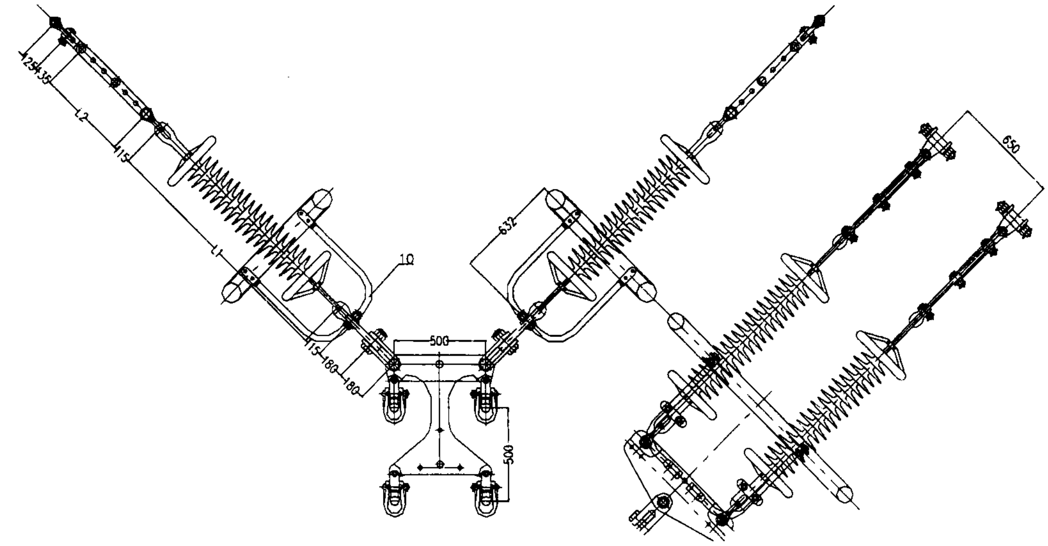


Figure 6.2-1(b) Schematic diagram for arrangement of V type double string

The conductor suspension string adopted in this project is shown in the following table through calculation:

Table 6.2-1 Main hardware string of conductor

Name	Applicable circumstance
300kN composite insulator single string V type suspension string	Ordinary load
420kN composite insulator single string V type suspension string	Relatively high load
300kN composite insulator double string V type suspension string	Important crossing

6.3 Strain String of Conductor

Triple-string 420kN disc type insulator string can be selected for strain string at ordinary segment through calculation, and double string 210kN disc type insulator string shall be adopted for the slack span of tower into gantry. Refer to the following diagram for the schematic diagram of triple-string 420kN disc type insulator string.

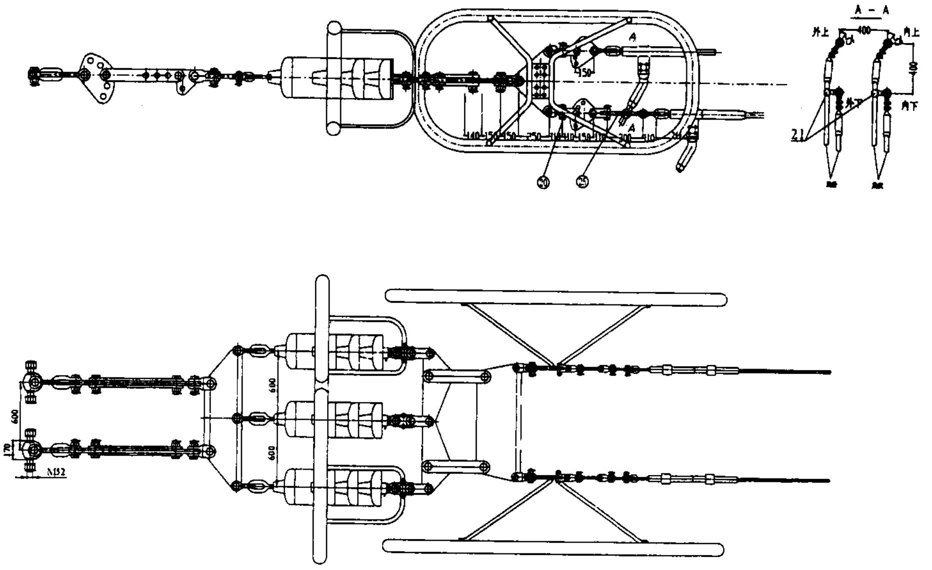


Figure 6.3-1 Schematic diagram for triple-string strain 420kN disc type insulator string

Refer to the following diagram for the schematic diagram of double string 210kN disc type insulator string.

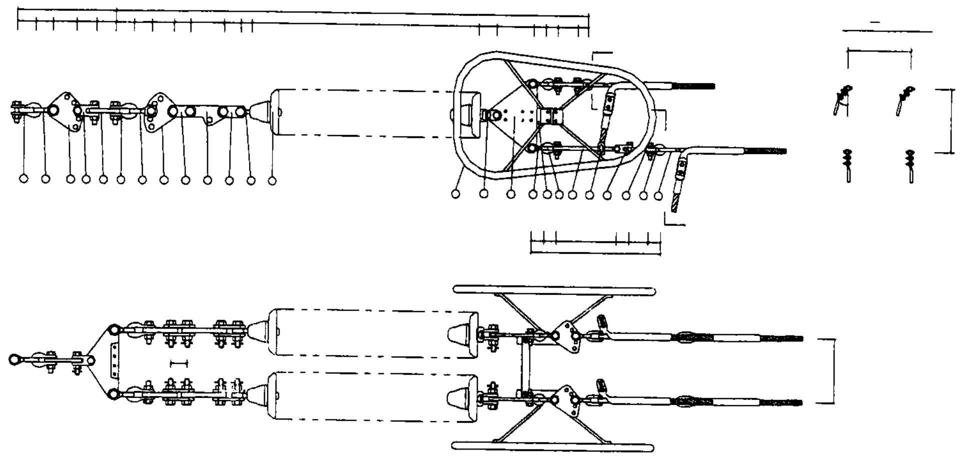


Figure 6.3-2 Schematic diagram for double string 210kN disc type strain insulator string

6.4 Jumper String

Double string V type string cage type hard jumper of 160kN composite insulator shall be adopted for the whole line. According to the structural arrangement and clearance analysis, the included angle of V type string shall not be less than 85°. Refer to the following diagram for the arrangement of cage type hard jumper.

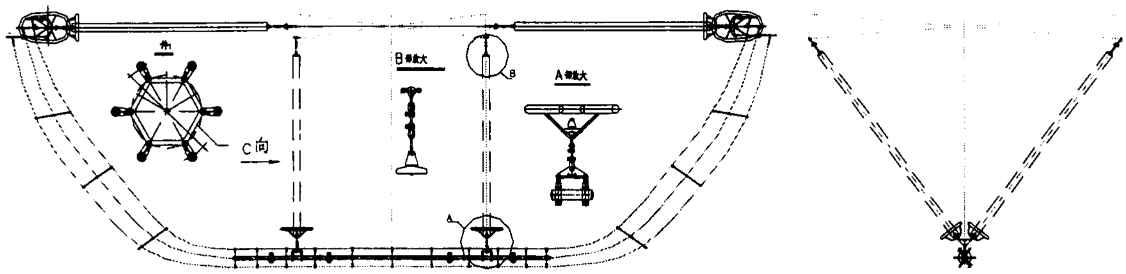


Figure 6.4-1 Schematic diagram for the arrangement mode of cage type hard jumper

6.5 Earth Wire String

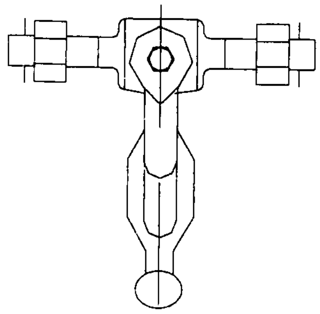
Single string 120kN hardware string shall be adopted for earth wire suspension hardware string and strain hardware string, and the whole line shall be reliably grounded.

6.6 Main Fittings

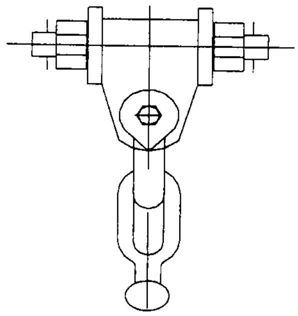
The main fitting sin the line shall include tower connecting fittings, suspension wire clip, split yoke plate, spacer and grading ring, etc.

6.6.1 Tower Connecting Fittings

For simplifying the design of suspension point and facilitating construction, it is recommended to adopt GD suspension plate for the hardware at suspension point of strain string, and adopt EB suspension plate for the hardware at suspension point of suspension string. The diameter of screw shall no longer been changed, and only the aperture and thickness of connection between suspension plate and hardware shall be adjusted. The connection between GD suspension plate, EB suspension plate and other hardware is shown in the following diagram.



(a) Connection mode of GD suspension plate

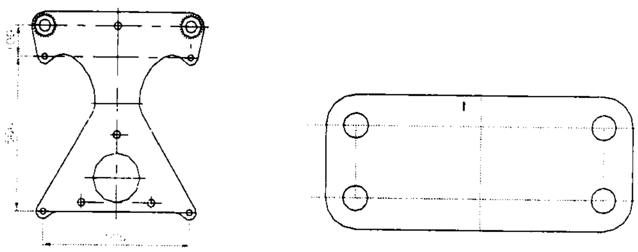


(b) Connection of EB suspension plate

Figure 6.6-1 GD suspension plate and EB suspension plate

6.6.2 Yoke Plate

It is recommended to adopt integral yoke plate for the suspension yoke plate and strain yoke plate in this project, as shown in the following diagram.

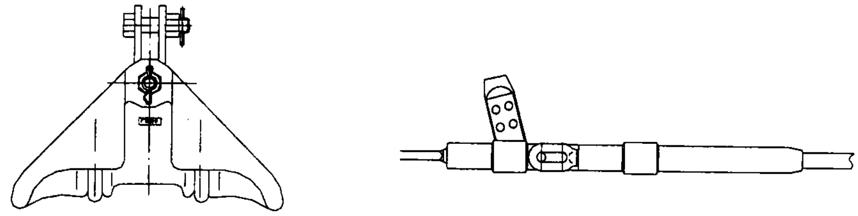


(a) Suspension yoke plate (b) Strain yoke plate

Figure 6.6-2 Yoke plate

6.6.3 Wire Clip

It is recommended to adopt handbag type corona shielding suspension wire clip for the conductor suspension wire clip in this project, and it is recommended to adopt hydraulic type for the conductor strain wire clip as shown in the following diagram.



(a)Handbag type suspension wire clip (b) Hydraulic type strain wire clip

Figure 6.6-3 Wire clip

6.6.4 Grading Ring and Shielding Ring

For suspension ring and strain ring, the installation position of grading ring shall be between the second piece and the third piece of insulator, the grading effect is relatively good, 100mm annular pipe shall be adopted for both grading ring and shielding ring, and the radius of ring shall be 500mm.

7 Distance to Ground and ROW

Value for the distance to ground and overhead crossing of ±660kV HVDC transmission line shall be taken temporarily by relevant requirements in chapter 13 of *DL 5497-2015:Technical code for design of HVDC overhead transmission line* and the experience in design of Ningdong-Shandong ±660kV HVDC project.

For residential areas, the synthetic field intensity shall be limited at 30kV/m in rainy days and 25kV/m in sunny days; and the ion flow density shall be limited at 100nA/m^2 in rainy days and 80nA/m^2 in sunny days.

For non-residential areas, the synthetic field intensity shall be limited at 36kV/m in rainy days and 30kV/m in sunny days; and the ion flow density shall be limited at 150nA/m^2 in rainy days and 100nA/m^2 in sunny days.

7.1 Distance to Ground

The distance to ground of this project is shown in the following table.

Table 7.1-1 Distance to ground of ±660kV HVDC line

Place	**Vertical distance (m)**	**Clear distance (m)**	**Horizontal distance (m)**
Agricultural area	16		
Non-agricultural area	14		
Difficult transport area	13.5		
Hillsides accessible on foot		11	
Hillsides, cliffs and rocks inaccessible on foot		8.5	
Building (maximum designed sag)	14.0		
Building(maximum designed wind deflection)		13.5	
Building(Conductor at opposite side under circumstance of no wind)			6.5
Tree (fruit tree)	10.5(12.0)	10.5	

Note: The calculation condition for distance to ground is the sag at +75℃.

7.2 Distance of Overhead Crossing

The distance of overhead crossing to the object of crossing in this project is shown in the following table.

Table 7.2-1 Distance of crossings

No.	Name of object of crossing		Minimum distance (m)	Calculation condition
1	Railway	To the rail top	18	The sag at +75℃
		To the catenary or line of contact (pole top)	8(10.5)	The sag at +75℃
2	Road	Grade 1—3	18	The sag at +75℃
3	Non navigable river	To once-in-a-century water level	10	The sag at+75℃
4	Power line	Within length of span	8	The sag at+75℃
		Pole top	10.5	The sag at+75℃
5	Communication line		14	The sag at+75℃
6	Special pipe		14	The sag at+75℃
7	Cableway		8	The sag at+75℃

Table 7.2-2 Minimum horizontal distance

Item				Minimum horizontal distance (m)
Railway	Tower boundary to track center		Crossing	35 m, or determined through negotiation
			Parallel	tower height plus 3.1 m,
Road	Crossing	Tower boundary to track center		15.0 or determined through negotiation
	Parallel	Track boundary to subgrade boundary	Open area	tower height
			Route restricted area	10.5 or determined through negotiation
Navigable River	Side phase conductor to upper limb of slop (lines in parallel with guying road)			tower height
Non-Navigable River				
Telecommunication Line	To side pole conductor（Parallel）		tower height	tower height
			Route restricted area under the maximum wind deflection)	11
Power Line	To side pole conductor（Parallel）		Open area	tower height
			Route restricted area	13 m to closest conductor and 8.5 to tower(under the maximum wind deflection)
Special	To any part		Open area	tower height

Pipeline&Cableway		Route restricted area under the maximum wind deflection)	13

7.3 Principle for Clearing of Corridor

When HVDC transmission line is adjacent to private house, the undistorted synthetic electric field on the ground surface in the location of private house under circumstance of wet conductor shall not exceed 15kV/m. The scope of house demolition in the line corridor shall be as follows in principle:

(1) It shall be demolished without exception when it is located at and within 6.5m from the ground projection of side conductor.

(2) For houses outside 6.5m, the clear distance shall be guaranteed to be 13.5m at the time of maximum wind deflection, and they can be left unremoved when the synthetic electric field of house ground 6.5m outside the side conductor is less than the restricted value of 15kV/m, otherwise, the all houses within the line corridor shall be pulled down and removed.

Ordinary forest trees below the line corridor shall be removed in principle, and economic crops and fruit trees shall be overhead crossed.

8 Lightning Protection and Grounding

For design of grounding for lightning protection of transmission lines, it is proposed to mainly adopt the following measures:

(1) Dual earth wire shall be adopted for the whole line, and the protection angle of earth wire shall be not more than 0°.

(2) The distance between two earth wires on the tower shall not exceed 5 times the vertical distance between conductor and earth wire, so as to guarantee the joint protection effect of two earth wires.

(3) At the time of no wind at +15℃, the distance between conductor and earth wire at the center of span shall meet the stipulations in "Technical guide for HVDC overhead transmission line": $S \geqq 0.012L+1.5$ (S is the distance between conductor and earth wire, and L is length of span);

(4) The footing resistance of tower should be restricted as to table 8-1..

Table 8- 1 The limiting values of tower footing resistance

Area	agricultural district	desert	desert
earth resistivity ρ (Ω•m)	$0 < \rho \leq 1000$	$1000 < \rho \leq 2000$	$\rho > 2000$
limiting values of tower footing resistance R (Ω)	10	20	25

9 Tower family

Analysis shows that the most economical span for this project shall be 460m, since certain margin shall be taken into consideration for wind span at the time of actual locating, combined with the utilization rate of wind span for tower in the previous project, the service conditions for tower in this project are shown in Table 9-1. Lattice tower will be used in this project

Table 9-1 Tower family

Tower Type	Angle	Wind Span (m)	Weight Span (m)	Range of Nominal Height (m)	Basic Nominal Height (m)
ZP1	0°	480	600	36～54	45
ZP2	0°	580	750	48～78	69
ZPT	0°	480	600	36～51	51
JP1	0-20°	450	650	30～42	42
JP2	20-40°	450	650	30～42	42
JP3 Terminal Tower	0-60°	450	650	30～42	42

NOTE: considering the section of this HVDC project is relatively long, in order to limit the extent of the damage in a long section, an enhanced suspension tower ZPT will be used for every 3.5km within a constant section.

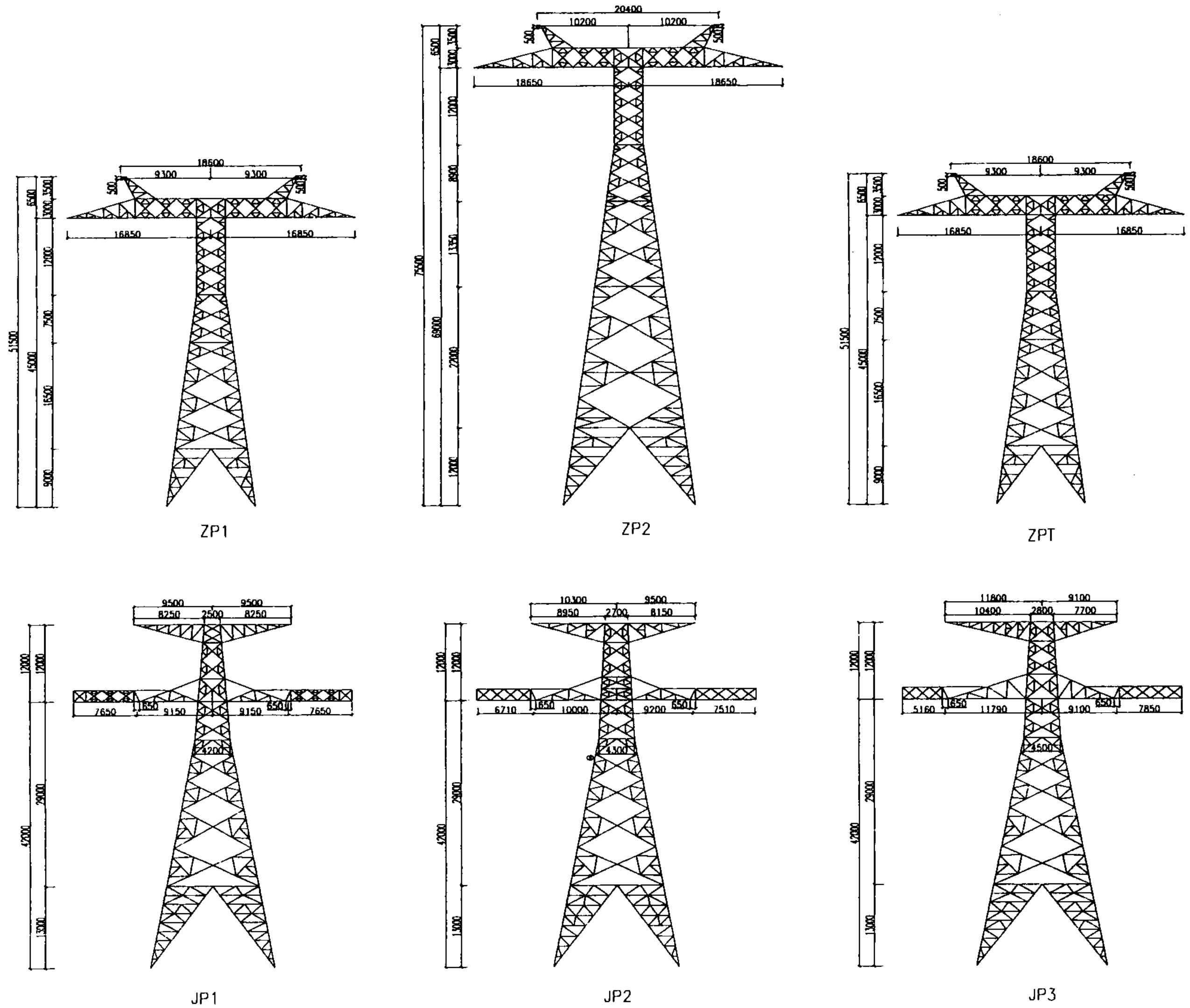


Figure 9 Outlines of tower

10 Tower and Foundation Design

10.1 Tower Design

10.1.1 Specifications, code and relevant design documents to be observed

The specifications, codes and relevant design documents to be observed during the design of the tower are as follows:

ASCE 74-2009-Guidelines for Electrical Transmission Line Structural Loading

IEC 60826 - Design criteria of overhead transmission lines

ASCE 10-97 - Design of latticed steel transmission structures

GB/T 3098.1 Mechanical Properties of Fasteners—Bolts, Screws and Studs,

GB/T 3098.2 Mechanical Properties of Fasteners—Nuts-Coarse Thread

GB/T 5117 Covered Electrodes for Manual Metal Arc Welding of Non-alloy and Fine

Grain Steels

GB/T 5118 Covered Electrodes for Manual Metal Arc Welding of Creep-resisting

Steels.

GB 50661Code for Welding of Steel Structures.

GB/T 1591 High Strength Low Alloy Structural Steels

GB/T 700Carbon Structural Steel.

GB 50017 Code for Design of Steel Structures

.etc, and/or other approved standard.

10.1.2 Calculation Model of Tower

The calculation analysis of tower is based on the finite element method and the 3D truss model according to the mechanics theory; PLS-TOWER software is used as the analysis software of tower in this project.

10.1.3 Wind Pressure in Basic Design

The designed basic wind velocity is determined as 160km/h (height 10m from the ground and time distance 3s) according to the technical data that have been collected. The corresponding earth wires, insulators and tower wind pressure are calculated as per the specification, and the wind load shape coefficients of conductor, earth wire and insulator are all 1.0.

10.1.4 Safety Factors

According to the existing project experiences, it is recommended to use the safety factors in the following table.

Description	Safety factor
Normal condition	1.7
Broken Wire condition	1.5
Installation condition	1.5

10.1.5 Load Conditions

According to the relevant provisions of ASCE74-2009, the load conditions and load combinations usually to be considered in the design are shown in the following table:

Operation condition name	Description of load condition
Normal Condition	Vertical Load: Dead weight of conductor, earth wire, insulator, hardware, tower,worker etc. Horizontal Load: wind pressure, angle tension, tower body wind velocity; Wind load direction: 90°, 45°
Failure Containment case	Structure failure load, e.g.broken wire load, etc.
Installation condition	Structure erection load; Stringing tension load; Worker load

10.1.6 Material for Tower

It is recommended to use China's supplies for the steel products of tower. Three categories of China's steel products in the following table shall be adopted while designing the tower at the current stage.

Steel products:

Mild steel: Q235B

High tensile steel: Q345B, Q420B

The characteristics of steel products are as follows:

Standard	Grade	Fy (Mpa) Yield Strength, Fy (Mpa)		Minimum Tensile Strength
		T<=16	t>16	Mpa
GB 700	Q235B	235	225	375
GB1591	Q345B	345	325	470
GB1591	Q420B	420	400	580

Bolts: Grade 6.8 in ISO 898

Yield point: $480N/mm^2$

Tensile strength: $600N/mm^2$

Bolts: Grade 8.8 in ISO 898

Yield point: $640N/mm^2$

Tensile strength: $800N/mm^2$

(1) The members of tower all use the hot-rolled equal-leg angle steels. The high-strength steel shall be selected according to the economic comparison. In general, it is not suitable to adopt the high-strength steel for the members whose slenderness ratio is greater than 80 or whose specification is less than 125×10 (excluding the tension member).

(2) When using the Q420 high-strength steel products, the drilling technology shall be used to make the holes. The drilling technology shall be used to make the holes when the thickness of Q345 and Q235 is equal to and greater than 14mm.

(3) Q235B and Q345B steel electrodes shall use E43 type and E50 type. The welding operation shall be avoided as far as possible for the Q420B high-strength steel.

(4) The connecting bolts shall use M16(Grade 6.8), M20(Grade 6.8) and M24 (Grade 8.8) common rough bolts.

10.1.7 Other Descriptions

(1) Anti-corrosion measures of tower

The hot-galvanized anti-corrosion measures shall be performed to all members of towers (including stub angle), bolts (including locking fastening nut and anti-theftbolts), gaskets and washers.

(2) Locking and antitheft measures

Antitheft bolts shall be used within the range of 10.0m over the ground of the shortest leg. The point of suspension connecting members all use the dual-cap bolts and the locking measures of one standard nut with one thin nut shall be taken for other bolts.

(3) Step bolts and others

The climbing step bolts shall be provided in the main members of tower, and they shall be mounted in a diagonal form. As for the tower with the full height of over 60m, the simple access platform shall be set up in appropriate position and the safety fence shall be set up at the periphery of the platform.

(4) Anti climbing device

The anti climbing device shall be set above the first septal surface using the barbed wire steel and set a doorlocking with bolts, nuts, fastening nut.

10.2 Foundation Design

10.2.1 Design Specifications

(1) American concrete institutes (ACI318)

(2) IEEE Guide for Transmission Structure Foundation Design and Testing (IEEE Std 691-2001)

(3) GB 50010 Code for Design of Concrete structures

(4) GB1499.1 Steel for the reinforcement of concrete：Hot rolled plain bars

(5) GB1499.2 Steel for the reinforcement of concrete：Ribbed bars

(6) JGJ 18 Specification for welding and acceptance of reinforcing steel bars

.etc, and/or other approved standard.

10.2.2 Selection of Foundation Types

Valleys and plains area: the drilled shaft foundation can be adopted in the locations distributed by plastic and hard-plastic clay if there is no underground water; the pad&chimney foundation can be adopted for the soft plastic clay according to the site conditions; the pile foundation can be adopted for the tower location that does not meet the requirement of natural foundation and the pile can use the borehole grouting piles; the pile foundation can be adopted in the locations distributed by silty sands if there exist the liquefied sandy soils and the pile can use the borehole grouting piles.

Desert Land: remove the surface floating sand in the dune area and use the middle compact silt and fine sand as the bearing stratum of the foundation. If there is no underground water, the drilled shaft foundation and pad&chimney foundation can be adopted without consideration of the liquefaction of silty sands. The pile foundation can be adopted for the tower location that does not meet the requirement of natural foundation and the pile can use the borehole grouting piles.

(1) Pad&chimney foundation

The main feature of this foundation is that the main column slope of the foundation is consistent with that of the tower leg. The result of this design enables the horizontal force perpendicular to the axial line of the foundation to be reduced for at least 50% and the axial action force of the foundation only increases by 1-2%. This result has significantly improved the force bearing situation of the foundation columns and base plates (slabs) to minimize the impact of the foundation horizontal force on the foundation slabs and improve significantly the stability of the foundation. Meanwhile, due to significant reduction of eccentric bending moment, the dimension of foundation slabs controlled by downward stability is correspondingly reduced so that the concrete quantity and slab reinforcement amount are reduced, which can greatly save the consumption of foundation materials. Foundation of this kind can be used in most of the locations in this project.

(2)Drilled shaft foundation

The drilled shaft foundation applies to the hard-plastic and plastic clay geological condition without underground water.

The application of the drilled shaft foundation has avoided the large excavation: on one hand, it has reduced the destruction to the environment; on the other hand, it has significantly enhanced the uplift-resisting ability of the foundation because the internal friction angle and cohesion of undisturbed soil has been brought into the full play due to the reduction of the disturbance for the undisturbed soils. The soil is used to replace the formwork and the reinforced framework and concrete of the foundation is directly grouted into the shaped soil structure to reduce the construction cost, which indicates the higher economic benefit and environment benefit.

(3) Pile foundation

In the area with flow-plastic geological condition, deeper foundation bearing stratum, flooding impact, higher diffuse water depth and river-crossing area, etc., the method of borehole grouting piles for the foundation is a kind of widely applied method in the design. The friction force with the surrounding soil and the pile end bearing capacity are used to bear the uplift force and down pressure of the foundation. It is characterized by convenient construction and safety and reliability. The disadvantages include big construction difficulty and high construction cost.

10.2.3 Safety Factors

It is recommended to use the safety factors in the following table.

Description	Safety factor
Uplift Condition	1.2
Compression Condition	1.2

10.2.4 Foundation Materials

For foundation materials, the equivalent quality materials can be used, such as GB、ASTM or other codes.

10.2.4.1 Foundation concrete

Foundation material is designed according to the following principles. The compressive strength of concrete shall be 21Mpa for normal type of foundation、27.5MPa for pile foundation and the quality of concrete shall conform to the ACI standards. For corrosive areas, improve concrete strength grade according to corrosion grades

10.2.4.2 Steel products for the foundation

For Chinese materials, the main reinforcement of the foundation adopts HRB400 reinforced bars and the stirrup and the structural reinforcement use the HPB300 reinforced bars.

For ASTM materials, characteristic strength of reinforcement (fy):

60 grade 420Mpa

10.2.5 Connecting Way of Tower and Foundation

The connecting way of stub angle is recommended in this project.

NATIONAL TRANSMISSION & DESPATCH
COMPANY (NTDC) LIMITED PAKISTAN

STATE GRID CORPORATION OF CHINA

FEASIBILITY STUDY

FOR

±660kVHVDC PROJECT

FROM MATIARI TO LAHORE IN PAKISTAN

VOLUME V-1

ELECTRODE AND ELECTRODE LINE OF MATIARI CONVERTER STATION

Pak Matiari-Lahore Transmission Company (Private) Limited

January 2017,Beijing, P.R. China

±660kV HVDC PROJECT
FROM MATIARI TO LAHORE IN PAKISTAN
GENERAL LIST OF CONTENTS

TECHNICAL DEFINITIONS

The following technical definitions apply tothis Specification:

Purchaser	National Transmission And Despatch Company Limited (NTDC)
Company	The project company for development, investment, construction, operation and maintenance of the ±660kV HVDC project from Matiari to Lahore in Pakistan.
HVDC System	All of the relevant equipments and systems in bipolar operation, including converter transformers, converter valves, DC yard equipment, AC filter, control& protection system, DC transmission line, electrode and electrode line, etc.
HVDC Project	HVDC System and the relevant construction works in this project. the relevant construction works including outlet and inlet line of converter station, buildings and structures, related auxiliary production facilities and living facilities.
M-L T/L	Matiari-Lahore Transmission Line
AC yard	AC switchgear area in converter station
DC yard	DC switchgear area in converter station
Life yard	Living facilities and part of auxiliary production facilities area in converter station
T area	Transformer area
M-E T/L	Matiari Electrode Grounding Transmission Line
M E/G	Matiari Electrode Grounding
L-E T/L	Lahore Electrode Grounding Transmission Line
L E/G	Lahore Electrode Grounding
M C/S	Matiari Converter Station
L C/S	Lahore Converter Station
M AC busbar	Matiari AC busbar
L AC busbar	Lahore AC busbar
M AC system	Matiari AC system
L AC system	Lahore AC system

P I	Pole I
P II	Pole II

The following abbreviations apply to this Specification:

AC	Alternating Current
ACI	American Concrete Institute
A/D	Analog to Digital
AN	Audible Noise
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing Material
BIL	Basic Impulse Insulation Level
BS	British Standard
BSL	Basic Switching Impulse Insulation Level
CB	Control Building
CCITT	International Consultative Committee on Telephone and Telegraph Systems
CT	Current Transformer
CTV	Capacitive Voltage Transformer
D/A	Digital to Analog
DC	Direct Current
DIN	Deutsches Institute fur Normung
EEI	Edison Electric Institute
EIA	Environmental Impact Assessment
ESCR	Effective Short Circuit Ratio
ESDD	Equivalent Salt Deposit Density
FAT	Factory Acceptance Tests
HF	High Frequency
HVDC	High Voltage Direct Current
IEC	International Electrotechnical Commission

IEEE	Institute of Electrical and Electronics Engineers
I/O	Input/Output
ISO	International Standards Organization
LED	Light Emitting Diode
MMI	Man Machine Interface
MVU	Multiple Valve Unit
NFPA	National Fire Protection Association
OPGW	Optical Fiber Composite Overhead Ground Wire
P&C	Protection and Control
PLC	Power-line Carrier
PT	Potential Transformer
RF	Radio Frequency
RI	Radio Interference
RIV	Radio Interference Voltage
RTU	Remote Terminal Unit
RPC	Reactive Power Controls
SCADA	Supervisory Control and Data Acquisition
SER	Sequence of Events Recorder
SLG	Single Line to Ground Fault
SMC	Station Master Clock
SPC	Software Production Control
SWC	Surge Withstand Capability
TFR	Transient Fault Recorder
UPS	Uninterruptible Power Supply
VDT	Video Display Terminal
VDU	Video Display Unit
VF	Voice Frequency
VT	Voltage Transformer

VOLUME V-1 CONTENTS

1 Project Overview

1.1 General

Based on the power grid planning reports, and to meet power demand of loads in load centers, optimize allocation of energy resources nationwide, and facilitate export of power in the southern areas, it is considered to construct a single-circuit ±660 kV DC transmission line between Matiari and Lahore.

Sending-end electrode is the **electrode** at Matiari Converter Station, the sending-end converter station of this transmission project. The DC voltage class, transmission capacity and rated DC current of this project are ±660 kV, 4000 MW and 3030 A, respectively.

Earth electrode line of Matiari Converter Station is the overhead line connecting the converter station and earth electrode. The length of the line is tentatively considered as 45 km. Conductors are made up of four heat-resistant steel-core aluminum alloy strands JNRLH1/G1A-630/45 and hung on both sides of the tower, and the earth wire is made up of one galvanized steel strand GJ-80. The tower is of self-supporting type.

The areas that earth electrode lines on both sides pass are of a flat terrain. The maximum temperature is 52.5°C, minimum temperature is -5°C, the design basic wind speed is 31.1 m/s, and no freezing will occur.

1.2 Main Design Basis

(1) LAVALIN feasibility study report provided by NTDC

(2) NTDC Draft Reply on Queries from CET - Gadani HVDC Transmission Project (Transmission Lines Part)

(3) "Minutes of meeting of Pakistan HVDC transmission project feasibility study" China Power Equipment Co., Ltd., July 14, 2014

(4) MINUTES OF MEETING HELD ON DATED 04.03.2015 IN WAPADA HOUSE, LAHORE HVDC PROJECT (SPIP)

(5) Minutes of Meetings for HVDC Transmission Line Project from Matiari to Lahore Held on March16-25, 2015 at NTDCL Head Office Wapda House, Lahore, Meeting Minutes March 25, 2015

(6) Minutes of Meetings for HVDC Transmission Line Project from Matiari to Lahore Held on May 20, 2015 at GM Planning (Power), PIA Building, Lahore, Meeting Minutes May 20, 2015

(7) May 4, 2015 NTDC's reply to route recommendation by our company, Preliminary Route alignment / coordination from MATIARI-LAHORE HVDC transmission line

(8) May 19, 2015, the adjustment (KMZ files) by NESPAK on the recommended route

(9) The summary of internal audit meeting of the project on feasibility study report

1.3 Standards and Specifications

According to the main design principles agreed with NTDC, the following standards and specifications will be used at the current stage:

(1) Electrical design standards and specifications

IEC60826-2003: Design criteria of overhead transmission lines.

IEC 61865: Overhead lines-Calculation of the electrical component of distance between live parts and obstacles- Method of calculation.

IEEE C2-2012: National Electrical Safety Code (NESC).

IEEE 516-2009: IEEE Guide for Maintenance Methods on Energized Power Lines.

GB 50545-2010: Code for design of 110-750kV overhead transmission line

Technical code for design of HVDC overhead transmission line (for approval)

DL437-2012: Technical code for design of HVDC electrode

DL/T621-1997: Grounding of AC electricity facilities

DL/T 5224-2014: Technical rule for the design of HVDC earth return operation system

(2) Structural design and material standards and specifications

ASCE 74-2009-Guidelines for Electrical Transmission Line Structural Loading

IEC 60826 - Design criteria of overhead transmission lines

ASCE 10-97 - Design of latticed steel transmission structures

American concrete institutes (ACI318)

IEEE Guide for Transmission Structure Foundation Design and Testing (IEEE Std 691-2001)

1.4 Major Technical Indices

Type of **electrode**: shallowly-buried;

Shape of electrode: dual-ring (with a radius of 380/270m);

Material and quantity of feeding rod: **FeSi** (with a diameter of 50), 2730 pieces (1.5 m per piece);

Active material and quantity: calcined petroleum coke, 4280t;

Total length of **electrode**: 4085 m

Burial depth: 3.5 m (outer ring) and 3 m (inner ring)

Current guiding mode: buried power cables

1.5 System Conditions

Electrode of this project are one-time designed and installed and have a service life of 30 years.Under bipolar operation, the positive pole and negative pole constitute a loop, and the current flowing through the **electrode** is very small, which will be controlled below 30 A according to Technical Rule for the Design of HVDC Earth Return Operation System. In early construction period, or in emergency conditions, or during maintenance, monopolar operation is allowed, and in this mode, the transmission capacity is half of the maximum rated capacity and the rated injection current at the electrode is 3030 A.

According to the minutes of meeting on the design scheme of **electrode**s for this project convened in March 2015, various DC currents of **electrode** are determined according to the DC currents considering measurement and control errors specified in Technical Code for Design of HVDC **Electrode** and Technical Rule for the Design of HVDC Earth Return Operation System, the time of **electrode** operating at the rated current is considered as 30 days, and pace voltage is checked against the maximum overload current, which is 1.1 times the rated injection current at the electrode.

Main system conditions for design of **electrode** for this project are listed below:

DC rated capacity:	4000 MW
Rated voltage of the D.C. Line:	±660 kV
Maximum continuous rated current:	3030 A
Maximum overload current (2h):	3333 A

Injection current at the electrode due to bipolar imbalance: below 30 A;

Maximum design temperature:	90°C

Maximum permissible pace voltage of the ground:	$7.42+0.0318\rho_s$ (V/m)
Continuous monopolarearth return operation time:	30 days

2 Electrode

2.1 Siting of Electrode

Siting of **electrode** is an important and complicated link of design of **electrode**. Proper siting of **electrode** contributes to safe operation of **electrode**, no or little impact on the environment, and high cost-effectiveness. For this project, the following factors are mainly considered in siting and demonstration of **electrode**:

(1) A sufficient distance from the converter station, generally 20-60 km;

(2) Spacious current diffusion area with good conductivity, in particular, the soil resistivity in the vicinity shall be lower than 100 Ωm.

(3) Soil with a high water content, high thermal capacity, and satisfactory heat conduction;

(4) No complicated or important underground metal facilities, no or minimum electric equipment earthed;

(5) Flat ground, for the ease of installation of **electrode**;

(6) Convenient routing of **electrode**.

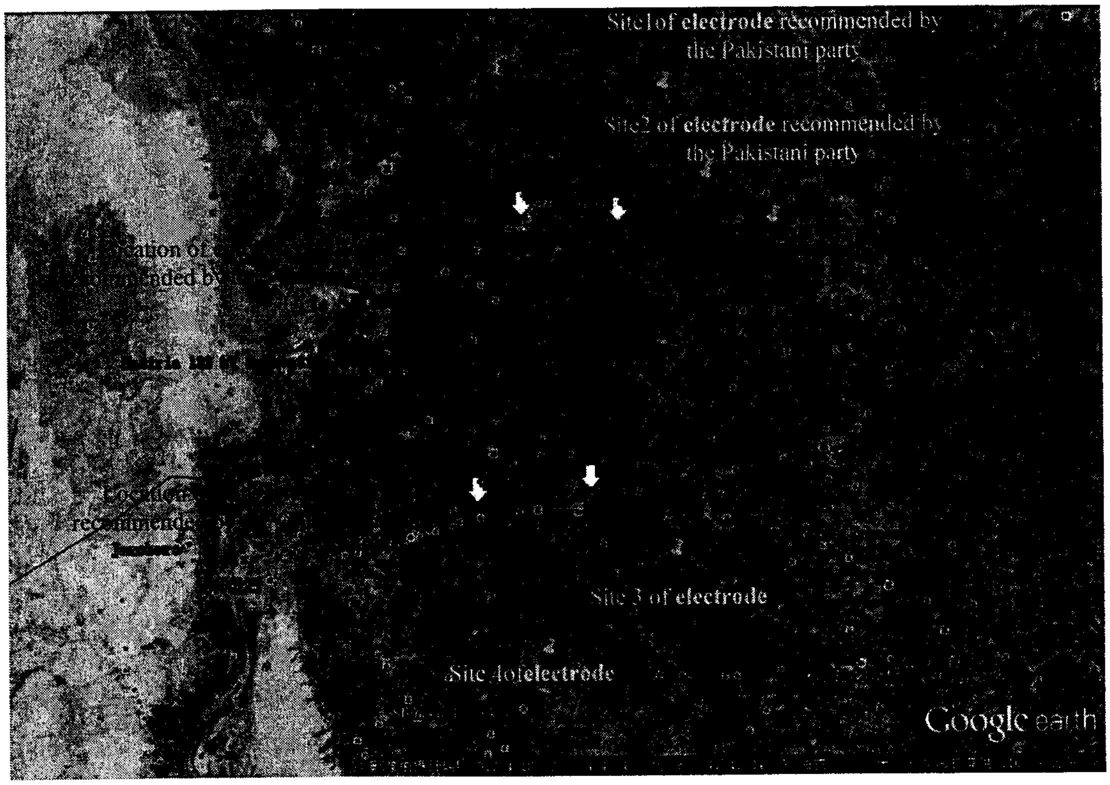


Figure 2.1-1: Site of M C/S and site of electrode

Based on preliminary field investigation, the following four sites (as shown in Figure 2.1-1) are tentatively considered as candidate sites of **electrode**:

Site: 1 (recommended by the Pakistani party): 25°53'31.16"N, 68°48'42.73"E;

Site 2 (recommended by the Pakistani party): 25°47′52.38″N, 68°51′43.68″E;

Site 3: 25°24′33.93″N, 68°49′53.76″E;

Site 4: 25°18'29.94"N, 68°41'9.82"E.

Further field investigation shows that a gas pipeline is routed around 1 km west of site 2, that is, the pipeline passes between site 1 and site 2.And the Hyderabad-MirpurK has Railway passes about 9 km north of site 3.As such, all the three sites are not appropriate. Therefore, site 4 is tentatively considered as the site of **electrode**.

2.2 Design of Electrode

2.2.1 Layout and Burial Mode

The design of **electrode** is closely related to such factors as the magnitude of injection current at the electrode, shape and size of the site, soil resistivity, and ambient environmental conditions.

(1) Factors directly affecting the layout and burial mode of **electrode**

The terrain and landform, depth of underground water, electrical performance and thermal performance are directly related to the shape, size and burial mode of **electrode**; therefore, they shall be considered in choosing the site of **electrode**.

(2) Layout

There are two types of **electrodes** by shape, one is well-type electrode, which is comprised of many sub-electrodes perpendicular to the ground, and the other is trench-type (or shallowly-buried) electrode.

Trench-type **electrode** has been widely used in common DC and UHVDC projects. And the experience in operation, design and installation of this type of **electrode** is more mature. Therefore, trench-type **electrode** is recommended for this project in view of the conditions of the **electrode** site recommended for this project.

(3) Selection of shape

Considering that the site of **electrode** is flat and open, a dual-ring shape is recommended. A major advantage of such a shape is that current is evenly distributed over the electrode and that no excessively high pace voltage will appear at a point. In addition, under the same design conditions, such a shape contributes to a smaller length of **electrode**, saving of materials, and a higher performance.

After preliminary calculation based on the measurement result of resistivity of shallow soil at the candidate site, and considering a certain margin, it is preliminarily planned to arrange the **electrode** as follows:

A dual-ring shape is tentatively considered: outer ring: radius R1=380 m (with a perimeter of 2388 m) and burial depth=3.5 m; inner ring: radius R2=270 m (with a perimeter of 1697 m), and burial depth=3.0 m.

The plane layout of **electrode** is as shown in the figure below.

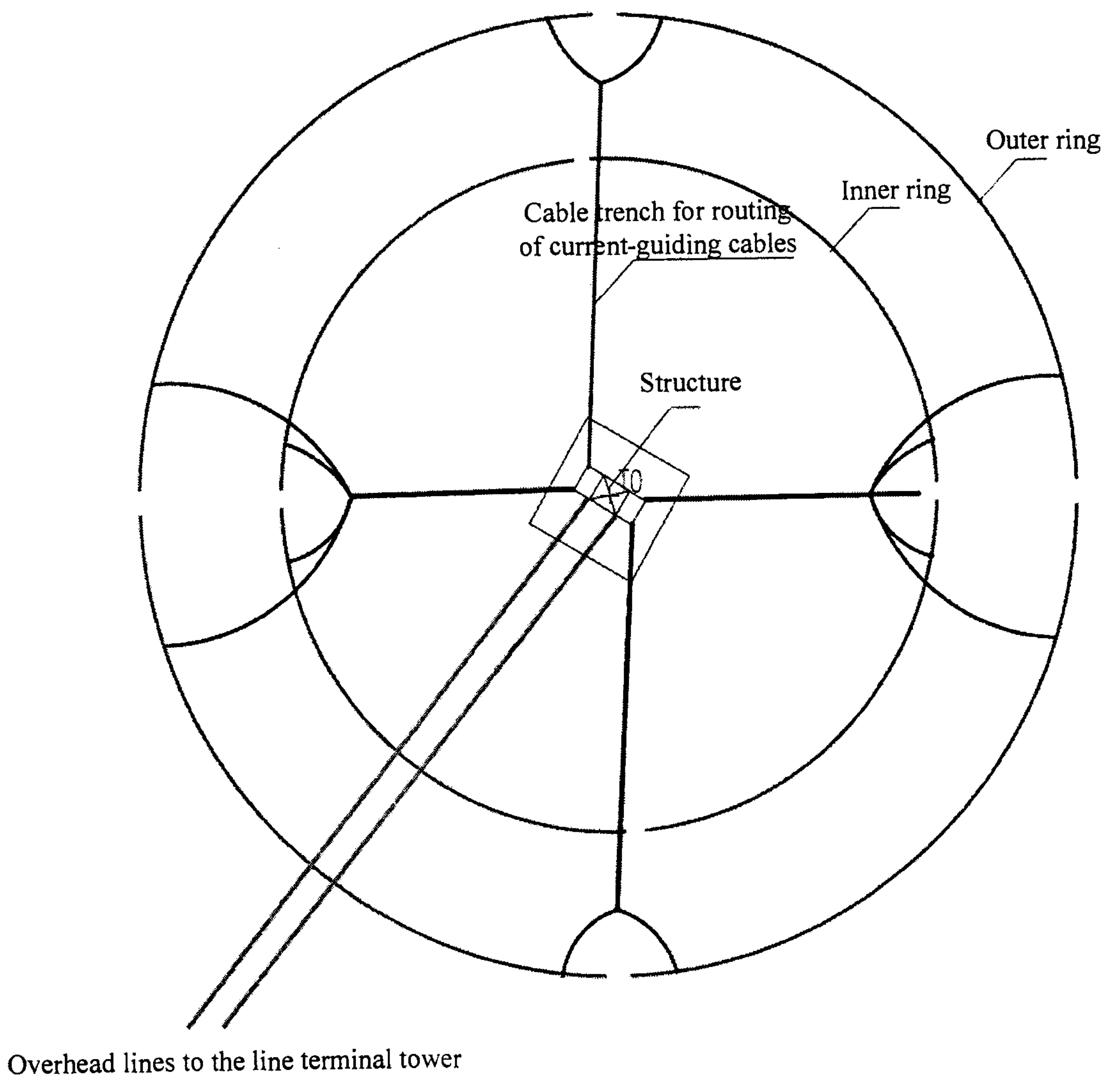


Figure 2.2-1: Schematic diagram of plane layout of electrode

2.2.2 Selection of material

(1) Principles

Investigation in China and abroad shows that DC **electrode** is generally made of two kinds of materials, namely, metal material and active material.Metal material functions for feed purpose, and is therefore called feed rod; active material is used as packing around the feed rod, to increase the diffusing area of the feed rod, reduce earthing resistance, and avoid direct contact of the feed rod with soil to minimize the corrosion of the feed rod.

For this project, Φ50**FeSi** is recommended for the feed rod.

(2) Packing (active material)

Active materials are materials filled around the feed rod.With conductive active materials around the feed rod, the surface area of **electrode** is increased, thereby reducing the current density and earthing resistance at the contact between the electrode and soil.Furthermore, the current of the feed rod is injected to the ground via the active material, and what flows between the feed rod and active material is mainly stream of electrons. This significantly slows down corrosion of the feed rod.

The active material often used is coke or coke debris. The former is a product of coal carbonization, and the latter is small solid particles from cracking of refined petroleum.

Up to now, coke and coke debris are the only active materials having successfully been used in **electrode**.

In this project, coke is recommended as the packing, and the sectional area of coke for the outer ring is tentatively determined as 0.95m×0.95m and that for the inner ring as 0.8m×0.8m.

2.2.3 Arrangement of Current Guiding System

To achieve even distribution of current and ensure operation safety of the current guiding system, and with reference to related documents home and abroad, it is concluded that the following principles shall be observed in arranging the current guiding system:

(1) The arrangement of the current guiding system shall match the shape of **electrode**.For **electrode** of a symmetrical structure, the current guiding cables shall also be arranged in a symmetrical structure;

(2) The number of current guiding branches shall be increased as appropriate, to ensure that when one of them is unavailable for service (damaged or during maintenance), the others can still operate safely, thereby enhancing reliability of the system;

(3) The current guiding cables shall have a sufficient current-carrying capacity, and the insulating sheath thereof shall have a satisfactory thermal property;

(4) Current guiding cables shall be, as practically as possible, kept away from points with a high current density, to prevent thermal deformation and damage of these cables due to heating of soil;

(5) Connection shall be made solidly and reliably.

(6) To minimize land occupation, it is recommended to use directly-buried cables to lead the current to the electrode ring.

Based on the principles listed above, the current guiding system of this project is recommended to be configured as follows: one incoming line center tower, outer ring and inner ring respectively divided into four sections, each section using two pieces of buried cables (model: 6kV YJY-6-1×300) to lead in current from the tower, back-up lead-in cables considered, all lead-in cables routed along the cable trench, and feed rod made of **FeSi**.

2.2.4 Main Technical Scheme

The main technical scheme of **electrode** is summarized as follows:

(1) The **electrode** is of a regular dual-ring shape, the radius and burial depth of the outer ring are 380 m and 3.5 m respectively; and those of the inner ring 270 m and 3 mrespectively.Both the outer ring and inner ring are divided into four sections.Both rings use Φ50 **FeSi** as the feed rod, and coke as packing (the sectional area of coke for the outer ring is 0.95m×0.95m and that for the inner ring 0.8m×0.8m).

(2) 82 infiltration holes and marking piles and 16 inspection wells at the site of **electrode**. The dimensions and burial depth of the marking piles are 150 mm ×150 mm×1200 mm and 800 mm respectively.

(3) Current guiding cables are directly buried. Four cable trenches with a sectional area of 1.2m (width) × 0.3m (depth) are dug from the incoming line center tower to the outer ring of **electrode** at a depth of 1.5 m and covered with concrete precast slab; cable trenches with a sectional area of 0.3m (width) × 0.3m (depth) are also dug at 2 m inside of each ring at a depth of 1.5 m and covered with concrete precast slab.

(4) The enclosure is 14 m (length) ×15 m (width), and the ground within the enclosure is hardened.An incoming line structure is set up within the enclosure, which comprises blocking reactor, blocking capacitor and busbar.

3 Electrode Line

3.1 Selection of Conductor and Earth Wire

(1) Selection of conductor wire

The design maximum continuous rated current and design maximum continuous overcurrent of earth electrode are 3030A and 3333A respectively. It is recommended to use 2 steel-core heat-resistant aluminum alloy strand JNRLH1/G1A-630/45 as the conductor. The technical parameters are given in the table below.

Table 3.1-1 **List of technical parameters of JNRLH1/G1A-630/45**

Item		Unit	Value
Construction	Heat-resistant aluminum alloy wire	Number of strand/diameter mm	45/4.22
	Galvanized steel wire	Number of strand/diameter mm	7/2.81
Sectional area	Aluminum	mm^2	629.4
	Steel	mm^2	43.41
	Sum	mm^2	672.81
Outer diameter		Mm	33.75
DC resistance at 20 °C		Ω/km	0.04667
Calculated tensile strength		kN	149.6
Integrated elasticity coefficient		N/mm^2	63700
Integrated linear expansion coefficient		1/°C	20.78×10^{-6}
Calculated weight		kg/km	2078.4

JNRLH1/G1A-630/45(2) Selection of earth wire

Galvanized steel strands GJ-80 are used as earth wire. The table below gives its characteristic parameters.

Table 3.1-2 Mechanical and physical characters of earth wire

Item \ Type		GJ-80
Structure Number of wire/diameter	Aluminum (mm)	-
	Steel (mm)	11.4/3.8
Calculated sectional area (mm^2)	Aluminum	-
	Steel	79.39
	Total	79.39
Outer diameter (mm)		11.4
Calculated weight (kg/m)		0.6300
Calculated tensile strength (N)		100100
Modulus of elasticity (10 MPa)		18500
Linear expansion coefficient (1/°C)		0.0000115

(3) Safety factor for Conductor and Earth Wire

The safety factor of conductor and earth wire should be no less than 2.5.The everyday tension of conductor and earth wire should be not more than 25%. The sag of earth wire should be not more than the sag of conductor.

(4) Anti-vibration of conductor and earth wire

The installation of spacers can prevent vibration of bundle conductor to a certain extent. According to the design code and past experience with earth electrode line, FR-4 damper shall be installed all along the 2-bundle conductor provided with spacers.

FR-1 damper is adopted for earth wire GJ-80 of the project for vibration prevention.Thenumber of dampers is as shown in Table 3.1-3.

Table 3.1-3 Number of dampers

Span (m)	L≤450	450≤L<800	800≤L<1200		JNRLH1/G1A-630/45JN RLH1/G1A-630/45 conductor
Number	1	2	3		
Span (m)	L<300	300≤L<600	600≤L<900	≥900	GJ-80 Earth wire
Number	1	2	3	4	

3.2 Insulation Design

3.2.1 Selection of insulator

Insulators of the project are all approved domestic products. The DC disc insulators are adopted in the conductor insulator string. Both the suspension insulator and tension insulator are model U160BP/170(XZP-160). The electromechanical properties of insulator are as shown in table3.2-1.

Table 3.2-1Electromechanical properties of conductor insulator

Code of insulator	U160BP/170	
Material	Porcelain	Glass
Disc diameter (mm)	320~340	320~340
Nominal structure height *H* (mm)*	170	170
Nominal creep distance *L* (mm)*	≥545	≥545
Connection marks*	20	20
Electromechanical breaking load required (kN)	160	160
Separate tensile test load (kN)	80	80
1min positive DC wet withstand voltage (kV)	55	60
Lightning impulse withstand voltage (kV)	140	140
1min positive and negative DC dry withstand voltage (kV)	140	150
Impulse breakdown voltage (p.u.)	2.8	2.8
Wireless disturbance voltage 10kV, 1MHz (V)	50	50

DC corona extinction voltage (kV)	50	50
Porcelain degradation rate/spontaneous explosion rate (%)	≤0.01	/
Glass spontaneous explosion rate (%)	/	≤0.02

Table3.2-2 Safety factor of insulator's mechanical strength

Condition	Maximum working load		Normal load	Check	Break	Disconnection
	Disc insulator	Rod insulator				
Safety factor	2.7	3	4	1.5	1.8	1.5

3.2.2 Selection of insulator quantity and arcing horn clearance

Based on recent research on earthing electrode line, it is recommended to provide five insulators for the suspension string and tension string respectively near the converter station (within 40% of the length of earthing electrode line away from the converter station), three insulators for the suspension string and four insulators for the tension string near the earthing electrode (40%-100% of the length of earthing electrode line away from converter station). Besides, the arcing horn shall be installed. The number of insulators and arcing horn clearance are as shown in the table below.

Table 3.2-3 Insulator quantity and arcing horn clearance

Distance from converter station	Number of insulators (suspension/tension/jumper)	Arcing horn gap (mm)
0-40%	5/5/3	700
40-100%	3/4/3	400

3.2.3 Air Gap of Tower Body

Under atmospheric conditions, the clearance between the charged part and tower body shall be designed to match the arcing horn clearance. The clearance between the charged part and tower body shall be no less than the arcing horn clearance to ensure that the discharge occurs on the arcing horn rather than between the conductor and tower body. The clearance varies depending on the distance between the tower and converter station, as shown in table 3.2-2 in details.

3.3 Insulator Strings and Fittings

3.3.1 Assembling of Insulator String

For suspension insulator strings of conductor, 160 kN single and dual strings are used; and for those of earth wire, 70 kN suspension insulator strings are used.

For tension insulator strings of conductor, 160 kN dual strings are used; and for those of earth wire, XDP-100CN insulators with the acing horn are adopted, which are assembled in single strings (two insulators).

For jumper insulator strings of conductor, 160kN single strings are used.

3.3.2 Main Fittings

The heat resistant NY-630/45N tension clamp and CF-630/45 suspension clamp are adopted for the conductor.

The heat resistant NY-80G tension clamp and XGU-2 suspension clamp are adopted for the earth wire.**3.3.3 Value of Safety Factor**

The safety factor adopted for the hardware in this project is shown in Table 6.3.4-1.

Table 3.3-1 List of safety factor for hardware

Condition	Maximum load	Maintenance	Line breakage	String breakage
Safety factor	2.5	1.5	1.5	1.5

3.4 Clearance to the Earth and Passage

The clearance between the conductor and earth and the distance between the conductor and objects crossed are as shown in table3.4-1 and 3.4-2.The operating temperature of conductor is 135°C.

Table 3.4-1Minimum distance between the conductor and the building/woods

No.		Minimum distance (m)	calculation condition
1	Residential area	7.0	Maximum sag
2	Nonresidential Area	6.0	Maximum sag
3	Traffic Inconvenience area	5.0	Maximum sag
4	Hillsides accessible on foot	5.0	Maximum wind displacement
5	Hillsides, cliffs and rocks inaccessible on foot	3.0	Maximum wind displacement
6	Vertical distance to the building	5.0	Maximum sag
7	Minimum clearance to the building	4.0	Maximum wind displacement
8	Vertical distance to forest taking consideration of natural growth of trees	4.0	Maximum sag
9	Minimum clearance to trees of the park, green area or tree reserve	3.5	Maximum wind displacement
10	Vertical distance to the fruit tree, commercial crop and urbane roadside tree	3.0	Maximum sag

Table 3.4-2Distance between conductor and objects/obstacles crossed

No.	Name of objects crossed		Minimum distance (m)	Calculation Condition
1	Railway	Clearance from track top	7.5	Maximum sag
		Clearance from load-bearing cable or contact wire	3.0	Maximum sag
2	Road	Class 1	7.0	Maximum sag
3	Un-navigable rivers	Clearance from 100-year flood level	3.0	Maximum sag
4	Power line		3.0	Maximum sag
5	Communication line		3.0	Maximum sag

3.5 Lighting Protection and Earthing

The following measures are mainly proposed in the lighting protection and earthing design of power transmission line:

(1)Provide the singe earthing line with a shielding angle of 30 degrees all the way;

(2) Keep the distance between two earthing lines of the tower within five times of the vertical distance between the conductor and earthing line to ensure combined protection from both earthing lines.

(3) In calm days with a temperature of +15°C, the distance between the conductor and lightning wire at the center of span shall meet the requirement in the *Design Code for 110kV-500kV Overhead Transmission Line*:$S \geq 0.012L+1$ (where S refers to the distance between the conductor and lighting wire and L refers to the span);

(4) The footing resistance of tower should be restricted as to table 3.5-1..

Table3.5-1 The limiting values of tower footing resistance

Area	agricultural district	desert	desert
earth resistivity ρ (Ω•m)	$0< \rho \leqslant 1000$	$1000< \rho \leqslant 2000$	$\rho > 2000$
limiting values of tower footing resistance R (Ω)	10	20	25

3.6 Tower Family

The service conditions for tower in this project are shown in Table 3.6-1. Lattice tower will be used in this project

Table 3.6-1Tower family

Tower Type	Angle	Horizontal span (m)	Vertical span (m)	Range of nominal height (m)	Nominal height (m)
ZP1	0°	380	480	18-33	24
ZP2	0°	450	600	21-36	30
ZPK	0°	600	800	45-60	54
JP1	0-30°	400	500	15-27	27
JP2	30-60° (including the terminal)	400	500	15-27	27

3.7 Tower and Foundation Design

3.7.1 Tower Design

3.7.1.1 Specifications, code and relevant design documents to be observed

The specifications, codes and relevant design documents to be observed during the design of the tower are as follows:

ASCE 74-2009-Guidelines for Electrical Transmission Line Structural Loading

IEC 60826 - Design criteria of overhead transmission lines

ASCE 10-97 - Design of latticed steel transmission structures

GB/T 3098.1 Mechanical Properties of Fasteners—Bolts, Screws and Studs,

GB/T 3098.2 Mechanical Properties of Fasteners—Nuts-Coarse Thread

GB/T 5117 Covered Electrodes for Manual Metal Arc Welding of Non-alloy and Fine Grain Steels

GB/T 5118 Covered Electrodes for Manual Metal Arc Welding of Creep-resisting Steels.

GB 50661 Code for Welding of Steel Structures.

GB/T 1591 High Strength Low Alloy Structural Steels

GB/T 700 Carbon Structural Steel.

GB 50017 Code for Design of Steel Structures

.etc, and/or other approved standard.

3.7.1.2 Calculation Model of Tower

The calculation analysis of tower is based on the finite element method and the 3D truss model according to the mechanics theory; PLS-TOWER software is used as the analysis software of tower in this project.

3.7.1.3 Wind Speed in Basic Design

The designed basic wind velocity is determined as 31.3m/s according to the technical data that have been collected.

3.7.1.4 Load Conditions

According to the relevant provisions of ASCE74-2009, the load conditions and load combinations usually to be considered in the design are shown in the following table:

Operation condition name	Description of load condition
Normal Condition	Vertical Load: Dead weight of conductor, earth wire, insulator, hardware, tower,worker etc. Horizontal Load: wind pressure, angle tension, tower body wind velocity; Wind load direction: 90°, 45°

Failure Containment case	Structure failure load, e.g.broken wire load, etc.
Installation condition	Structure erection load; Stringing tension load; Worker load

3.7.1.6 Material for Tower

It is recommended to use China's supplies for the steel products of tower. Two categories of China's steel products in the following table shall be adopted while designing the tower at the current stage.

Steel products:

Mild steel: Q235B

High tensile steel: Q345B

The characteristics of steel products are as follows:

Standard	Grade	Fy (Mpa) Yield Strength, Fy (Mpa)		Minimum Tensile Strength
		T<=16	t>16	Mpa
GB 700	Q235B	235	225	375
GB1591	Q345B	345	325	470

Bolts: Grade 6.8 in ISO 898

Yield point: 480N/mm^2

Tensile strength: 600N/mm^2

Bolts: Grade 8.8 in ISO 898

Yield point: 640N/mm^2

Tensile strength: 800N/mm^2

(1) The members of tower all use the hot-rolled equal-leg angle steels. The high-strength steel shall be selected according to the economic comparison. In general, it is not suitable to adopt the high-strength steel for the members whose slenderness ratio is greater than 80 or whose specification is less than 125×10 (excluding the tension member).

(2) Q235B and Q345B steel electrodes shall use E43 type and E50 type. The welding operation shall be avoided as far as possible for the Q420B high-strength steel.

(3 The connecting bolts shall use M16(Grade 6.8), M20(Grade 8.8) and M24 (Grade 8.8) common rough bolts.

3.7.1.7 Other Descriptions

(1) Anti-corrosion measures of tower

The hot-galvanized anti-corrosion measures shall be performed to all members of towers (including stub angle), bolts (including locking fastening nut and anti-theftbolts), gaskets and washers.

(2) Locking and antitheft measures

Antitheft bolts shall be used within the range of 10.0m over the ground of the shortest leg. The point of suspension connecting members all use the dual-cap bolts and the locking measures of one standard nut with one thin nut shall be taken for other bolts.

(3) Step bolts and others

The climbing step bolts shall be provided in the main members of tower, and they shall be mounted in a diagonal form. As for the tower with the full height of over 60m, the simple access platform shall be set up in appropriate position and the safety fence shall be set up at the periphery of the platform.

(4) Anti climbing device

The anti climbing device shall be set above the first septal surface using the barbed wire steel and set a doorlocking with bolts, nuts, fastening nut

3.7.2 Foundation Design

3.7.2.1 Design Specifications

(1) American concrete institutes (ACI318)

(2) IEEE Guide for Transmission Structure Foundation Design and Testing (IEEE Std 691-2001)

(3) GB 50010 Code for Design of Concrete structures

(4) GB1499.1 Steel for the reinforcement of concrete: Hot rolled plain bars

(5) GB1499.2 Steel for the reinforcement of concrete: Ribbed bars

(6) JGJ 18 Specification for welding and acceptance of reinforcing steel bars

.etc, and/or other approved standard.

3.7.2.2 Selection of Foundation Types

The pad&chimney foundation can be adopted for the soft plastic clay according to the site conditions.

Pad&chimney foundation

The main feature of this foundation is that the main column slope of the foundation is consistent with that of the tower leg. The result of this design enables the horizontal force perpendicular to the axial line of the foundation to be reduced for at least 50% and the axial action force of the foundation only increases by 1-2%. This result has significantly improved the force bearing situation of the foundation columns and base plates (slabs) to minimize the impact of the foundation horizontal force on the foundation slabs and improve significantly the stability of the foundation. Meanwhile, due to significant reduction of eccentric bending moment, the dimension of foundation slabs controlled by downward stability is correspondingly reduced so that the concrete quantity and slab reinforcement amount are reduced, which can greatly save the consumption of foundation materials. Foundation of this kind can be used in most of the locations in this project.

3.7.2.3 Foundation Materials

The grade of concrete strength of the foundation is generally C25 and C30. As for the tower location with corrosion, the grade of concrete strength shall be improved based on the specific corrosion. The cushion layer and protective cap shall all use the C15 concrete. The main reinforcement of the foundation adopts HRB400 reinforced bars and the stirrup and the structural reinforcement use the HPB300 reinforced bars.

For foundation materials, the equivalent quality materials can be used, such as GB、ASTM or other codes.

3.7.2.4Foundation concrete

Foundation material is designed according to the following principles.The compressive strength of concrete shall be 21Mpa for normal type of foundation、27.5MPa for pile foundation and the quality of concrete shall conform to the ACI standards. For corrosive areas, improve concrete strength gradeaccording to corrosion grades

3.7.2.5 Steel products for the foundation

For Chinese materials, the main reinforcement of the foundation adopts HRB400 reinforced bars and the stirrup and the structural reinforcement use the HPB300 reinforced bars.

For ASTM materials, characteristic strength of reinforcement (fy):

60 grade 420Mpa

3.7.2.6 Connecting Way of Tower and Foundation

The connecting way of stub angle is recommended in this project.

3.7.2.7 Foundation Insulation and Corrosion Prevention

Insulation and corrosion prevention measures shall be taken for the tower foundation within 2.0km from the electrode according to relevant specifications.

NATIONAL TRANSMISSION & DESPATCH
COMPANY (NTDC) LIMITED PAKISTAN

FEASIBILITY STUDY

FOR

±660kV HVDC PROJECT

FROM MATIARI TO LAHORE IN PAKISTAN

VOLUME Ⅴ-2

ELECTRODE AND ELECTRODE LINE OF LAHORE CONVERTER STATION

Pak Matiari-Lahore Transmission Company (Private) Limited

January 2017,Beijing, P.R. China

±660kV HVDC PROJECT
FROM MATIARI TO LAHORE IN PAKISTAN
GENERAL LIST OF CONTENTS

TECHNICAL DEFINITIONS

The following technical definitions apply to this Specification:

Purchaser	National Transmission And Despatch Company Limited (NTDC)
Company	The project company for development, investment, construction, operation and maintenance of the ±660kV HVDC project from Matiari to Lahore in Pakistan.
HVDC System	All of the relevant equipments and systems in bipolar operation, including converter transformers, converter valves, DC yard equipment, AC filter, control& protection system, DC transmission line, electrode and electrode line, etc.
HVDC Project	HVDC System and the relevant construction works in this project. the relevant construction works including outlet and inlet line of converter station, buildings and structures, related auxiliary production facilities and living facilities.
M-L T/L	Matiari-Lahore Transmission Line
AC yard	AC switchgear area in converter station
DC yard	DC switchgear area in converter station
Life yard	Living facilities and part of auxiliary production facilities area in converter station
T area	Transformer area
M-E T/L	Matiari Electrode Grounding Transmission Line
M E/G	Matiari Electrode Grounding
L-E T/L	Lahore Electrode Grounding Transmission Line
L E/G	Lahore Electrode Grounding
M C/S	Matiari Converter Station
L C/S	Lahore Converter Station
M AC busbar	Matiari AC busbar
L AC busbar	Lahore AC busbar
M AC system	Matiari AC system
L AC system	Lahore AC system

P I	Pole I
P II	Pole II

The following abbreviations apply to this Specification:

AC	Alternating Current
ACI	American Concrete Institute
A/D	Analog to Digital
AN	Audible Noise
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing Material
BIL	Basic Impulse Insulation Level
BS	British Standard
BSL	Basic Switching Impulse Insulation Level
CB	Control Building
CCITT	International Consultative Committee on Telephone and Telegraph Systems
CT	Current Transformer
CTV	Capacitive Voltage Transformer
D/A	Digital to Analog
DC	Direct Current
DIN	Deutsches Institute fur Normung
EEI	Edison Electric Institute
EIA	Environmental Impact Assessment
ESCR	Effective Short Circuit Ratio
ESDD	Equivalent Salt Deposit Density
FAT	Factory Acceptance Tests
HF	High Frequency
HVDC	High Voltage Direct Current
IEC	International Electrotechnical Commission

IEEE	Institute of Electrical and Electronics Engineers
I/O	Input/Output
ISO	International Standards Organization
LED	Light Emitting Diode
MMI	Man Machine Interface
MVU	Multiple Valve Unit
NFPA	National Fire Protection Association
OPGW	Optical Fiber Composite Overhead Ground Wire
P&C	Protection and Control
PLC	Power-line Carrier
PT	Potential Transformer
RF	Radio Frequency
RI	Radio Interference
RIV	Radio Interference Voltage
RTU	Remote Terminal Unit
RPC	Reactive Power Controls
SCADA	Supervisory Control and Data Acquisition
SER	Sequence of Events Recorder
SLG	Single Line to Ground Fault
SMC	Station Master Clock
SPC	Software Production Control
SWC	Surge Withstand Capability
TFR	Transient Fault Recorder
UPS	Uninterruptible Power Supply
VDT	Video Display Terminal
VDU	Video Display Unit
VF	Voice Frequency
VT	Voltage Transformer

VOLUME V-2 CONTENTS

1Project Overview

1.1 General

Based on the power grid planning reports, and to meet power demand of loads in load centers, optimize allocation of energy resources nationwide, and facilitate export of power in the southern areas, it is considered to construct a single-circuit ±660 kV DC transmission line between Matiari and Lahore.

Receiving-end **electrode** is the **electrode** for Lahore Converter Station, the receiving-end converter station of this transmission project. The DC voltage class, transmission capacity and rated DC current of this project are ±660 kV, 4000 MW and 3030 A, respectively.

Earth electrode line of Lahore Converter Station is the overhead line connecting the converter station and earth electrode. The length of the line is tentatively considered as 50 km.

The areas that earth electrode lines on both sides pass are of a flat terrain. The maximum temperature is 52.5°C, minimum temperature is -5°C, the design basic wind speed is 31.1 m/s, and no freezing will occur.

1.2 Main Design Basis

(1) LAVALIN feasibility study report provided by NTDC

(2) NTDC Draft Reply on Queries from CET - Gadani HVDC Transmission Project (Transmission Lines Part)

(3) "Minutes of meeting of Pakistan HVDC transmission project feasibility study" China Power Equipment Co., Ltd., July 14, 2014

(4) MINUTES OF MEETING HELD ON DATED 04.03.2015 IN WAPADA HOUSE, LAHORE HVDC PROJECT (SPIP)

(5) Minutes of Meetings for HVDC Transmission Line Project from Matiari to Lahore Held on March16-25, 2015 at NTDCL Head Office Wapda House, Lahore, Meeting Minutes March 25, 2015

(6) Minutes of Meetings for HVDC Transmission Line Project from Matiari to Lahore Held on May 20, 2015 at GM Planning (Power), PIA Building, Lahore, Meeting Minutes May 20, 2015

(7) May 4, 2015 NTDC's reply to route recommendation by our company, Preliminary Route alignment / coordination from MATIARI-LAHORE HVDC transmission line

(8) May 19, 2015, the adjustment (KMZ files) by NESPAK on the recommended route

(9) The summary of internal audit meeting of the project on feasibility study report

1.3 Standards and Specifications

According to the main design principles agreed with NTDC, the following standards and specifications will be used at the current stage:

(1) Electrical design standards and specifications

IEC60826-2003: Design criteria of overhead transmission lines.

IEC 61865: Overhead lines-Calculation of the electrical component of distance between live parts and obstacles- Method of calculation.

IEEE C2-2012: National Electrical Safety Code (NESC).

IEEE 516-2009: IEEE Guide for Maintenance Methods on Energized Power Lines.

GB 50545-2010: Code for design of 110-750kV overhead transmission line

Technical code for design of HVDC overhead transmission line (for approval)

DL437-2012: Technical code for design of HVDC electrode

DL/T621-1997: Grounding of AC electricity facilities

DL/T 5224-2014: Technical rule for the design of HVDC earth return operation system

(2) Structural design and material standards and specifications

ASCE 74-2009-Guidelines for Electrical Transmission Line Structural Loading

IEC 60826 - Design criteria of overhead transmission lines

ASCE 10-97 - Design of latticed steel transmission structures

American concrete institutes (ACI318)

IEEE Guide for Transmission Structure Foundation Design and Testing (IEEE Std 691-2001)

1.4 Major Technical Indices

Type of **electrode**: shallowly-buried;

Shape of electrode: dual-ring (with a radius of 380/270m);

Material and quantity of feeding rod: **FeSi** (with a diameter of 50), 2730 pieces (1.5 m per piece);

Active material and quantity: calcined petroleum coke, 4280t;

Total length of **electrode**: 4085 m

Burial depth: 3.5 m (outer ring) and 3 m (inner ring)

Current guiding mode: buried power cables

1.5 System Conditions

Electrode of this project are one-time designed and installed and have a service life of 30 years. Under bipolar operation, the positive pole and negative pole constitute a loop, and the current flowing through the **electrode** is very small, which will be controlled below 30 A according to Technical Rule for the Design of HVDC Earth Return Operation System. In early construction period, or in emergency conditions, or during maintenance, monopolar operation is allowed, and in this mode, the transmission capacity is half of the maximum rated capacity and the rated injection current at the electrode is 3030 A.

According to the minutes of meeting on the design scheme of **electrode**s for this project convened in March 2015, various DC currents of **electrode** are determined according to the DC currents considering measurement and control errors specified in Technical Code for Design of HVDC **Electrode** and Technical Rule for the Design of HVDC Earth Return Operation System, the time of **electrode** operating at the rated current is considered as 30 days, and pace voltage is checked against the maximum overload current, which is 1.1 times the rated injection current at the electrode.

Main system conditions for design of **electrode** for this project are temporarily set as below:

DC rated capacity:	4000 MW
Rated voltage of the D.C. Line:	±660 kV
Maximum continuous rated current:	3030 A
Maximum overload current (2h):	3333 A
Injection current at the electrode due to bipolar imbalance:	30 A;
Maximum design temperature:	90°C
Maximum permissible pace voltage of the ground:	$7.42+0.0318\rho_s$ (V/m)
Continuous monopolar earth return operation time:	30 days

2. Electrode

2.1 Siting of Electrode

Siting of **electrode** is an important and complicated link of design of **electrode**. Proper siting of **electrode** contributes to safe operation of **electrode**, no or little impact on the environment, and high cost-effectiveness.For this project, the following factors are mainly considered in siting and demonstration of **electrode**:

(1) A sufficient distance from the converter station, generally 20-60 km;

(2) Spacious current diffusion area with good conductivity, in particular, the soil resistivity in the vicinity shall be lower than 100 Ωm.

(3) Soil with a high water content, high thermal capacity, and satisfactory heat conduction;

(4) No complicated or important underground metal facilities, no or minimum electric equipment earthed;

(5) Flat ground, for the ease of installation of **electrode**;

(6) Convenient routing for **electrode line**.

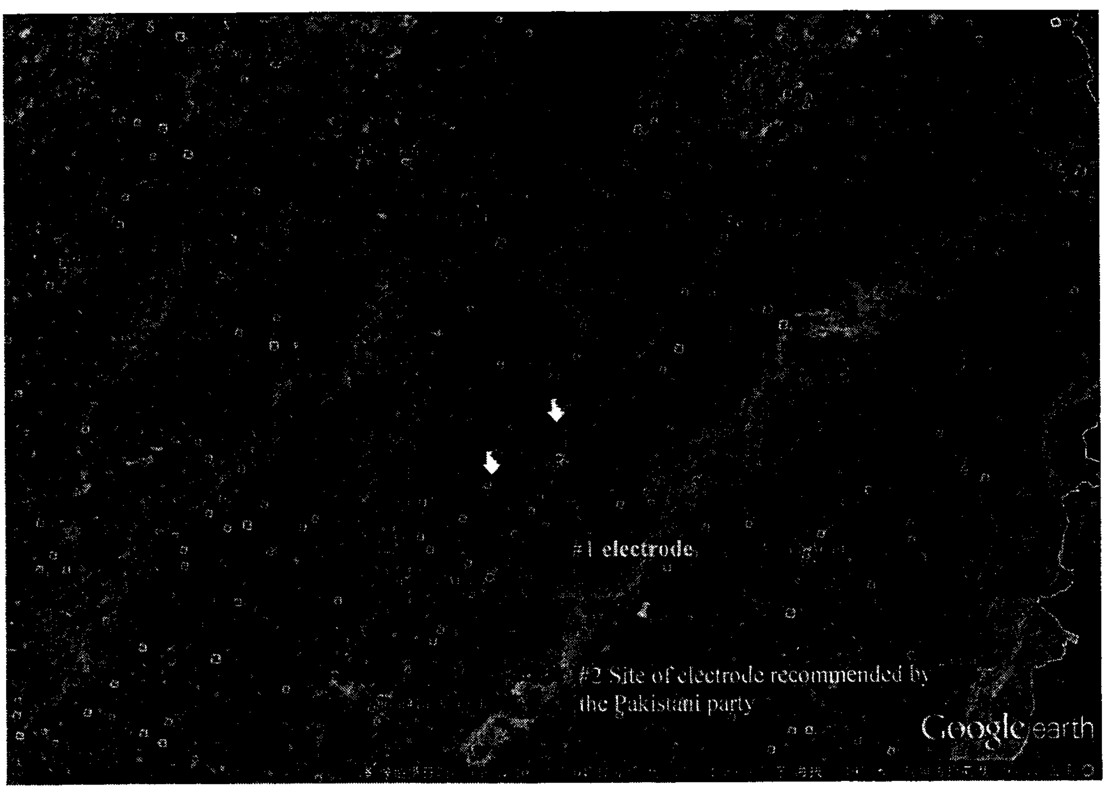


Figure 2.1-1: Site of L C/S and site of electrode

Based on preliminary field investigation, the following two sites (as shown in Figure 2.1-1) are tentatively considered as candidate sites of **electrode**:

Site 1: 30°52′12.55″N, 73°52′17.28″E;

Site: 2 (recommended by NTDC): 30°50′41.47″"N, 73°43′35.47″E;

Further field investigation shows that at about 9km to the north of site 2 lies N5 express, along which there are one 220kV line and two 132kV lines, making site 2 inappropriate. Therefore, site 1 is tentatively considered as the site of **electrode**.

2.2 Design of Electrode

2.2.1 Layout and Burial Mode

The design of **electrode** is closely related to such factors as the magnitude of injection current at the electrode, shape and size of the site, soil resistivity, and ambient environmental conditions.

(1) Factors directly affecting the layout and burial mode of **electrode**

The terrain and landform, depth of underground water, electrical performance and thermal performance are directly related to the shape, size and burial mode of **electrode**; therefore, they shall be considered in choosing the site of **electrode**.

(2) Layout

There are two types of **electrodes** by shape, one is well-type electrode, which is comprised of many sub-electrodes perpendicular to the ground, and the other is trench-type (or shallowly-buried) electrode.

Trench-type **electrode** has been widely used in common DC and UHVDC projects.And the experience in operation, design and installation of this type of **electrode** is more mature. Therefore, trench-type **electrode** is recommended for this project in view of the conditions of the **electrode** site recommended for this project.

(3) Selection of shape

Considering that the site of **electrode** is flat and open, a dual-ring shape is recommended.A major advantage of such a shape is that current is evenly distributed over the electrode and that no excessively high pace voltage will appear at a point.In addition, under the same design conditions, such a shape contributes to a smaller length of **electrode**, saving of materials, and a higher performance.

After preliminary calculation based on the measurement result of resistivity of shallow soil at the candidate site, and considering a certain margin, it is preliminarily planned to arrange the **electrode** as follows:

A dual-ring shape is tentatively considered: outer ring: radius R1=380 m (with a perimeter of 2388 m) and burial depth=3.5 m; inner ring: radius R2=270 m (with a perimeter of 1697 m), and burial depth=3.0 m.

The plane layout of **electrode** is as shown in the figure below.

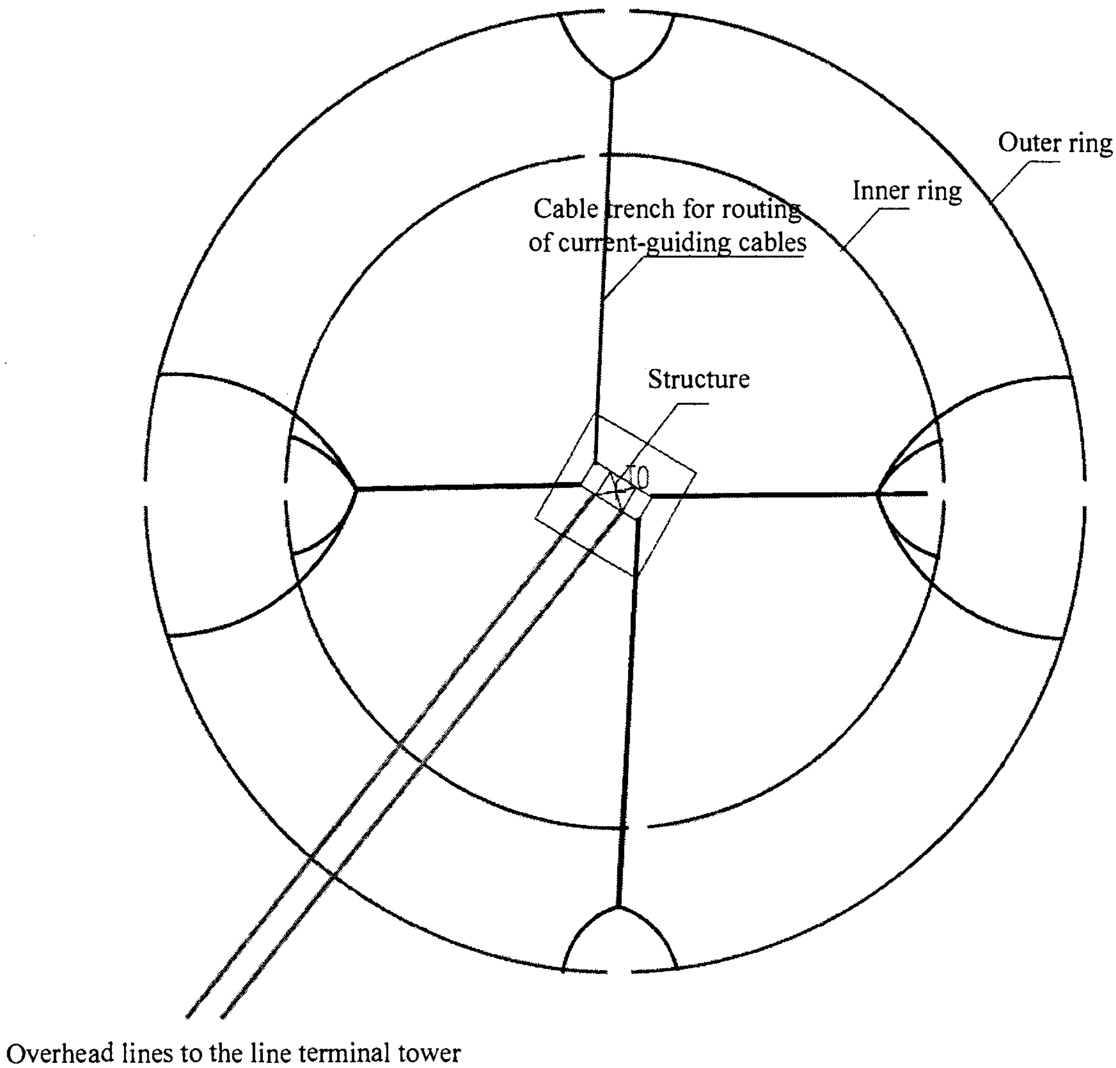


Figure 2.2-1: Schematic diagram of plane layout of electrode

2.2.2 Selection of material

(1) Principles

Investigation in China and abroad shows that DC **electrode** is generally made of two kinds of materials, namely, metal material and active material. Metal material functions for feed purpose, and is therefore called feed rod; active material is used as packing around the feed body, to increase the diffusing area of the feed body, reduce earthing resistance, and avoid direct contact of the feed body with soil to minimize the corrosion of the feed rod.

For this project, Φ50**FeSi**is recommended for the feed rod.

(2) Packing (active material)

Active materials are materials filled around the feed rod. With conductive active materials around the feed rod, the surface area of **electrode** is increased, thereby reducing the current density and earthing resistance at the contact between the electrode and soil. Furthermore, the current of the feed rod is injected to the ground via the active material, and what flows between the feed rod and active material is mainly stream of electrons. This significantly slows down corrosion of the feed body.

The active material often used is coke or coke debris. The former is a product of coal carbonization, and the latter is small solid particles from cracking of refined petroleum.

Up to now, coke and coke debris are the only active materials having successfully been used in **electrode**.

In this project, coke is recommended as the packing, and the sectional area of coke for the outer ring is tentatively determined as 0.95m×0.95m and that for the inner ring as 0.8m×0.8m.

2.2.3 Arrangement of Current Guiding System

To achieve even distribution of current and ensure operation safety of the current guiding system, and with reference to related documents home and abroad, it is concluded that the following principles shall be observed in arranging the current guiding system:

(1) The arrangement of the current guiding system shall match the shape of **electrode**. For **electrode** of a symmetrical structure, the current guiding cables shall also be arranged in a symmetrical structure;

(2) The number of current guiding branches shall be increased as appropriate, to ensure that when one of them is unavailable for service (damaged or during maintenance), the others can still operate safely, thereby enhancing reliability of the system;

(3) The current guiding cables shall have a sufficient current-carrying capacity, and the insulating sheath thereof shall have a satisfactory thermal property;

(4) Current guiding cables shall be, as practically as possible, kept away from points with a high current density, to prevent thermal deformation and damage of these cables due to heating of soil;

(5) Connection shall be made solidly and reliably.

(6) To minimize land occupation, it is recommended to use directly-buried cables to lead the current to the electrode ring.

Based on the principles listed above, the current guiding system of this project is recommended to be configured as follows: one incoming line center tower, outer ring and inner ring respectively divided into four sections, each section using two pieces of buried cables (model: 6kV YJY-6-1×300) to lead in current from the tower, back-up lead-in cables considered, all lead-in cables routed along the cable trench, and feeding rod made of **FeSi**.

2.2.4 Main Technical Scheme

The main technical scheme of **electrode** is summarized as follows:

(1) The **electrode** is of a regular dual-ring shape, the radius and burial depth of the outer ring are 380 m and 3.5 m respectively; and those of the inner ring 270 m and 3 mrespectively. Both the outer ring and inner ring are divided into four sections. Both rings use Φ50 **FeSi** as the feed body, and coke as packing (the sectional area of coke for the outer ring is 0.95m×0.95m and that for the inner ring 0.8m×0.8m).

(2) 82 infiltration holes and marking piles and 16 inspection wells at the site of **electrode**. The dimensions and burial depth of the marking piles are 150 mm ×150 mm×1200 mm and 800 mm respectively.

(3) Current guiding cables are directly buried. Four cable trenches with a sectional area of 1.2m (width) × 0.3m (depth) are dug from the incoming line center tower to the outer ring of **electrode** at a depth of 1.5 m and covered with concrete precast slab; cable trenches with a sectional area of 0.3m (width) × 0.3m (depth) are also dug at 2 m inside of each ring at a depth of 1.5 m and covered with concrete precast slab.

(4) The enclosure is 14 m (length) ×15 m (width), and the ground within the enclosure is hardened. An incoming line structure is set up within the enclosure, which comprises blocking reactor, blocking capacitor and busbar.

3. Electrode Line

3.1 Selection of Conductor and Earth Wire

(1) Selection of conductor wire

The design maximum continuous rated current and design maximum continuous overcurrent of earth electrode are 3030A and 3333Arespectively.It is recommended to use 2 steel-core heat-resistant aluminum alloy strand JNRLH1/G1A-630/45 as the conductor. The technical parameters are given in the table below.

Table3.1-1List of technical parameters of JNRLH1/G1A-630/45

Item		Unit	Value
Construction	Heat-resistant aluminum alloy wire	Number of strand/diameter mm	45/4.22
	Galvanized steel wire	Number of strand/diameter mm	7/2.81
Sectional area	Aluminum	mm^2	629.4
	Steel	mm^2	43.41
	Sum	mm^2	672.81
Outer diameter		Mm	33.75
DC resistance at 20 °C		Ω/km	0.04667
Calculated tensile strength		kN	149.6
Integrated elasticity coefficient		N/mm^2	63700
Integrated linear expansion coefficient		1/°C	20.78×10^{-6}
Calculated weight		kg/km	2078.4

(2) Selection of earth wire

Galvanized steel strands GJ-80 are used as earth wire. The table below gives its characteristic parameters.

Table 3.1-2Mechanical and physical characters of earth wire

Item \ Type		GJ-80
Structure Number of wire/diameter	Aluminum (mm)	-
	Steel (mm)	11.4/3.8
Calculated sectional area (mm^2)	Aluminum	-
	Steel	79.39
	Total	79.39
Outer diameter (mm)		11.4
Calculated weight (kg/m)		0.6300
Calculated tensile strength (N)		100100
Modulus of elasticity (10 MPa)		18500
Linear expansion coefficient (1/°C)		0.0000115

(3) Safety factor for Conductor and Earth Wire

The safety factor of conductor and earth wire should be no less than 2.5.The everyday tension of conductor and earth wire should be not more than 25%. The sag of earth wire should be not more than the sag of conductor.

(4) Anti-vibration of conductor and earth wire

The installation of spacers can prevent vibration of bundle conductor to a certain extent. According to the design code and past experience with earth electrode line, FR-4 damper shall be installed all along the 2-bundle conductor provided with spacers.

FR-1 damper is adopted for earth wire GJ-80 of the project for vibration prevention. The number of dampers is as shown in Table 3.1-3.

Table 3.1-3 Number of dampers

Span (m)	L≤450	450≤L<800	800≤L<1200		JNRLH1/G1A-630/45 conductor
Number	1	2	3		
Span (m)	L<300	300≤L<600	600≤L<900	≥900	GJ-80 Earth wire
Number	1	2	3	4	

3.2 Insulation Design

3.2.1 Selection of insulator

Insulators of the project are all approved domestic products. The DC disc insulators are adopted in the conductor insulator string. Both the suspension insulator and tension insulator are model U160BP/170(XZP-160). The electromechanical properties of insulator are as shown in table3.2-1.

Table 3.2-1Electromechanical properties of conductor insulator

Code of insulator	U160BP/170	
Material	Porcelain	Glass
Disc diameter (mm)	320~340	320~340
Nominal structure height *H* (mm)*	170	170
Nominal creep distance *L* (mm)*	≥545	≥545
Connection marks*	20	20
Electromechanical breaking load required (kN)	160	160
Separate tensile test load (kN)	80	80
1min positive DC wet withstand voltage (kV)	55	60
Lightning impulse withstand voltage (kV)	140	140
1min positive and negative DC dry withstand voltage (kV)	140	150
Impulse breakdown voltage (p.u.)	2.8	2.8
Wireless disturbance voltage 10kV, 1MHz (V)	50	50

DC corona extinction voltage (kV)	50	50
Porcelain degradation rate/spontaneous explosion rate (%)	≤0.01	/
Glass spontaneous explosion rate (%)	/	≤0.02

Table3.2-2 Safety factor of insulator's mechanical strength

Condition	Maximum working load		Normal load	Check	Break	Disconnection
	Disc insulator	Rod insulator				
Safety factor	2.7	3	4	1.5	1.8	1.5

3.2.2 Selection of insulator quantity and arcing horn clearance

Based on recent research on earthing electrode line, it is recommended to provide five insulators for the suspension string and tension string respectively near the converter station (within 40% of the length of earthing electrode line away from the converter station), three insulators for the suspension string and four insulators for the tension string near the earthing electrode (40%-100% of the length of earthing electrode line away from converter station). Besides, the arcing horn shall be installed. The number of insulators and arcing horn clearance are as shown in the table below.

Table 3.2-3Insulator quantity and arcing horn clearance

Distance from converter station	Number of insulators (suspension/tension/jumper)	Arcing horn gap (mm)
0-40%	5/5/3	700
40-100%	3/4/3	400

3.2.3 Air Gap of Tower Body

Under atmospheric conditions, the clearance between the charged part and tower body shall be designed to match the arcing horn clearance. The clearance between the charged part and tower body shall be no less than the arcing horn clearance to ensure that the discharge occurs on the arcing horn rather than between the conductor and tower body. The clearance varies depending on the distance between the tower and converter station, as shown in table 3.2-3 in details.

3.3 Insulator Strings and Fittings

3.3.1 Assembling of Insulator String

For suspension insulator strings of conductor, 160 kN single and dual strings are used; and for those of earth wire, 70 kN suspension insulator strings are used.

For tension insulator strings of conductor, 160 kN dual strings are used; and for those of earth wire, XDP-100CN insulators with the acing horn are adopted, which are assembled in single strings (two insulators).

For jumper insulator strings of conductor, 160kN single strings are used.

3.3.2 Main Fittings

The heat resistant NY-630/45N tension clamp and CF-630/45 suspension clamp are adopted for the conductor.

The heat resistant NY-80G tension clamp and XGU-2 suspension clamp are adopted for the earth wire.

3.3.3 Value of Safety Factor

The safety factor adopted for the hardware in this project is shown in Table 3.3-1.

Table 3.3-1 List of safety factor for hardware

Condition	Maximum load	Maintenance	Line breakage	String breakage
Safety factor	2.5	1.5	1.5	1.5

3.4 Clearance to the Earth and Passage

The clearance between the conductor and earth and the distance between the conductor and objects crossed are as shown in table3.4-1 and 3.4-2.The operating temperature of conductor is 135°C.

Table 3.4-1Minimum distance between the conductor and the building/woods

No.		Minimum distance (m)	calculation condition
1	Residential area	7.0	Maximum sag
2	Nonresidential Area	6.0	Maximum sag
3	Traffic Inconvenience area	5.0	Maximum sag
4	Hillsides accessible on foot	5.0	Maximum wind displacement
5	Hillsides, cliffs and rocks inaccessible on foot	3.0	Maximum wind displacement
6	Vertical distance to the building	5.0	Maximum sag
7	Minimum clearance to the building	4.0	Maximum wind displacement
8	Vertical distance to forest taking consideration of natural growth of trees	4.0	Maximum sag
9	Minimum clearance to trees of the park, green area or tree reserve	3.5	Maximum wind displacement
10	Vertical distance to the fruit tree, commercial crop and urbane roadside tree	3.0	Maximum sag

Table 3.4-2Distance between conductor and objects/obstacles crossed

No.	**Name of objects crossed**		**Minimum distance (m)**	**Calculation Condition**
1	Railway	Clearance from track top	7.5	Maximum sag
		Clearance from load-bearing cable or contact wire	3.0	Maximum sag
2	Road	Class 1	7.0	Maximum sag
3	Un-navigable rivers	Clearance from 100-year flood level	3.0	Maximum sag
4	Power line		3.0	Maximum sag
5	Communication line		3.0	Maximum sag

3.5 Lighting Protection and Earthing

The following measures are mainly proposed in the lighting protection and earthing design of power transmission line:

(1)Provide the singe earthing line with a shielding angle of 30 degrees all the way;

(2) Keep the distance between two earthing lines of the tower within five times of the vertical distance between the conductor and earthing line to ensure combined protection from both earthing lines.

(3) In calm days with a temperature of +15°C, the distance between the conductor and lightning wire at the center of span shall meet the requirement in the *Design Code for 110kV-500kV Overhead Transmission Line*: $S \geq 0.012L+1$ (where S refers to the distance between the conductor and lighting wire and L refers to the span);

(4) The footing resistance of tower should be restricted as to table 3.5-1..

Table3.5-1 The limiting values of tower footing resistance

Area	agricultural district	desert	desert
earth resistivity ρ (Ω•m)	0< ρ ≤1000	1000< ρ ≤2000	ρ > 2000
limiting values of tower footing resistance R (Ω)	10	20	25

3.6 Tower Family

The service conditions for tower in this project are shown in Table 3.6-1. Lattice tower will be used in this project

Table 3.6-1Tower family

Tower Type	Angle	Horizontal span (m)	Vertical span (m)	Range of nominal height (m)	Nominal height (m)
ZP1	0°	380	480	18-33	24
ZP2	0°	450	600	21-36	30
ZPK	0°	600	800	45-60	54
JP1	0-30°	400	500	15-27	27
JP2	30-60° (including the terminal)	400	500	15-27	27

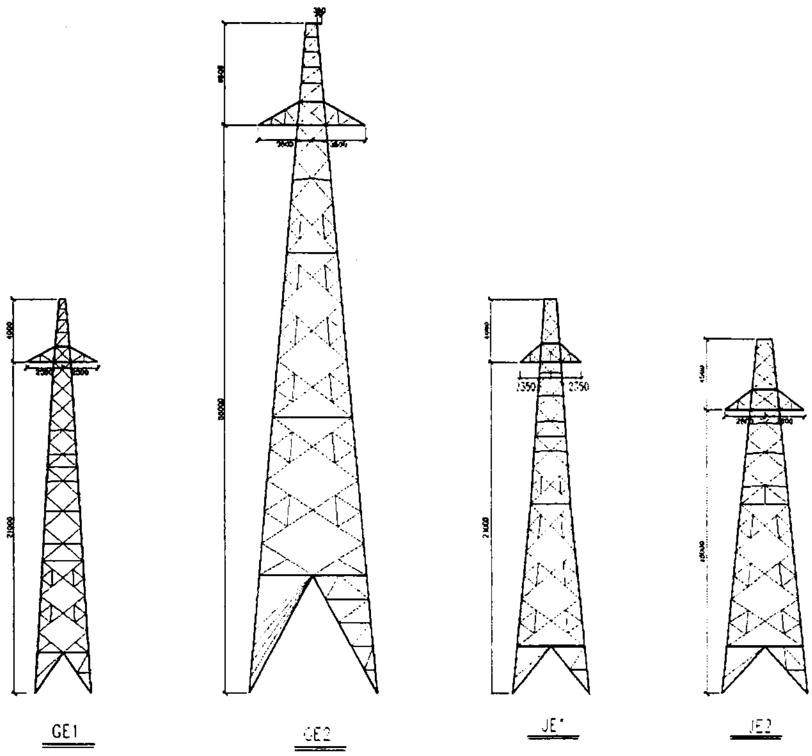


Figure3.6-1:Outlines of towers

3.7 Tower and Foundation Design

3.7.1 Tower Design

3.7.1.1 Specifications, code and relevant design documents to be observed

The specifications, codes and relevant design documents to be observed during the design of the tower are as follows:

ASCE 74-2009-Guidelines for Electrical Transmission Line Structural Loading

IEC 60826 - Design criteria of overhead transmission lines

ASCE 10-97 - Design of latticed steel transmission structures

GB/T 3098.1 Mechanical Properties of Fasteners—Bolts, Screws and Studs,

GB/T 3098.2 Mechanical Properties of Fasteners—Nuts-Coarse Thread

GB/T 5117 Covered Electrodes for Manual Metal Arc Welding of Non-alloy and Fine Grain Steels

GB/T 5118 Covered Electrodes for Manual Metal Arc Welding of Creep-resisting Steels.

GB 50661 Code for Welding of Steel Structures.

GB/T 1591 High Strength Low Alloy Structural Steels

GB/T 700 Carbon Structural Steel.

GB 50017 Code for Design of Steel Structures

.etc, and/or other approved standard.

3.7.1.2 Calculation Model of Tower

The calculation analysis of tower is based on the finite element method and the 3D truss model according to the mechanics theory; PLS-TOWER software is used as the analysis software of tower in this project.

3.7.1.3 Wind Speed in Basic Design

The designed basic wind velocity is determined as 31.3m/s according to the technical data that have been collected.

3.7.1.4 Load Conditions

According to the relevant provisions of ASCE74-2009, the load conditions and load combinations usually to be considered in the design are shown in the following table:

Operation condition name	Description of load condition
Normal Condition	Vertical Load: Dead weight of conductor, earth wire, insulator, hardware, tower,worker etc. Horizontal Load: wind pressure, angle tension, tower body wind velocity; Wind load direction: 90°, 45°
Failure Containment case	Structure failure load, e.g.broken wire load, etc.
Installation condition	Structure erection load; Stringing tension load; Worker load

3.7.1.6 Material for Tower

It is recommended to use China's supplies for the steel products of tower. Two categories of China's steel products in the following table shall be adopted while designing the tower at the current stage.

Steel products:

Mild steel: Q235B

High tensile steel: Q345B

The characteristics of steel products are as follows:

Standard	Grade	Fy (Mpa) Yield Strength, Fy (Mpa)		Minimum Tensile Strength
		T<=16	t>16	Mpa

GB 700	Q235B	235	225	375
GB1591	Q345B	345	325	470

Bolts: Grade 6.8 in ISO 898

Yield point: 480N/mm²

Tensile strength: 600N/mm²

Bolts: Grade 8.8 in ISO 898

Yield point: 640N/mm²

Tensile strength: 800N/mm²

(1) The members of tower all use the hot-rolled equal-leg angle steels. The high-strength steel shall be selected according to the economic comparison. In general, it is not suitable to adopt the high-strength steel for the members whose slenderness ratio is greater than 80 or whose specification is less than 125×10 (excluding the tension member).

(2) Q235B and Q345B steel electrodes shall use E43 type and E50 type. The welding operation shall be avoided as far as possible for the Q420B high-strength steel.

(3 The connecting bolts shall use M16(Grade 6.8), M20(Grade 8.8) and M24 (Grade 8.8) common rough bolts.

3.7.1.7 Other Descriptions

(1) Anti-corrosion measures of tower

The hot-galvanized anti-corrosion measures shall be performed to all members of towers (including stub angle), bolts (including locking fastening nut and anti-theftbolts), gaskets and washers.

(2) Locking and antitheft measures

Antitheft bolts shall be used within the range of 10.0m over the ground of the shortest leg. The point of suspension connecting members all use the dual-cap bolts and the locking measures of one standard nut with one thin nut shall be taken for other bolts.

(3) Step bolts and others

The climbing step bolts shall be provided in the main members of tower, and they shall be mounted in a diagonal form. As for the tower with the full height of over 60m, the simple access platform shall be set up in appropriate position and the safety fence shall be set up at the periphery of the platform.

(4) Anti climbing device

The anti climbing device shall be set above the first septal surface using the barbed wire steel and set a doorlocking with bolts, nuts, fastening nut

3.7.2 Foundation Design

3.7.2.1 Design Specifications

(1) American concrete institutes (ACI318)

(2) IEEE Guide for Transmission Structure Foundation Design and Testing (IEEE Std 691-2001)

(3) GB 50010 Code for Design of Concrete structures

(4) GB1499.1 Steel for the reinforcement of concrete: Hot rolled plain bars

(5) GB1499.2 Steel for the reinforcement of concrete: Ribbed bars

(6) JGJ 18 Specification for welding and acceptance of reinforcing steel bars

.etc, and/or other approved standard.

3.7.2.2 Selection of Foundation Types

The pad&chimney foundation can be adopted for the soft plastic clay according to the site conditions.

Pad&chimney foundation

The main feature of this foundation is that the main column slope of the foundation is consistent with that of the tower leg. The result of this design enables the horizontal force perpendicular to the axial line of the foundation to be reduced for at least 50% and the axial action force of the foundation only increases by 1-2%. This result has significantly improved the force bearing situation of the foundation columns and base plates (slabs) to minimize the impact of the foundation horizontal force on the foundation slabs and improve significantly the stability of the foundation. Meanwhile, due to significant reduction of eccentric bending moment, the dimension of foundation slabs controlled by downward stability is correspondingly reduced so that the concrete quantity and slab reinforcement amount are reduced, which can greatly save the consumption of foundation materials. Foundation of this kind can be used in most of the locations in this project.

3.7.2.3 Foundation Materials

The grade of concrete strength of the foundation is generally C25 and C30. As for the tower location with corrosion, the grade of concrete strength shall be improved based on the specific corrosion. The cushion layer and protective cap shall all use the C15 concrete. The main reinforcement of the foundation adopts HRB400 reinforced bars and the stirrup and the structural reinforcement use the HPB300 reinforced bars.

For foundation materials, the equivalent quality materials can be used, such as GB、ASTM or other codes.

3.7.2.4Foundation concrete

Foundation material is designed according to the following principles.The compressive strength of concrete shall be 21Mpa for normal type of foundation、27.5MPa for pile foundation and the quality of concrete shall conform to the ACI standards. For corrosive areas, improve concrete strength gradeaccording to corrosion grades

3.7.2.5 Steel products for the foundation

For Chinese materials, the main reinforcement of the foundation adopts HRB400 reinforced bars and the stirrup and the structural reinforcement use the HPB300 reinforced bars.

For ASTM materials, characteristic strength of reinforcement (fy):

60 grade 420Mpa

3.7.2.6 Connecting Way of Tower and Foundation

The connecting way of stub angle is recommended in this project.

3.7.2.7 Foundation Insulation and Corrosion Prevention

Insulation and corrosion prevention measures shall be taken for the tower foundation within 2.0km from the electrode according to relevant specifications.

NATIONAL TRANSMISSION AND DESPATCH COMPANY LTD.

±660KV HVDC TRANSMISSION LINE FROM MATIARI TO LAHORE

JULY 2015

Environmental Impact Assessment (EIA) REPORT

Volume 1 of 2 (Main Report)

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HVDC ± 660 KV TRANSMISSION LINE FROM MATIARI TO LAHORE (DRAFT)

Environmental Impact Assessment (EIA) Report

Volume 1 of 2 (Main Report)

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Disclaimer:

This report has been prepared based on the Project information provided by the designer to NESPAK dated 15th July, 2015. NESPAK is not responsible or control over the changes in the Project design data which may require update of this report.

LIST OF ABBREVIATIONS

AC	Alternating Current
ADB	Asian Development Bank
AHs	Affected Houses
ALAO	Assistant Land Acquisition Officer
AM	Angle Marker
ANSI	American National Standards for Electric Power Insulators
ASTM	American Standard for Testing Material
BOD	Board of Directors
BOOT	Built Operate Own Transfer
CAS	Compulsory Acquisition Surcharge
CASA	Central Asia, South Asia Regional Electricity Trade Project
CBD	Convention on Biological Diversity
CBOs	Community Based Organizations
CCR	Community Complaints Register
CE	Chief Engineer
CET	China Electrical Power Equipment and Technology Company
COI	Corridor of Impact
CPPA	Central Power Purchasing Agency
CRPEA	Contract Registrar and Power Exchange Administrator
DC	Direct Current
DCR	District Census Reports
DISCOs	Distribution Companies
EA	Environmental Assessment
ECO	Economic Corporation Organization
EHV	Extra High Voltage
EIA	Environmental Impact Assessment
EMF	Electromagnetic Field
EMMP	Environmental Management and Monitoring Plan
EN	Euronorm Standard Specifications
EPA	Environmental Protection Agency
ESA	Environmental Social Assessment
EURONORM	European Legal Requirements to Musculoskeletal Disorders
GDP	Gross Domesatic Product
GENCOs	Generation Companies
GIS	Geographical Information System
GMT	Greenwich Mean Time

GOP	Government of Pakistan
GRC	Grievance Redress Committees
GSC	Grid Station Construction
GSO	Grid Station Operation
HSE	Health Safety and Environment
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
ICB	International Competative Bidding
ILO	International Labour Organization
IEE	Initial Environmental Examination
IGF	Inspector General Forestry
IPPs	Independent Power Projects
KMC	Karachi Metropolitan Cooperation
KV	Kilo Volt
LAA	Land Acquisition Act
LAC	Land Acquisition Collector
LAR	Land Acquisition and Resettlement
LARF	Land Acquisition and Resettlement Framework
LARP	Land Acquisition and Resettlement Plan
M&E	Monitoring and Evaluation
MLO	Martial Law Order
MMM	Mitigation and Management Matrix
MSDS	Material Safety Data Sheet
MVA	Mega Volts Amperes
NCS	National Conservation Strategy
NEPRA	National Electric Power Regulatory Authority
NEQS	National Environmental Quality Standards
NESC	National Electrical Safety Code
NGOs	Non-Governmental Organizations
NOC	No Objection Certificate
NPO	No Project Option
NRP	National Resettlement Policy
NTDC	National Transmission and Dispatch Company
O & M	Operation and Maintenance
OHSW	Overhead Shield Wire
OIC	Organization of Islamic Countries
OPGW	Optic Fibre Ground Wire

PAPs	Project Affected Persons
PC-1 Proforma	Planning Commission Proforma
PD	Project Director
PEPA	Pakistan Environmental Protection Act
PEPC	Pakistan Environmental Protection Councl
pH	Power of Hydrogen
QUAD S/C	Quad Bundle Single Circuit
REA	Rapid Environmental Assessment
RNR	Renewable Natural Resources
ROW	Right of Way
SAARC	South Asian Atlantic Regional Corporation
SDO	Sub-Divisional Officer
SEPA	Sindh Environmental Protection Agency
SI	Survey and Soil Investigations
SPS	Safeguard Policy Statement
SPSS	Statistical Pakage for Social Science
SSR	Sub-Synchronous Resonance
TA	Telegraph Act
T/L	Transmission Line
T/Ls	Transmission Lines
TLC	Transmission Line Construction
TOR	Terms of Reference
TSS	Total Suspended Solid
UC	Union Concil
UNO	United Nations Organization
UTS	Ultimate Tensile Strength
WAPDA	Water and Power Development Authority
XEN	Executive Engineer

EXECUTIVE SUMMARY

Pakistan is facing electricity crisis due to demand and supply short fall as well as ever increasing electricity prices in Pakistan. Moreover, the existing network of National Transmission and Dispatch Company (NTDC) is already overloaded and needs expansion. With the induction of new Power sources, new Transmission Lines (T/Ls) are required for carrying the additional Power to the major electricity distribution centres of the Country.

In order to cope with these crises, Government of Pakistan (GOP) has looked out for various Power Generation options other than Natural Gas and Furnace Oil. In this regard, GOP has planned to generate additional power in the Karachi region and utilize the Coal reserves of Thar, Sindh in Pakistan.

GOP has decided to implement two (02) key options i.e. to have Power generation from Thar coal reserves and have Power Plants based on imported coal to be located in Karachi. Taking a proactive approach, National Transmission & Dispatch Company (NTDC), has accordingly proposed to construct the T/L on BOOT basis from Matiari to Upcountry (Lahore) on priority basis. In order to have this Project implemented, number of tasks including T/L route selection, environmental and resettlement studies and economic and financial analysis of the Project is required. This Report deals with the Environmental Impact Assessment (EIA) of the proposed T/L from Matiari to Lahore.

The proposed T/L is a $\pm$ 660KV High Voltage Direct Current (HVDC) circuit starting from the district Matiari near Hyderabad at a converter Station located in Matiari, Sindh and ending at the Punjab province district Nankana Sahab near Lahore. Figure 1-1 shows the location map of the proposed T/L. Total length of the T/L is about 865.55 km, of which 314.9 km falls in Sindh province and remaining 550.65 km are located in Punjab province. Proposed T/L route passes through twelve (12) districts, out of which five (05) districts are located in Sindh and the remaining seven (07) are located in Punjab province.

Purpose of the Study

The purpose of this study is to assess the positive and significant adverse environmental and social impacts and to suggest mitigation and remedial measures to make the Project environment friendly and achieve sustainability during the construction and operational stages of the Project, prepare Environmental Management and Monitoring Plan (EMMP) with cost estimates and to intiate the NOC process from the concerned provincial EPAs i.e Sindh Enviornmental Protection Agency (SEPA) and EPA, Punjab.

Approach and Methodology

The detailed approach and methodology used for the EIA study is as follows:

- Literature Review;
- Route Optimization Study;
- Review of Environmental Laws and Institutional Requirements;
- Delineation of Corridor of Impact (COI);
- Baseline Survey of COI;
- Analysis of Alternatives;
- Baseline Conditions of the COI;
- Stakeholder Consultations;
- Impact Assessment and Mitigation Measures;
- Environmental Management and Monitoring Plan (EMMP); and,
- Conclusions and Recommendations.

Applicable Polices, Laws and Guidelines

Following are the applicable policies, laws, regulations and guidelines related to the proposed Project:

- National Environmental Policy, 2005;
- National Conservation Strategy, 1991;
- Pakistan Environmental Protection Act (PEPA), 1997;
- Regulations for Environmental Assessment, 2000;
- National Environmental Quality Standards (NEQS), 2000;
- Land Acquisition Act, 1894
- Telegraphy Act, 1910;
- Affected Persons Ordinance, 2001;
- Electricity Act, 1910;
- Provincial Wildlife (Protection, Preservation, Conservation and Management) Acts, Ordinances and Rules (Act, 1972);
- Cutting of Trees (Prohibition) Act, 1975;
- Punjab Plantation and Maintenance of Trees Act, 1974;
- Protection of Trees and Brushwood Act, 1949;
- Provincial Local Government Ordinances, 2001;
- Antiquities Act, 1975;
- Sindh Cultural Heritage (Preservation) Act, 1994;
- Factories Act, 1934;
- Explosives Act, 1884;
- Punjab Wildlife (Protection, Preservation, Conservation and Management) Act, 1974;
- Sind Wildlife Protection Ordinance, 1972;
- Forest Act,1927;
- Pakistan Penal Code,1860;
- West Pakistan Water and Power Act, 1958;
- Guidelines for Sensitive and Critical Areas;
- ADB Safeguard Policy Statement, 2009;
- Convention on Biological Biodiversity, 1994
- Convention on Conservation of Migratory Species of Wild Animals, 1979;
- Rio Declaration, 1992; and,
- Convention on Wetlands (Ramser Convention), 1971.

Project Description

Proposed project have two main components i.e. Converter Stations and T/L.

Converter Stations will be located at each end of the proposed T/L (Matiari and Lahore) to transform the Alternating Current (AC) used in the national networks into Direct Current (DC) for transmission and vice versa. One of the main advantages of DC transmission consists in the savings achieved by not having intermediate Sub Stations along the T/L. Depending on the final design the Converter Stations dimensions will be finalized. T/L main design components are the Towers and the Conductors.

Taking into account the possibility of the transmission of more Power through the proposed T/L in the future years, ± 660KV Bi-pole Thrasher conductors in quad bundle configuration for the HVDCT/L has been recommended for interconnection. These functional specifications have been prepared at this stage of the Project. It may be added that detailed specifications of the T/L will be based on these functional specifications and will be prepared at a later stage once the Project implementation is finalized.

For Extra High Voltage (EHV) lines, safety considerations are of two types. One is related with the safety of the system, while others are those that are related to the public safety. It is for this reason that NTDC has adopted a 100 m wide (50 m either side from the centreline) corridor as the ROW and 500 m wide (250 m either side from the centreline) corridor as the COI for the T/L. NTDC has planned to implement the Project on BOOT basis.

Analysis of Alternatives

The various alternatives which have been considered during the conduct of the study are:

- No Project Option (NPO);
- Technological System Study of T/L Alternative;
- Alternative Route Alignment selection; and,
- Design Alternatives.

The proposed T/L Project is a cost effective, sustainable and environmental friendly option to dispatch the bulk electricity from Matiari to major electricity supply centres of Pakistan. Based on the facts No Project Option (NPO) if exercised, electricity produced from Karachi and Thar areas cannot be supplied to the national grid hence it will not be available to the consumers. This may result in lost an opportunity to cope with the shortage of Power and boost in the national economy. In light of above situation, NPO is not acceptable for Pakistan.

Two options were considered for the technical comparison as given below for the proposed T/L project:

- Alternative 1: HVDC
- Alternative 2: HVAC

Technical comparison results [1]of both the alternative schemes concluded that HVDC is more economical and technically viable.

Therefore, Alternative-1 is feasible and technically superior.

Baseline Conditions

Following is the brief of the baseline conditions of T/L COI. Principally the whole T/L has been divided into two (02) sections namely Section I&II. Section-I lies in the Sindh Province i.e. from AM #1 to AM #49 while Section-II lies in Punjab Province i.e. from AM #50 to AM #169. Following is the brief of baseline conditions in the COI of the proposed T/L Project:

[1]See Phase-1 Report Vol1 for detailed technical comparison

Physical Environment

Section I:

T/L starts at the Summo village in Matiari district. The whole area is the part of rich fertile land of Matriari district. There exist the orchards of Mango, Guava, and Citrus etc. along with wheat, rice, vegetables due to the avaialbity of irrigation water.

At AM # 8 the proposed T/L enters the Sanghar district. The district does not have any mountain or hill. The district can be divided into two parts: a fertile plain area in the west; and desert area in the east. The T/L passes through eastern desert area as well as the agriculture part of Sanghar district. Most of the area consists of barren tracks of sand dunes covered by thorny bushes.

At AM # 28 district Khairpur starts. The portion where T/L enters the district consists of hills of windblown sand running in parallel rows from north-east to south-east.

From Khairpur T/L enter the Sukkur district at AM # 36. The T/L passes through desert portion of the Salehput sub-division.

T/L passes through the Ghotki district from AM # 41 to AM # 49. T/L passes through the desert area of the district which consists of hills of windblown sand and is part of the Thar Desert.

Table ES-1 below describes the mean daily maximum and minimum temperatures in Summer and Winter seasons of the Meteorological Gauging Stations which represents the climate of Section-I.

Table ES-1: Mean Daily Temperatures at Meteorological Gauging Stations (1981-2010)

Sr. No.	Meteorological Gauging Station	District	Mean Daily Temperature (Summer) ^{0}C		Mean Daily Temperature (Winter) ^{0}C	
			Minimum	Maximum	Minimum	Maximum
1	Sukkur	Sukkur	34.6	35.6	14.8	16.5
2	Nawabshah	Benazirabad	33.8	35.7	15.4	16.9
3	Hyderabad	Hyderabad	32.4	34.0	18.0	19.6

Source: 1. Pakistan Meteorological Services; and
2. Surface Water Hydrology Project, WAPDA.

Section II

T/L enters the district Rahim Yar Khan at AM # 50. Desert area is called Cholistan. T/L passes through the desert area. The surface of the desert consists of a succession of sand dunes and covered with the vegetation peculiar to sandy tracts.

Bahawalpur district starts at AM # 63 on the desert area known as Cholistan. It extends along the entire eastern boundary of Bahawalnagar district in the north and Rahim Yar Khan district in the south. The surface of the desert consists of a succession of sand dunes. It is covered with the vegetation peculiar to the sandy tracks.

T/L enters Bahawalnager district at AM # 75. The line passes through the irrigated agriculture area. The main source of irrigation in this area is semi-perennial and perennial canals which debouche from Sulemanki Head Works. T/L also crosses the Sutlej River in Bahawalnagar district.

T/L enters Pakpattan district at AM # 95. The area is a flat plain, covered on the north by the old bed of the Bias River. Soil impregnated with soda and other salts is common and known as Kallarathi. The major means of irrigation in the COI are canal and tube wells. Pakpattan canal takes off from Sulemanki Headwork's also cross by the T/L. This canal and its branch namely Khadir branch irrigate a vast area of the district.

T/L enters Okara after AM # 125. T/L is crossed by Depalur canal. T/L crosses the semi-urban area which is rich in agriculture.

T/L enters Kasur district at AM # 151 near village Kitan Kalan and passes through the upland area where T/L also crosses the old bed of Bias River. The soil is sandy. The upland is flat plain sloping from north-east to south-west.

Table ES-2 below shows the mean daily maximum and minimum temperatures in Summer and Winter seasons of the Meteorological Gauging Stations which represents the T/L Section-II.

Table ES-2: Mean Daily Temperatures at Meteorological Gauging Stations (1981-2010)

Sr. No.	Meteorological Gauging Station	District	Mean Daily Temperature (Summer) ^{0}C		Mean Daily Temperature (Winter) ^{0}C	
			Minimum	Maximum	Minimum	Maximum
1	Khanpur	Rahim Yar Khan	33.1	34.8	13.3	15.1
2	Bahawalpur	Bahawalpur	32.2	35.0	13.5	15.5
3	Bahawalnagar	Bahawalnagar	33.4	35.0	13.3	15.4
4	Faisalabad	Faisalabad	31.4	33.5	11.8	13.7
5	Lahore (PBO)	Lahore	31.3	33.6	13.3	14.8

Source: 1. Pakistan Meteorological Services; and
2. Surface Water Hydrology Project, WAPDA.

Ecological Environment

The proposed Transmission Line (TL) from Matiari to Lahore passes through two main eco-regions i.e. Desert-Xeric shrublands and Sub-Tropical Thorn area. The Desert-Xeric shrubland category includes districts of Sanghar, Khairpur, Sukkur, Ghotki, Rahim Yar Khan, Bahawalpur and Bahawalnagar, and consists of Angle Marks No. 8 to 94. The eco-region of Sub-Tropical Thorn area includes rest of the districts i.e. Matiari, Pakpattan, Okara, Kasur, and Nankana Sahib and stretches over AM-1 to AM-7 and AM-95 to AM-169. However, for the purpose of collection of field data, the proposed T/L route has been split up into two Sections i.e. Section-I (districts falling in Sindh) and Section II (districts falling in the Punjab).

The original flora of the area consists of the tropical thorn vegetation with acacia species predominanting with particular charateristics of thorny hard wooded species of short boles and low branching crowns. Fauna includes mammal species of jackal, rabbit, porcupine and wild boar. Reptiles consist of snakes and small sized lizards. Squirrel and mouse are the basic rodents while frog and toad are commonly found in the Project Area.

Game Reserves, National Parks and Wildlife Sanctuaries

]The proposed T/L will not pass through or cross any protected area i.e. Game Reserves, National Parks, Wildlife Sanctuaries etc. However, proposed T/L passes at a distance of about 12 kilometers from Changa Manga Reserve Forest (RF) at AM-160. Proposed Project, therefore, will not cause any impact on the flora and fauna of the Reserved Forest.

Socio-Economic Environment

To document the socio-economic conditions of the population settled in the COI, socio-economic surveys of the selected households were carried out. One of the major steps after the identification of the villages and their estimated populations was the calculation of sample size. Total 164 villages were found within the T/L COI for Matiari to Nankana Saheb and socio-economic survey was conducted in these villages. Based on the field visit and DCRs of the relevant districts, total number of households and population is estimated along the COI. Based on the estimated population and household sample size of 450 was determined using a statistical formula.

Section-I

T/L in Section-I passes through some semi urban and mostly rural areas. In this section, about 64 village are located along the COI. As per socio-economic survey highest population in this section is residing in Sanghar district and lowest population in Ghotki district because in Ghotki district most of the T/L route is in desert area. 2nd highest population is living in Khairpur district which is 41,600 persons. Total population in the COI of Section-I is 103,855 persons.

Based on the field survey major occupations in the COI are agriculture farming, labour (unskilled workers), service (government or private employ), business (small shop keeper) and livestock rearing (sale and purchase of livestock and dairy products). As per data collected for the baseline, it was noticed that agriculture/farming and unskilled labour is the main source of income for the locals.

The optimum cropping pattern refers to the allocation of the cropped area under different crops during the year in order to attain maximum output within the existing resources. In general, there are four (04) main crops (i.e. wheat, cotton, maize, sugarcane,) being grown in the COI from Matiari to Ghotki.

The results derived based on the 'village profile surveys' shows that out of 64 villages / Goths, 75 to 85 percent population in the COI had access to roads, electricity, fuel wood and schools especially for boys, while the other facilities like health, sui-gas, drinking water and telephones were found with only less than 10 percent population. Drinking water/ water supply schemes were also not available in most of the villages. In the COI from Matiari to Ghotki districts, drinking water is a major issue for the people especially in desert and barren areas of Sanghar, Khairpur and Ghotki where people are forced to use pond water for drinking. The major sources of drinking water in the COI are streams, nullahs, pumps and tubewell etc. In some areas of Sanghar and Ghotki districts, women have to fetch water from far away ponds and dug wells from their houses.

Section-II

As per socio-economic survey, highest population in the COI is calculated as 95,000 persons of Okara district. Due to urban or semi urban area population density is high in Okara. The lowest population is 11,400 persons in Bahawalpur district with most part of TL pass through the rural areas in this district. Total population falling in the COI from Rahim Yar Khan to Nankana Saheb is 297,400.

Saraiki and Punjabi as the mother tongue in the COI of Section-II, however, Balochi and Pashto are also spoken in the few areas.In Rahim Yar Khan and Bahawalpur, Saraiki is dominant language while from Bahawalnagar to Nankana Saheb Punjabi and Urdu are spoken.

Based on the field survey, major occupations in the COI are agriculture / farming, unskilled labour, service, business, shops and livestock rearing. As per data collected for the baseline, it was noticed that agriculture farming and unskilled labour is the main source of the income for the locals.

The optimum cropping pattern refers to the allocation of the cropped area under different crops during the year in order to attain maximum output within the existing resources. In general, there are four (04) main crops (i.e. wheat, cotton, Maize, sugarcane) being grown in the COI from Rahim Yar Khan to Nankana Sahib.

During the field surveys, it was observed that in case of farm households, the major sources of income included the income from crops and livestock (Dairy products). For non-farm or landless households, the main sources of income are the income from off-farm activities, such as business, Govt. or private employment, labour etc.

The survey results derived based on the 'village profile' shows that out of 95 villages, 80 to 90 percent of the villages in the COI had access to roads, electricity, fuel wood and schools especially for boys, while the other facilities like health, sui-gas, drinking water and telephones were found at less than 50 percent villages. Drinking water/ water supply schemes were also not available in most of the villages. The major sources of drinking water are hand pumps, streams, nullahs, pumps and tubewell etc. in the COI. In some areas of Rahim Yar Khan and Bahawalpur districts, women have to fetch water from dug well or water ponds far away from their houses.

Stakeholder Consultation

Stakeholders, especially the local population, involvement is an important feature of the environmental assessment and can lead to a better and more acceptable decision-making regarding the Project design and implementation. As a part of EIA studies consultations with the Proponent (NTDC), government departments such as Sindh, EPA (SEPA), EPA, Punjab, Sind Wildlife and Forest Department, Punjab Wildlife and Forest Department, Archaeology Departments of Sind and Punjab, Irrigation Departments of Sindh and Punjab, Revenue Departments etc., NGOs working in the COI and the potential project affectees were consulted.

Feedback received during public consultation are related to the willingness of people to accept project, compensation for their effected crops, livelihood, electricity and compensation/relocation/resettlement while concerns include drinking water supply and sewerage, health facilities, road infrastructures, education, women issues, agriculture and security.

Numbers of scoping sessions/focus group discussions with the women were also carried out at various locations in the COI. The purpose of focus group discussions was to share information about the Project activities and to analyze the gender related activities.

Project related concerns and feedback by the women in the COI were mostly related to their privacy, benefits associated with the project, any special provision related to jobs for the women in the area.

Impact Assessment and Mitigation Measures

With the implementation of the proposed Project following major positive impacts are foreseen:

- Dispatch of Electricity from Matiari to Lahore;
- Flexibility in the NTDC T/L system;
- Employment Opportunities;
- Infrastructure Development;
- Increase in Land Value; and
- Socio-economic Uplift.

Some of the indirect benefits envisaged due to the increase of electricity in the national grid are as follows:

- Due to the implementation of the Project, increase in the availability of electricity in the national grid will be ensured;
- Expansion of the industrial base is expected due to the availability of electricity in the national grid; and
- Better quality of life will be available for the residents of the Study Area if electricity from the national grid is provided to the locals of COI.

Apart from positive impacts proposed T/L Project also have some potential adverse environmental and social impacts. These are divided into two (02) major components which are given below:

- Transmission Line (T/L); and,
- Converter Stations.

Summary of identified potential significant environmental and social impacts of T/L and Converter Stations along with their mitigation measures are outlined below:

- The proposed T/L will not involve the permanent land acquisition as per NTDC practice in the light of LAA and Telegraph Act, 1910. No permanent land acquisition will be made for the land at the Tower footings as the landowner will be allowed to use the area under the Towers after the installation. T/L Section I and II a is mostly passing over the agriculture land. Some part of Section I and II is also crossing the desert. The Contractors will require temporary land acquisition for the construction camps.

The land for construction camps should be selected and leased prior to the start of construction phase. Land will be directly rented from the private landowners by the Contractors. The provisions of the LAA will not be involved as the acquisition of the land will be temporary and will be covered by short-term lease agreements between the landowners and Contractor. Rental terms should be negotiated to the satisfaction of the concerned landowners and the agreement should be in local language to make the process clear.

- Permanent acquisition of land will be required for the Converter Station at Matiari and at Nankana Sahib near Lahore. Final selection of the sites for the Converter Stations is in process;

Permanent land will be acquired as per LAA and ADB policy requirements for Involuntary Resettlement will also be fulfilled. It is recommended that existing market price of the land should be paid to the landowner. In this regard proper LARP should be prepared and implemented prior to the construction of the Converter Station.

- Ambient air quality will be affected by the fugitive dust and emissions from the construction machinery and vehicular traffic during the construction phase.

The measures such as the use of existing quarries, Concrete batching plants equipped with dust control equipment such as fabric filters or wet scrubbers to reduce the level of dust emissions; periodic tuning of the vehicles; regular sprinkling of water and Haul-trucks carrying sand aggregate and other materials will be kept covered with tarpaulin to reduce the dust pollution, will be adopted.

- Noise generated by the construction machinery during the construction stage is likely to affect the COI particularly the sensitive receptors like nearby schools, hospital etc. This impact will be more pronounced in both the sections however, end of Section II is more sensitive due to proximity to the urban to semi-urban residential areas.

As the proposed T/L route at some locations is passing near houses, so special care must be taken for noise producing activity by providing casing to the noise generating part of the machinery or use of noise absorbing materials. Properly tuned vehicles and oiling of moving part of equipment may also reduce the noise levels. Construction timing should be coordinated with locals. Normally noise generating activities are allowed from 9 AM to 5 PM during day time to avoid disturbance to humans as well as fauna.

- Approximate proposed strength of the labour in all camps is 179 persons for the T/L, Towers and stringing of conductors. These persons will be involved during hauling and installation stage. As a general rule the water consumption will be about 20 gallon/capita/day (75.7 liter/capita/day) and will subsequently generate about 70 to 80% of this water as sewage.

- Approximate proposed strength of the labour in each camp for Converter Station will be about 25 persons which will generate about 1.9 m^3/day of wastewater and about 12.5 kg/day of solid waste. Improper wastewater and solid waste management activities can increase disease transmission, contaminate ground and surface water and ultimate damage to the ecosystem.

Domestic and chemical effluents from the construction camp should be disposed by the development of on-site sanitation systems i.e. septic tanks along with soakage pits. Proper monitoring to check the compliance of NEQS will be carried out. Proper solid and hazardous waste management system should be adopted for camps;

- Construction activities such as clearing and grubbing, excavation, filling, laying down concrete foundation for Towers and setting up construction camps will affect the existing soil condition in the COI.

Good engineering practices will help to control or minimize the soil erosion both at the construction sites and in peripheral areas, particularly at the Tower foundations and along the haul tracks. All the disturbed areas need to be protected against soil erosion by stripping and stockpiling of all the available topsoil for later re-vegetation. Special slope protection measures should be adopted in the sensitive areas i.e. desert or semi-desert areas. Site restoration plan for the Project should be strictly followed.

- Natural streams and irrigation channels mostly in agicultural areas of Sinddh and Punjab may be prone to increase in sedimentation and silt due to excavated material (loose aggregate) with the runoff from the construction area, workshops and equipment washing-yards.

The excavated material will be managed by ensuring proper storage areas located far away from the water bodies. It will not cause the siltation of the irrigation channels. All the areas disturbed due to erosion need to be protected against soil erosion by stripping and stockpiling of all the available topsoil for later re-vegetation. At sand dunes, proper slope protection should be provided to reduce the erosion of the slopes.

- Land may be contaminated due to the spillage of chemicals, fuels, solvents, oils, paints, concrete, solid waste generated at campsites etc. This normally happens when these materials are transported in open or loosely capped containers.

The Contractors will be required to instruct and train their workforce in the storage handling and management of materials and chemicals that can potentially cause soil contamination. Material Safety Data Sheets (MSDS) implementation should be enforced.

- Construction stage of the proposed Project may affect the existing infrastructure within the ROW of the T/L where Towers are to be installed and stringing activities to take place. Estimated list of infrastructure falling within the ROW (100 m) is provided in the report. Exact number will be identified after the availability of project foot / spotting of Towers on ground.

During the detailed design stage, NTDC will coordinate with NHA and local road department/authorities for the installation of the Towers and during stringing of the conductors where the line is crossing the existing roads for the provision of alternate traffic route and management. Special care is required during the construction of Towers as well as stringing of conductors. During the stringing of conductors, temporary shutdown of the existing T/Ls will be ensured to safeguard the workers and the surroundings.

- Surface and groundwater resources may get contaminated by the fuel and chemical spills, or by solid waste and effluents generated by the kitchens and toilets at the construction camp sites. Moreover, runoff from the chemical storage areas may also contaminate the surface water bodies.

As a mandatory step, all the effluents should be disposed as per the requirements of NEQS. Moreover, to reduce the risk of surface and groundwater contamination, good management practices will be adopted to ensure that fuels, chemicals, raw sewage and wastewater effluent are disposed in a controlled manner.

- T/L section passing through agriculture land, where trees have been raised by the farmers along the boundaries of their agricultural fields or along the water channels. Orchards (mostly Mangos, Banana, Guava and Citrus exist) which may have to be removed.

Land holders should be paid reasonable compensation for the loss of their standing trees, in accordance with the prevailing market rates. This will mitigate the financial losses of the land holders. They should be encouraged to plant new trees, outside the ROW of the T/L.

- Based on the Google images and field surveys, the total cultivated area, which will be affected due to this Project, is nearly 16,500 hectares, which forms about 38.8% of the total area coming in the COI. The agriculture of the tract in Sindh and Punjab will receive significant adverse impact due to various operations such as movement of heavy machinery, erection of Towers, dragging, stretching and stringing etc.

Land holders will be paid compensation for the loss of their standing agricultural crops in accordance with the prevailing market rates as per LAA, Telegraph Act, NTDC practices and LARP specific to the Project. The landholders will also be allowed to salvage the agricultural crops and other vegetation from the affected fields.

- The damages may occur to existing crops during the construction stage due to the following activities:
  - Considerable vehicular movement for the transportation of materials/water and steel work will be involved at the time of concreting of Tower foundations. This movement and storage of materials will cause damage to the existing crops; and
  - The stringing of conductors involves movement of equipment and vehicles along the corridor, which may involve the cutting of trees and considerable damage to the existing crops.

Compensation for the loss of crops to the land owners and cultivators as the case may be will be paid, in accordance with the prevailing market prices and uniformity in rates will be ensured within the local areas;

- It is anticipated that local water resources will be utilized to meet the camp and construction requirements, bringing its use into competition with the local use especially in the desert areas of Sindh and Punjab province in Sections I to II where the water availability is limited.

Approval from the local administration and representatives of the concerned irrigation departments or other relevant authorities will be obtained before using the local surface water resources

- During the construction activities of the Tower foundations, erection and stringing of conductor, people will suffer loss in their annual income due to the loss of crops, trees etc. The land under the Towers during the operation stage may also restrict the current land use for agriculture purposes;

Fair, prompt and negotiated compensation for the crops and trees on private land will be provided to the affectees. Generally, in the areas which are devoid of irrigation and very few trees exist along the Project corridor some assistance if seem possible in the form of good compensation rates may be awarded. However, orchards of Mango, Banana, Citrus need special provision for the compensation

- As the Project route is passing through the rural areas of Okara, Pakpattan, Bahawalnagar, Bahawalpur, Rahim Yar Khan and all districts of Sindh from Ghotki to Matiari, women activities in the field may become affected due to the construction activities;

The Contractor have to select the specific timings for the construction activities like Tower footings, erection and stringing of conductors so as to cause least disturbance to the local population particularly women considering their routine movement hours.

- During baseline survey it was identified that, T/L also crosses some houses of vulnerable people in few areas. During the field visit it was also identified that the owners of the affected structures fall below the poverty line. Income of these vulnerable groups may be affected due to the implementation of the Project like crossing of T/L upon their infrastructure, affect of any assets such as houses, tube wells room etc.

LARP provisions should be strictly followed to eliminate the impact on livelihood.

- Occurrence of accidents/incidents during the construction stage is a common phenomenon and workers as well as locals will be more prone to serious accidents. The COI falls in Sindh and Punjab in which area is sensitive from the law and order point of view and the security of the Contractor and Consultant staff will be a major issue.

Special provision of security for all the activities should be kept to deal with any unpleasant incident. To avoid accidents HSE provisions should be strictly followed. Moreover, complying with the safety precautions for the construction workers as per International Labour Organization (ILO), Convention No. 62 as far as applicable to the Project Contract is highly recommended.

- Removal of the infrastructure like buildings, huts, animal sheds, tube wells etc. will cause the loss of community shelters and sources of income. Although the number of public infrastructure fall into the proposed T/L route, no significant relocation is expected as the Project has the flexibility to provide proper horizontal/vertical clearance for safe passage over the existing infrastructure.

In order to mitigate or compensate the impact of land acquisition and resettlement LARP provisions should be followed.

- During the operational stage, electric current (induction) may travel into the Towers due to short circuiting and may become a hazard to the public and livestock.

It is recommended that NTDC at the planning stage of the Project would plan necessary arrangements in the form of Earthling system of the Towers to avoid accidents. As exact location of Towers spotting is not yet finalized at this stage. However, it is recommended that at least two (02) diagonal legs of the Towers should be properly grounded to avoid any such incident.

- The electromagnetic field (EMF) may have significant adverse impacts on the health of locals. EMF due to extra high voltage (EHV) can cause the risk of *leukaemia,* which is a disease in which white blood cells mutate and become cancerous before maturity. These cells are important in fighting against infection in the body. Leukaemia also slows down the production of red blood cells that are needed to carry oxygen in the blood. Leukaemia is the second leading cause of death for children ages 2-15 years.

Since the Project has been planned to pass through the least populated area and the T/L will be kept at least 100 m from the populated areas, effects due to EMF are envisaged to be minimal due to safe distance. Similarly a vertical clearance required as per international standards will also be maintained especially near the populated areas. During operation stage check will be kept by the NTDC that no construction will be allowed within 100 m of the proposed T/L.

- Collapse of the Towers due to the high wind or earthquake will be dangerous for human as well as animal life and can cause loss to property.

The Towers are designed on the basis of proper subsoil investigations and climatic conditions of the area including maximum wind velocity and earthquakes which are normally based on last 50 years data. At the time of detailed survey for fixing the Tower positions proper soil investigations will be carried out to check the presence of collapsible soils and if detected, Engineer will be informed immediately for design change. It will be ensured that no accident due to collapsing of Towers would occur during the life of the Project. Morover, electrode stations are planned to groubd the current in case of any disaster.

Compensation and Resettlement Policy Framework

In order to mitigate the impact of land acquisition, loss of crops, loss of infrastructure, loss of livelihood etc. a compensation and resettlement framework has been developed. The Project is at the feasibility stage and detailed survey along with the spotting of the T/L Towers and their design are still to be finalized. Same in the case with the Converter Stations for the proposed T/L. Only demarcation of the T/L route and AMs has been marked on maps. In the absence of the demarcation of T/L in the field and spotting of Towers, it was very difficult to identify the PAPs within the ROW. The number of affectees will be identified within the ROW when the detailed LARP survey after the spotting of Towers at the site will be available. Occurrence of any public and religious structures such as mosque or graveyard will also be identified/verified at that stage, which may be affected due to the Project implementation.

Major laws related to the compensation and resettlements are Land Acquisition Act, Telegraphy Act, Local Provincial Laws such as Sindh and Punjab Katchi Abadies Act and ADB Policy.

In principle, Pakistan Law and ADB Policy adhere not only to the objective of PAPs compensation, but also to the objective of rehabilitation. However, LAA is unclear on how rehabilitation is to be achieved and in practice the provision of rehabilitation is left to ad hoc arrangements taken by local governments and specific Project Proponents. To clarify these issues and reconcile eventual gaps between Pakistan Law and ADB Policy, the LARF and LARP for the proposed T/L is being prepared as a separate document to ensure compensation at replacement cost of all items, the rehabilitation of informal settlers and the provision of subsidies or allowances for PAPs that may be relocated, suffer business losses, or may be severely affected.

Entitlement provisions for PAPs cover such impacts as land losses, house and buildings losses, crops and trees losses, a relocation subsidy, rehabilitation measures and a business losses allowance based on tax declarations and/or lump sums.

Agricultural land impacts will be compensated based on whether a PAP's access to, or use of, their land is restricted. For PAPs whose access to and use of, agricultural land is not restricted i.e. they can continue to cultivate the land, compensation will be for removed or damaged crops and trees. For PAPs whose access to, or use of, agricultural land is restricted i.e. they cannot continue to cultivate the land compensation will be paid at replacement value in: (i) cash at current market rates plus a 15% compulsory acquisition surcharge (CAS), or (ii) through replacement land equal in value/productivity to the plot lost. When >10% of an PAP's income or agricultural land is affected, AHs (owners, leaseholders and sharecroppers) will get an additional allowance for severe impacts equal to the market value of a year's gross yield of the land lost (inclusive of winter and summer harvest). Eventual transaction taxes/fees will either be paid by NTDC or waived by local governments. Market rates will be assessed through a survey of prevalent land prices, carried out by local government and financing institutions along with involvement of community.

Residential/commercial land will be compensated at replacement value by either (i) land for land or (ii) cash at current market rates free of any deductions. Renters/leaseholders will receive an allowance corresponding to 3 months' rent. However, the land under Towers and line (100 m wide ROW) can be used by the landowner or sharecropper for cultivation.

Houses, buildings, structures will be compensated in cash at replacement cost free of depreciation, salvaged materials and transaction cost deductions. The compensation for houses/buildings will also include the cost of lost water and electricity connections.

Crops: Cash compensation at current market rates for the net harvest actually lost as it may be the winter, the summer crop, or both. Crop compensation will be paid both to landowners and tenants based on their specific sharecropping agreements.

Trees: Cash compensation shall reflect income replacement based on market price.

Businesses: compensation for permanent business losses will be encashed for a 1-year income based on tax declaration or, if unavailable, based on the official minimum salary; compensation for temporary business will be encashed for the period of income interruption (1 to 3 months) based on tax declaration or, if unavailable, official minimum salary.

Business workers and employees: Indemnity for lost wages for the period of business interruption up to a maximum of 3 months.

Agricultural land leaseholders, sharecroppers and workers: Where the access to, or use of, the land is restricted; affected leaseholders will receive either a renewal of the lease in other plots or cash corresponding to the yearly yield of land lost for remaining years of the lease up to a maximum of (3) years. Sharecroppers will receive their share of harvest at market rates (if impact is temporary) or if the land is lost permanently additional compensation for 1 crop. Agricultural workers, with contracts interrupted, will get an indemnity in cash corresponding to their salary in cash and kind for the remaining part of the agricultural year (inclusive of both winter and summer crops).

Community structures and public utilities: These will be fully compensated or replaced/rehabilitated so as to satisfy their pre-Project functions.

Relocation subsidy: PAPs forced to relocate will receive a relocation subsidy sufficient to cover transport costs and living expenses for 1 month.

Framework provides the entitlement matrix and the proposed guidelines for the LARP.

Environmental Management and Monitoring Plan (EMMP)

In the end Environmental Management and Monitoring Plan (EMMP) has been developed. The main objectives of the EMMP are:

- Provide the details of the Project impacts along with the proposed mitigation measures and the corresponding implementation activities;
- Define the role and responsibilities of the Project Proponent, Contractor, Supervisory Consultants and other role players and effectively communicate environmental issues among them;
- Define a monitoring mechanism, reporting frequency and identify monitoring parameters to ensure that all the mitigation measures are completely and effectively implemented; and
- Identify the resources required to implement the EMMP and outline the corresponding financing arrangements.

An Environmental Mitigation & Management Matrix (MMM) for the T/L and Converter Stations are attached in the EMMP, which establishes the linkages between the environmental and social impacts, mitigation strategy and the agencies responsible for execution.

EMMP includes the Monitoring Mechanism, Monitoring Plan, Site Restoration Plan Guidelines, Solid and Hazardous Plan Guidelines, Chance Find Procedures, Tree Plantation

Plan, Documentation Plan, which will ensure that the proper results are achieved by the implementation of measures from concerned entities. The monitoring of environmental and social activities will be carried out by NTDC through Environmental and Social Experts from their Environmental Cell or hired staff by NTDC Internal Monitoring agency. The Environment and Social Expert working under the NTDC field staff will supervise all the activities in the field and will provide assistance to the NTDC staff in this regard. He will also ensure public participation.

Monitoring and evaluation (M&E) is also proposed in the EMMP.

An estimated cost for Environmental Management, Monitoring and Training has also been provided in the EMMP for inclusion in the PC-I or overall Project Cost. It should be noted that as referred earlier the Project is at a preliminary stage and the detailed survey is to be carried out for the Project showing the actual position of the Towers, so at this stage only tentative and lump sum amount has been allocated for the relocation of the infrastructure and the compensation for Land Acquisition and Resettlement is based on the environmental and social field surveys.

As a conclusion of the Study, the proposed Project have positive as well as some significant adverse impacts that can however be managed by proper mitigation and compensation measures and residual adverse impacts will not be of significant nature.

1 INTRODUCTION

1.1 Background

The main sources of the Power generation in Pakistan are based on Fuel Oil and Gas, Hydel and Nuclear Power Plants. Since Pakistan is not an oil producing Country, therefore, the high price of electricity in Pakistan is due to the significant contribution of Thermal Power based on Fuel Oil. Pakistan is facing Power crisis due to demand and supply shortfall as well as ever increasing electricity prices. With the reduction in the gas supply in Pakistan the conditions are further deteriorated. Moreover, the existing network of National Transmission and Dispatch Company (NTDC) is already overloaded and with the potential of induction of new PowerSources, new Transmission Lines (T/Ls) are very much required on urgent basis to despatch the additional planned Power to the major distribution centers of the Country for supply to the consumers.

In order to cope with imminent Power crises and reduce load shedding, Government of Pakistan (GOP) has looked out for various Power Generation options based on Regasified Liquified Natural Gas (RLNG), Imported Coal, Coal reserves of Thar, Solar etc.

Taking a proactive approach, NTDC has proposed to include the T/L from the planned Power Plants near Karachi and Thar region. It is envisaged that a capacity of about 4000 MW would be developed in Thar and Karachi regions in few years and new T/Ls need to be developed for transmitting this quantum of Power to major load center of Pakistan which are located in Upcountry. In order to transmit this Power from Thar and Karachi to Upcountry,a 500 kV collector/switching station is being developed at Matair. In order to evacuate the power at Matari station, T/L needs to be established on the basis of technical studies. A Coverter Station has been proposed at Matiari to collect the power and T/L from Matiari to Lahore has been proposed for the implementation on fast track basis.

It is important to mention here that as per information made available the proposed T/L will be implemented in Built Operate Own and Transfer (BOOT) mode. National Engineering Services Pakistan (Pvt.) Limted (NESPAK) has been assigned the challanging task to complete the Enviornmental Imapct Assessment (EIA) study to fulfil the requirements of Enviornmental Protection Agencies (EPAs) and to initate the proess of NOC. Terms of Reference (TOR) for the study as provided by the NTDC is attached as Annex-I.

Note: This EIA Report comprises two volumes namely, 1 and 2. Volume 1 is the main report while Volume 2 contains maps, annexes and photologs.

1.2 Nature, Size and Location of the Project

The proposed Project is a linear project of T/L from Matiari to Lahore to transfer the Power. The proposed T/L crosses thorugh two provinces i.e. Sindh and Punjab hence the T/L is divided into the two (02) mian sections namely Section-I and II, Section-I, Angle Marker (AM) # 1 to 49 are located in Sindh province and Section-II AM # 50 to 169 are located in Punjab province.Figure 1-1 shows the location map of the proposed T/L. In this report, Sindhand Punjab provinces are used to indicate the T/L route districts falling in the respective provinces. Sindh and Punjab provices hosts large number of districts proposed T/L only passes few of these districts. Figure 1-2 shows the location of T/L in desert of these two provices in Pakistan.

Proposed T/L is divided into AMs, which is the point where the proposed T/L changes its direction (angle).

The proposed T/L starts from Matiari district Sindh and finishes in Punjab province in district Nankana Sahib. Length of the T/L is about 865.55 km, of which 314.9km falls in Sindh province and remaining 550.65 km in Punjab province. Proposed T/L route passes through total twelve (12) districts, of which five (05) districts are located in Sindh and the remaining seven (07) are located in Punjab. Figure 1-3 a&b shows the map of Sindh and Punjab provinces showing the districts being crossed by the proposed T/L. Proposed. T/L Section-I and II mostly crosses the rural agriculture and some desert areas in Sindh province, while as it enters Punjab province at Sadiqabad, some Part of Section-II alos crosses over desert in Rahimyar Khan and Bahawalpur districts and some part in the semi-urban to urban areas of Okara and Kasur districts.

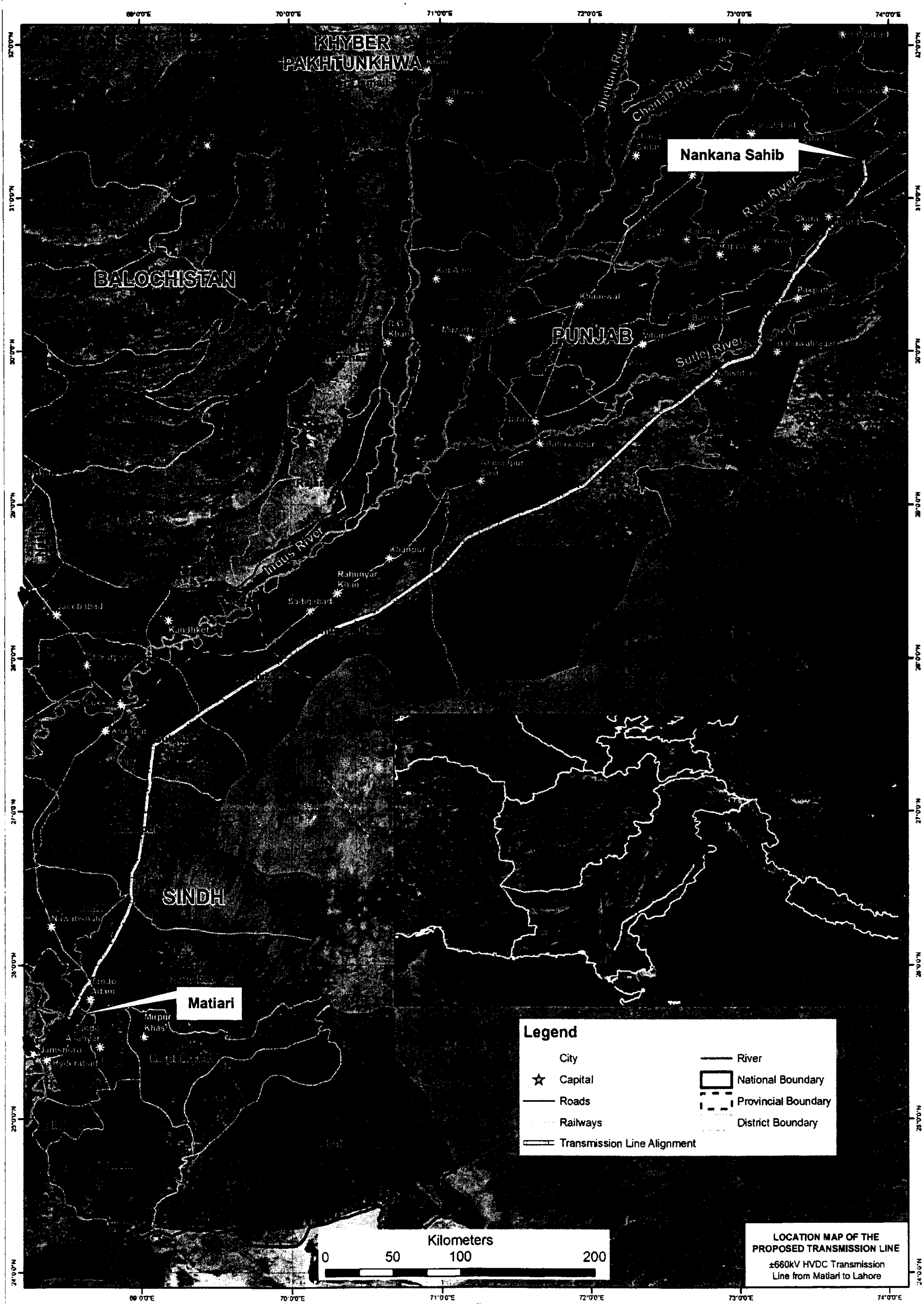
1.3 Project Objectives

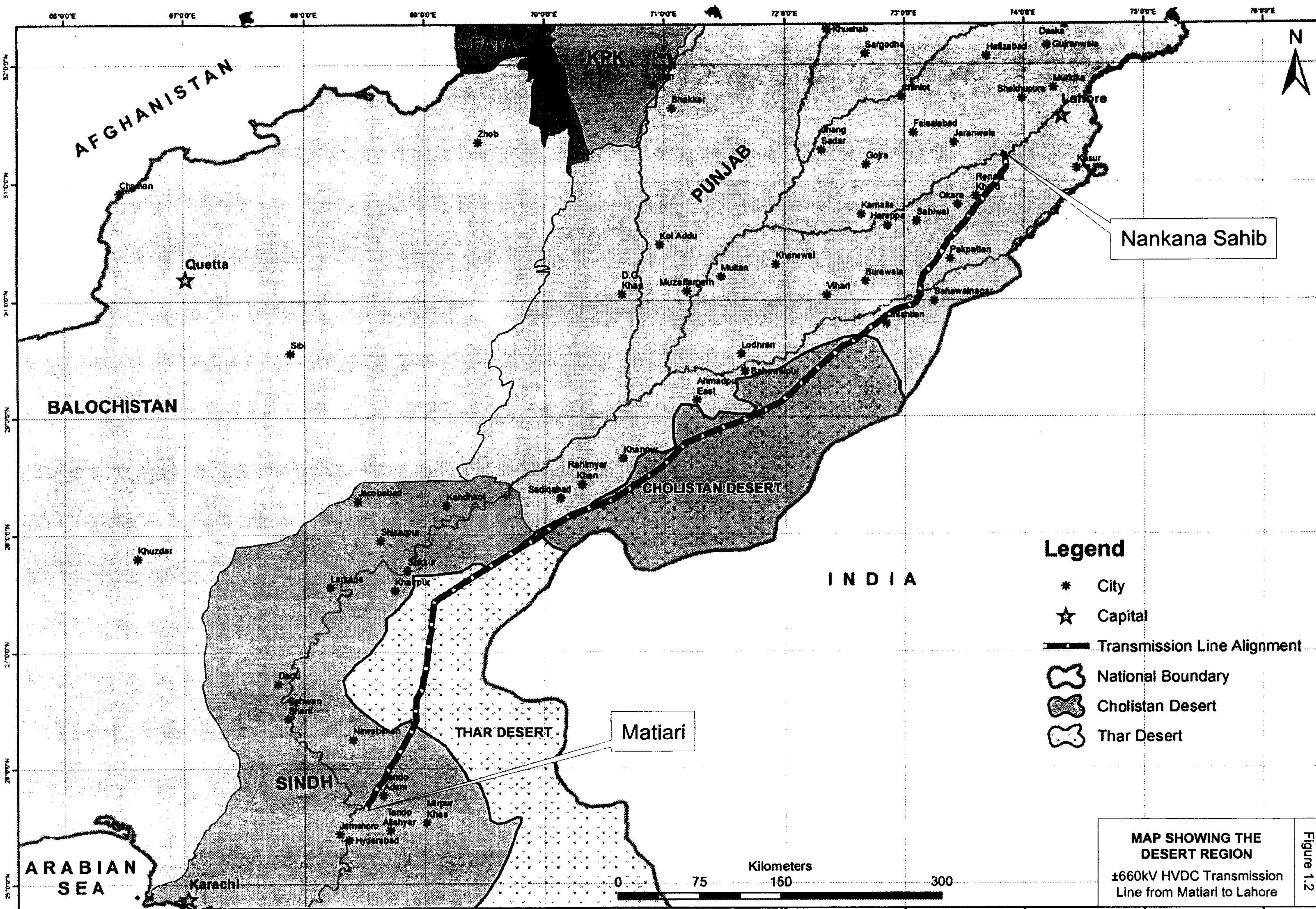
Considering the increasing demand of energy and current shortfalls, Government is planning to install new Power Plants and additional T/Ls and Grid Stations which are required to meet the growing demand of transmission and to strengthen the existing NTDC transmission system. The proposed Project is the part of NTDC Power Sector Expansion Program. The main objectives of NTDC's program is to provide adequate facilities for reliable and stable transmission of electrical Power, keeping in view the growing demand of domestic, commercial, industrial and agricultural customers of Pakistan Water and Power Development Authority (WAPDA).

WAPDA's Power Wing has been unbundled and corporative into Distribution Companies (DISCOs), Generation Companies (GENCOs) and NTDC. Main objective of NTDC is to procure Power from GENCOS, IPPs and WAPDA's Hydro Wing on behalf of DISCOs and to deliver it to the networks of DISCOs through integrated system of 500 KV and 220 KV T/Ls and Sub Stations.

As the major Hydro Resources are located in the northern areas of the country and thermal generation facilities are concentrated in southern parts, a large and extensive Power transmission network consisting of 500, 220, 132 and 66 KV T/Ls and Grid Stations was built for delivering Power to the main distribution centers which are also located mostly in the middle part of the country. Further expansion in this transmission network is being constantly carried out in line with the plan for expansion of generation schemes for system improvements.

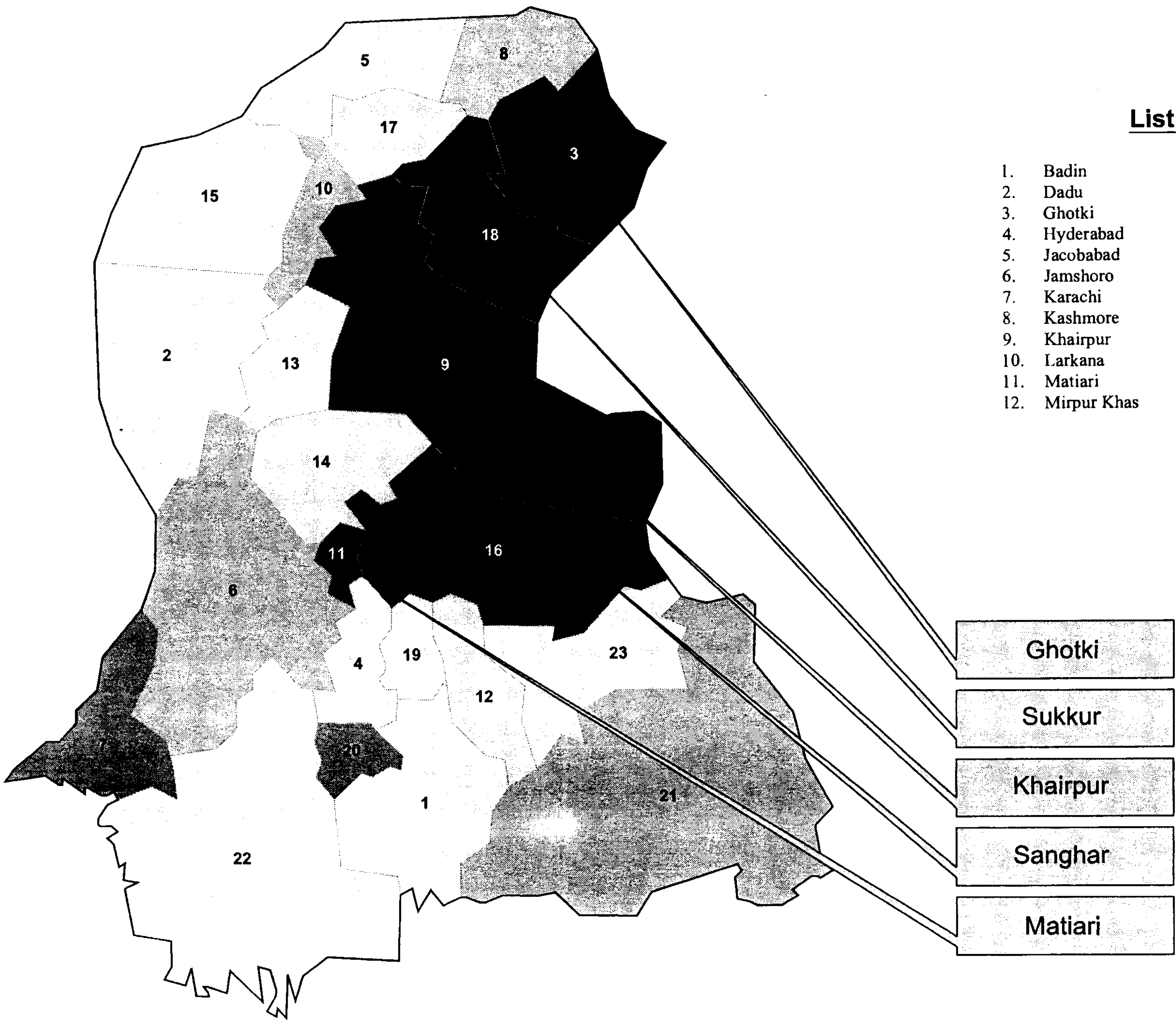
Figure 1.1


KHYBER PAKHTUNKHWA
BALOCHISTAN
PUNJAB
SINDH
Nankana Sahib
Matiari
Jhelum River
Chenab River
Ravi River
Sutlej River
Indus River
Rahimyar Khan
Sadiqabad
Kandhkot
Tando Adam
Mirpur Khas
Hyderabad
Legend
City
Capital
Roads
Railways
Transmission Line Alignment
River
National Boundary
Provincial Boundary
District Boundary
Kilometers
0 50 100 200
LOCATION MAP OF THE PROPOSED TRANSMISSION LINE
±660kV HVDC Transmission Line from Matiari to Lahore



AFGHANISTAN
BALOCHISTAN
PUNJAB
SINDH
KPK
FATA
INDIA
ARABIAN SEA
CHOLISTAN DESERT
THAR DESERT
Quetta
Lahore
Karachi
Nankana Sahib
Matiari
Legend
City
Capital
Transmission Line Alignment
National Boundary
Cholistan Desert
Thar Desert
Kilometers
0
75
150
300
N
MAP SHOWING THE DESERT REGION
±660kV HVDC Transmission Line from Matiari to Lahore

Figure 1.2



List of Districts

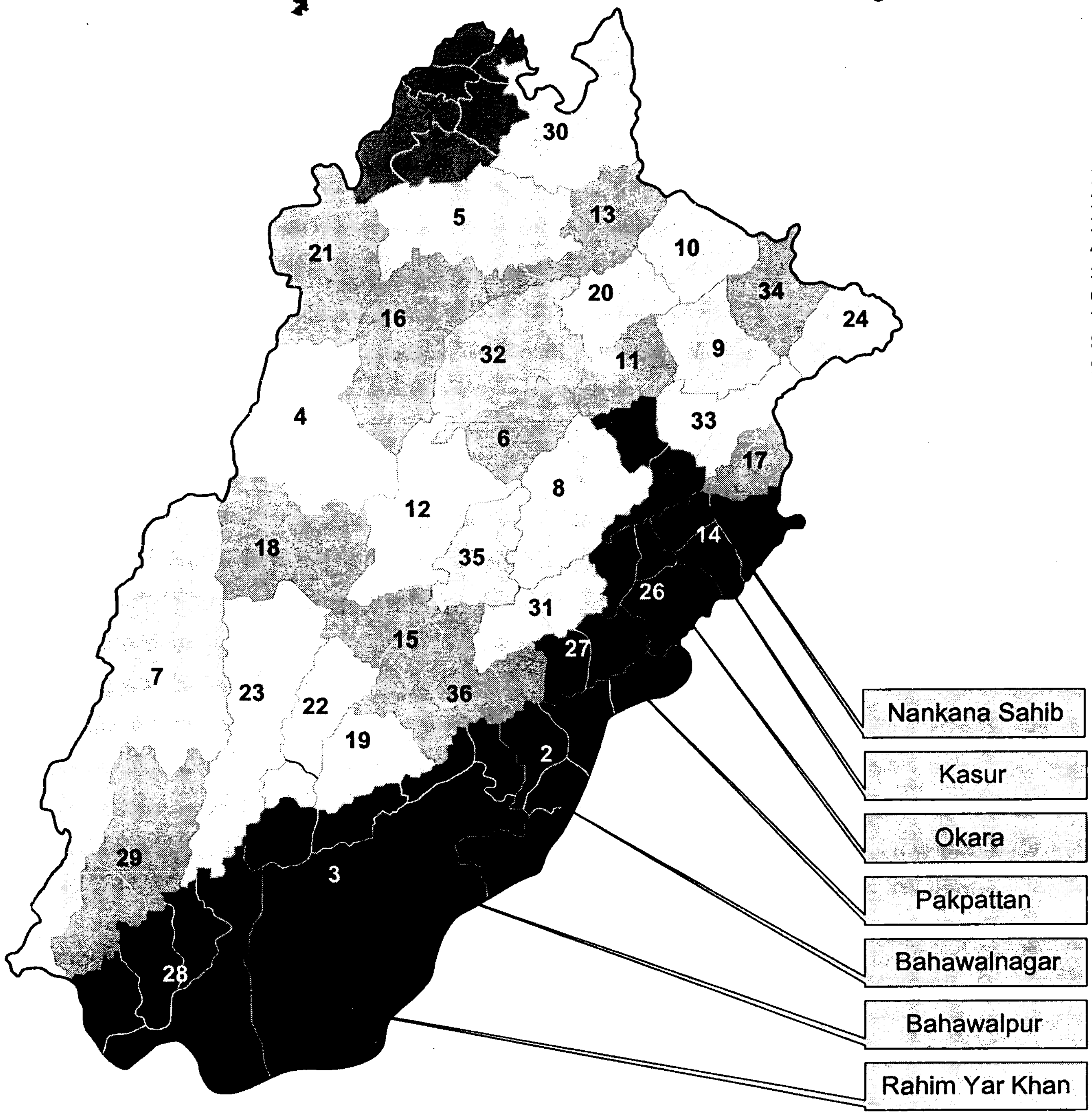
1. Badin
2. Dadu
3. Ghotki
4. Hyderabad
5. Jacobabad
6. Jamshoro
7. Karachi
8. Kashmore
9. Khairpur
10. Larkana
11. Matiari
12. Mirpur Khas
13. Naushahro Feroze
14. Shaheed Benazirabad
15. Qambar Shahdadkot
16. Sanghar
17. Shikarpur
18. Sukkur
19. Tando Allahyar
20. Tando Muhammad Khan
21. Tharparkar
22. Thatta
23. Umerkot

- Not to Scale

MAP OF SINDH PROVINCE

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 1.3a



- Not to Scale

List of Districts

1. Attock
2. Bahawalnagar
3. Bahawalpur
4. Bhakkar
5. Chakwal
6. Chiniot
7. Dera Ghazi Khan
8. Faisalabad
9. Gujranwala
10. Gujrat
11. Hafizabad
12. Jhang
13. Jhelum
14. Kasur
15. Khanewal
16. Khushab
17. Lahore
18. Layyah
19. Lodhran
20. Mandi Bahauddin
21. Mianwali
22. Multan
23. Muzaffargarh
24. Narowal
25. Nankana Sahib
26. Okara
27. Pakpattan
28. Rahim Yar Khan
29. Rajanpur
30. Rawalpindi
31. Sahiwal
32. Sargodha
33. Sheikhupura
34. Sialkot
35. Toba Tek Singh
36. Vehari

MAP OF PUNJAB PROVINCE

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 1.3h

The proposed Project aims to meet not only incremental demand for Power but also overcome voltage problems and enhance reliability of Power supply in service areas of DISCOs. The Project will also reduce overloading on existing 220/132 KV transformers. Finally, the Project may reduce transmission losses to about 20.22 MW.[2] Immediate objectives of the proposed Project can briefly be summarized as under:

- Dispatch Power from Matiari nearby areas to the major load distribution center of the Country to reduce the existing shor falls;
- Improvement in the voltage profile of Grid Stations;
- Reduction in T/L losses;
- Improvement in the NTDC System reliability; and
- Socio-economic uplift of the T/L route areas.

1.4 Scope of the Study

Consultants have envisaged the following Scope of Work (SOW) related to environmental and resettlement studies in the light of Terms of Reference (TOR) and discussions held with the NTDC:

- Review of national and local guidelines, laws and policies;
- Review of all relevant existing data, studies, reports and drawings;
- Minimize and avoid the environmental and resettlement effects during design;
- Identification of the most environmentally and socially feasible T/L route;
- Collection of baseline data related to Physical, Ecological and Social/Cultural environmental aspects;
- Identification, evaluation and categorization of the potential significant adverse physical, ecological and socio-economic impacts on the local environment during the construction and operational stages of the proposed T/L;
- Recommend appropriate environmental and social mitigation measures for the identified adverse impacts and monitoring plans to address them;
- Review the capability of the NTDC staff for the development of the Environmental Management and Monitoring Plan (EMMP);
- Preparation of EMMP;
- Determine the regulatory procedures and protection measures needed to obtain environmental and forestry clearances from the concerned departments;
- Provide technical assistance to NTDC for the issuance of No Objection Certificate (NOC) from the concerned EPAs; and
- Prepare future line of action/further studies required such as Land Acquisition and Resettlement Framework (LARF), Land Acquisition and Resettlement Plan (LARP) etc.

Copy of TOR's relevant portion is attached as Annex-I.

1.5 Purpose of the Report

The purpose of this EIA Report is to assess whether or not significant adverse environmental and social impacts are anticipated and to suggest mitigation and remedial measures to make the Project environmental friendly and sustainable during the construction and operational stages of the Project and to initiate the process of NOC from the concenred EPAs. In order

[2] EIA Report of Lahore New Grid Station Project

to implement the proposed mitigation measures, an EMMP with cost estimates has been developed. EMMP also provides the environmental management capability and recommends institutional strengthening measures of the management units of NTDC.

1.6 Extent of the Study

As per PEPA, 1997 and Pak-EPA (Review of IEE and EIA) Regulations, 2000, Schedule-II, T/L of 11 KV and above requires an EIA study.

According to the PEPA, 1997 & EPA Regulations, 2000 a separate EIA, study is required for the Converter Stations. At this stage these stations are considered as a part of the Project, but at the time of Project implementation a separate environmental study would be carried out for the proposed Sub Stations and Converter Stations.

This EIA study covers the environmental impacts of the proposed T/L, Converter Stations comprising the physical, ecological and socio-economic aspects. A minimum strip of 100 m (50 m on either side from the centerline) was delineated as Right of Way (ROW) in which direct impacts of the proposed T/L are envisaged due to the implementation. However, for indirect impact related to physical, ecological and social domains, a COI of 500 m on each side of transmission centerline was considered as project corridor or COI.

It is worth to mention here that the location of spotting of Towers and the material quarry sites is not finalized yet. Project foot print has not been made available on ground. Therefore, their general anticipated impacts are identified. The site specific comments will be taken up after the finalization of the spotting and marking of related sites. This study also suggests the mitigation measures and describes the institutional arrangements and the Mitigation Management Matrix (MMM) with cost estimates.

1.7 Project Proponent

Ministry of Water and Power of Pakistan's is managing the Power sector with the crisis management objectives to improve the efficiency of the Power sector and to meet customers' electric energy requirements on a sustainable and environment friendly basis. The specific objectives are:

- Stop load shedding;
- Constructing new Grid Stations;
- Reducing line losses; minimizing tripping and theft control;
- Revamping of generation units and to improve customer services; and
- Development of an integrated automated Power planning system for generation, transmission and distribution to ensure system stability, fault isolation and upgrade relying, metering and tripping system at NTDC as well as DISCOs levels.

NTDC under the Ministry of Water and Power is the Project Proponent of the proposed T/L. NTDC operates under WAPDA. It commenced commercial operation on December 24, 1998 after incorporation on November 6, 1998. It was organized to take over all properties, rights and assets obligations and liabilities of 220 KV and 500 KV Grid Stations and T/Ls network owned by WAPDA. NTDC operates and maintains nine (09) 500 KV Grid Stations, 4,160 km of 500 KV T/Ls and 4,000 km of 220 KV T/Ls in Pakistan. NTDC was granted a transmission license on December 31, 2002 by National Electric Power Regularity Authority (NEPRA) to engage in the exclusive transmission business for a term of thirty (30) years, pursuant to Section 17 of the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997. NTDC's headquarter is situated at WAPDA House Lahore[3] with details as given below.

National Transmission & Dispatch Company Limited (NTDC)

[3] NTDC Official Website

Room # 414, WAPDA House

Shahrah-e-Quaid-e-Azam, Lahore

Tel: 92 (042) 99202229

Fax: 92 (042) 99200894

E-mail: ceo@ntdc.com.pk

1.8 Approach and Methodology

The detailed approach and methodology used for the EIA study is as follows:

1.8.1 Literature Review

Before mobilization, Consultants carried out a desk study through collection and review of guidelines, data and reports related to the Project that included (a) review of National Environmental Legislations and international best practices related to Environmental and Social Assessment Guidelines/Safeguards; (b) Google Earth Satellite Imagery; (c) Relevant District Census Reports (DCR) and any other relevant documents/drawings; and (d) Reference documents such as HVDC/HVAC T/L from Thar to Lahore, Thar to Matiari and Peshawar to Tajikistan (CASA Project), T/L from Iran to Pakistan to Import 1000 MW, Lahore New Grid Station and Allied T/Ls and other projects.

1.8.2 Route Optimization Study

Judicious route selection is the most cost effective method of reducing the environmental and social impacts of the construction and operation of the T/L and other linear infrastructure. Consequently, the identification and optimization of the route was the most critical phase of the present Feasibility Study.

The objective of this work was to obtain first-hand overview of the Project environmental and social setting and to conduct an initial analysis of the physical, biological and social constraints posed within the proposed T/L route.

A map was prepared by digitizing the Google Imageries over which the existing Sub Stations and T/Ls along with the proposed tentative route for the proposed T/L from Matiari to Lahore was marked by CET with NTDC. This tentiave route was handed over to NESPAK experts by NTDC for further route optimization. NESPAK experts based on the GIS and existing information and experience developed a critiera for route optimization. Efforts were made to optimize the route in such a way as to avoid environmentally sensitive areas such as protected areas, game reserves, lakes, archaeological and historical sites, settlements etc. The objective of route optimization was to propose an initial corridor that will minimize technical and environmental constraints.

An initial assessment of the infrastructure, types of land and the settlement pattern were also made based on the preliminary plans. The existing main towns and villages were identified along the proposed Project alignment through which accessibility to the proposed alignment was made.

The following environmental criteria were used in addition to technical and design considerations for the proposed T/L route.

- Avoid towns/populated areas;
- Avoid indigenous or tribal settlements;
- Avoid cultural, religious and historical buildings;
- Maintain minimum disturbance to the natural habitat and vegetation;
- Maintain appropriate distance from the sensitive receptors (500 m);
- Avoid large water bodies like lakes, rivers or streams; and

- Avoid airports and other such facilities.

After the marking of proposed T/L route based on the above criteria, route optimization was carried out jointly by the design and environmental teams of NESPAK and route was send to CET for finalization.

1.8.3 Review of Environmental Laws and Institutional Requirements

National laws, legislations, guidelines as well as ADB Safeguards and Policies/Guidelines in the absence of local laws related to resettlement along with relevant international protocols were reviewed.

1.8.4 Delineation of Corridor of Impact (COI)

COI/Study Area include the actual Project Right of Way (ROW) as well as the area in the surroundings in which positive and adverse impacts may be foreseen due to the implementation of the proposed Project was marked based on the .

Based on the available tentative T/L route marked at Google Earth, a route optimization of the T/L was made by a team of experts to highlight any potential sensitive physical, ecological and socio-economic constraints in and along the proposed T/L route. Based on the above considering the urgency and short time avaialble, a maximum COI of 500 m with 250 m on each side from the centerline was selected as COI for the baseline survey.

1.8.5 Survey of COI

A team of environmental and social experts including surveyers, ecolgists, land experts, valuation experts, enumerators etc. carried out the environmental and social survey of the COI to familiarize themselves with the local conditions and the environmental settings. During the survey, the information regarding the topography, soils, rock, surface water, groundwater, flora and fauna, wetlands, forested areas, social settings and villages/towns along the COI was observed.

1.8.6 Analysis of Alternatives

The analysis of different alternatives was carried out during the selection of the most feasible T/L route of the study in consultation with NTDC and CET staff in order to select the most viable route keeping in view the environmental, economic and social constraints.

It is an international practice for the preparation of EIA that the proposed Project is compared with other alternative arrangements that could be developed to meet the objectives for which the proposed Project has been planned.

An analysis was carried out in consideration of technical and environmental aspects. Moreover, No Project Option (NPO) was also considered with reference to the effect on the Country's economics. This exercise provides justification for the need of the proposed Project.

The following alternatives were considered for the Project:

- NPO;
- Technological System Study of T/L Alternatives;
- Route Alignment Alternatives; and
- Design Alternatives.

1.8.7 Environmental Baseline Survey of the Project

After the selection of the most feasible route for the T/L based on satellite images and the delineation of COI, detailed environmental survey was carried out within the COI. The T/L route has been divided into two (02) Sections based on provincial boundaries. Detailed investigations/surveys were carried out on all the T/L sections for environmental parameters on which any adverse or positive impacts were envisaged by the implementation of the Project. Baseline surveys were carried out during the month of June and July, 2015.

Prior to the start of field activities, comprehensive checklists, proformas and maps were developed covering the following main parameters:

1.8.7.1 Physical Environment

The information needed for the preparation of physical environment included the following main parameters:

- Land resources (including landuse pattern, soil composition, contamination of soil and soil erosion etc.);
- Water (including available surface and groundwater resources and natural streams, hydrology, spring water, water supply, water contamination etc.);
- Climate (including temperature, rainfall, humidity, wind speed and direction etc.);
- Ambient air quality and noise Level;
- Existing solid waste management and effluents disposal practices and storm water drainage;
- Buildings, including residential, commercial and animal shed for complete/partial relocation;
- Cultural properties (mosques, shrines, graveyards);
- Archaeological monuments; and
- Other private/public infrastructures such as roads, telephone poles, hand pumps, tubewells etc.

1.8.7.2 Ecological Environment

- Flora (including vegetation cover, trees, shrubs and grasses, valuable or rare trees and their loss due to implementation of the Project etc.);
- Fauna (including wildlife, avifauna, domestic animals etc.);
- Reserved forests and wildlife sanctuaries in COI;
- Wetlands;
- Migratory birds corridors; and
- Endangered species (both flora and fauna).

1.8.7.3 Socio-Economic Environment

A sample survey was carried out within the COI in order to develop the socio-economic baseline information of the general settled population. There are 164 villages/settlements located in the COI of the proposed T/L in twelve districts. Based on the statistical sampling methodology, 450 households were interviewed and consulted for the collection of baseline socio-economic data.

The following major aspects were covered in the socio-economic baseline survey of the sample population settled along the COI:

- Demographic characteristics;
- Literacy status/ education;
- Nature of business/occupation;
- Livelihood/income;
- Living standard of the population;

- Access to credit;
- Social Infrastructure available;
- Gender issues;
- Pressing needs of the people;
- Community perception about the Project etc.; and
- Other aspects.

Checklists and Proformas which are used during the baseline surveys for the EIA study are attached as Annex-II.

1.8.8 Stakeholder Consultations

The Consultants identified Project stakeholders and held meetings with them during the surveys to receive feedback on the expected environmental issues related to the Project impacts and suggested mitigation measures. Meetings were carried out with the Project affectees, relevant departments including Wildlife, Agriculture, Fisheries, Provincial EPAs, Irrigation and Power Departments, WAPDA, NTDC, Non-Governmental Organizations (NGOs) etc. to discuss the issues/constraints and get their views and feedback to mitigate the potential environmental impacts associated with the implementation and operation of the Project. All in all more than 67 consultations/group discussions with the locals residing in the COI were carried out along the T/L route at various locations.

Based on the above, letters were also written to the concerned Wildlife and Forest Departments regarding the occurrence of any protected areas. The copies of the letters are attached as Annex-III. The proceedings of the consultations/meetings along with the photographs and list of participants are documented in Chapter 6.

1.8.9 Impact Assessment and Mitigation Measures

A logical and systematic approach was adopted for impact identification and assessment. The process began during the screening and continued through scoping which identified the key issues and classified them into different categories. The tools, which were used for impact assessment, are:

- Checklists;
- Matrices; and
- Overlays.

Identification of potential environmental and social impacts in terms of their nature, magnitude, extent, location, timing and duration were carried out. The impacts were correlated to the Project location, design stage, construction stage and operation stage. Based on the impacts prediction methods and as a result of public/stakeholder consultations, the Consultants screened the adverse environmental impacts for inclusion in the mitigation measures and environmental management plan. The same process was followed for the identification of social impacts. Public consultations (which provided feedback of the impacts from the stakeholder's viewpoint) were used to screen out the insignificant impacts. Matrices and overlays were used for the evaluation of temporal and spatial impacts respectively.

The Consultants proposed practicable, economically feasible and socially acceptable mitigation measures for the significant adverse environmental and social impacts. These measures were based on exploring the ways to achieve the Project objectives causing least disturbance to the existing environment by alternative ways, proposing changes in the Project design (ROW, height of the T/L Towers and sitting of facilities), through improved monitoring and management practices (storage of construction materials, labour camps, waste disposal, disposal of construction debris etc. or through monitory compensation).

1.8.10 Environmental Management and Monitoring Plan (EMMP)

An EMMP has been prepared to ensure the adequacy and effectiveness of the proposed protocol by clearly identifying the roles and responsibilities of the agencies responsible for implementation, monitoring and auditing of EMMP activities, existing and suggested framework, necessary approvals, training needs and the required further studies. EMMP also include organizational setup, a monitoring mechanism, monitoring plan, environmental and social parameters to be monitored with their frequency. Similarly, costs for environmental monitoring and social component/social mitigation measures were also included as part of the EMMP. Environmental monitoring, evaluation, auditing and reporting mechanism were also proposed in the EMMP.

1.8.11 Conclusions and Recommendations

Based on the baseline conditions, identified impacts and suggested mitigation measures and proposed environmental cost, conclusions are made. Based on the conclusions, recommendations regarding the future plan of action and outcome of the EIA report are provided.

1.9 Report Structure

The EIA report has been structured into following chapters:

Chapter-1 provides the Project background and nature, size and location of the Project, Project objectives, Project Proponent followed by scope of the study, purpose of the study and its approach, extent of the study and the report structure.

Chapter-2 provides a brief about national environmental policies, legal and administrative frameworks applicable to the Project together with the applicable International Safeguards/Guidelines and international protocols.

Chapter-3 provides the analysis of alternatives considered for the proposed Project so far.

Chapter-4 presents description of the Project including Project components, approvals and implementation schedule for Project and other information available so far.

Chapter-5 explains in detail the existing environmental baseline conditions of the Study Area considering the physical, ecological and social environment.

Chapter-6 depicts the consultations carried out with the stakeholders to know the concerns and issues.

Chapter-7 exhibits the environmental and social impacts assessment with the proposed mitigation measures during the design, construction and operation stages of the Project.

Chapter 8 presents the compensation and resettlement framework for the loss of assets by the erection of the line with an estimate of the budget and a schedule of actions to be implemented to make the inventories and the monitoring of the compensations.

Chapter-9 provides an overall approach for managing and monitoring the environment related issues and describes the institutional framework and resource allocations to implement the EMMP along with the environmental monitoring plan.

Chapter-10 provides the major conclusions in the light of the available Project plans, field surveys and impacts assessment; mitigation measures; and necessary recommendations.

2 POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK

2.1 General

This chapter provides an overview of the official policy framework and legislation that applies for controlling the environmental consequences of the Project implementation and operation. The Project is expected to comply with all the policies, laws, guidelines, acts and legislations of the Pakistan and other related environmental aspects.

2.2 National Policy Framework

Following elements of national policy framework are relevant to this Project:

2.2.1 National Conservation Strategy, 1992

The Pakistan National Conservation Strategy (NCS), which was approved by the federal cabinet in March 1992, is the principal policy document on environmental issues in the Country (EUAD/IUCN, 1992).

The NCS outlines the Country's primary approach towards encouraging sustainable development, conserving natural resources and improving efficiency in the use and management of resources. The NCS has 68 specific programs in 14 core areas in which policy intervention is considered crucial for the preservation of Pakistan's natural and physical environment. The core areas that are relevant in the context of the proposed Project are pollution prevention and abatement, restoration of rangelands, increasing energy efficiency, conserving biodiversity, supporting forestry and plantation and the preservation of the cultural heritage.

2.2.2 National Environment Policy, 2005

The national environmental policy 2005 aims to protect, conserve and restore Pakistan's environment in order to improve quality of life of the citizens through sustainable development. The main objectives of the policy are:

- Conservation, restoration and efficient management of the environmental resources;
- Integration of the environmental considerations in policy making and planning process;
- Capacity building of government agencies and other stakeholders at all levels for the better environmental management;
- Meeting international obligations effectively in line with the national aspirations; and
- Creation of a demand for environment through mass awareness and community mobilization.

2.2.3 National Climate Change Policy, 2012

The National Climate Change Policy provides a framework for addressing the issues that Pakistan faces or will face in future due to the changing climate. In view of Pakistan's high vulnerability to the adverse impacts of climate change, in particular extreme events, adaptation effort is the focus of this policy document. The vulnerabilities of various sectors to climate change have been highlighted and appropriate adaptation measures spelled out.
The policy covers measures to address issues in various sectors such as water, agriculture, forestry, coastal areas, biodiversity and other vulnerable ecosystems.

Notwithstanding the fact that Pakistan's contribution to global greenhouse gas (GHG) emissions is very small, its role as a responsible member of the global community in combating climate change has been highlighted by giving due importance to mitigation efforts in sectors such as energy, forestry, agriculture and livestock.

Furthermore, appropriate measures relating to disaster preparedness, capacity building, institutional strengthening; technology transfer; introduction of the climate change issue in higher education curricula; ensuring environmental compliance through Initial Environmental Examinations (IEE) and Environmental Impact Assessments (EIA) in the development process; addressing the issue of deforestation and illegal trade in timber; promoting Clean Development Mechanisms (CDM); and raising Pakistan's stance regarding climate change at various international forums, have also been incorporated as important components of the policy.

The policy thus provides a comprehensive framework for the development of Action Plans for national efforts on adaptation and mitigation. This policy document is a 'living' document and will be reviewed and updated regularly to address emerging concepts and issues in the ever-evolving science of climate change.

2.2.4 National Disaster Risk Reduction Policy, 2013

Disasters have an enormous and significant adverse impact on the development of key sectors of economy like agriculture, infrastructure, housing, health, and education and above all the environment, they result in a serious social and economic set-back to the sustainable development. Disasters also pose threat to increasing poverty and resultantly backslide the national development targets set to achieve the Millennium Development Goals (MDGs). Climate change induced disasters pose even greater threat to sustainable development in developing country like Pakistan which is ranked quite amongst the most vulnerable countries. Continuous floods of 2010, 2011 and 2012 are seen as an indication of more intense and frequent extreme events in the future.

Disaster risk reduction interventions were being carried out in the country till date by different departments / agencies in isolation at national, province and district levels. There was a strong need to give them directions and sound guidelines to align their activities in line with the true spirit of National Disaster Management Act, 2010 to counter the threats of disasters faced by the country. NDMA, being the lead focal agency for disaster preparedness and management, has therefore, embarked upon formulation of a comprehensive National Disaster Risk Reduction Policy through wider consultations with all stakeholders including all provinces, state of AJ&K and regions. This policy covers disasters risk reduction in a more holistic way and introduces a proactive and anticipatory approach by laying special emphasis on risk assessment and prevention.

2.2.5 Pakistan Labor Policy, 2010

The main objective of the Labour Policy, 2010 is the social and economic well-being of the labour of Pakistan. The Labour Policy, 2010 has following four (04) parts:

i) Legal Framework;
ii) Advocacy: rights of workers and employers;
iii) Skill development and employment; and
iv) Manpower export.

2.2.6 Poverty Reduction Strategy Paper, 2003

The full Poverty Reduction Strategy Paper of Pakistan (PRSP), prepared after a long consultative process involving the ministries, provincial and district governments, civil society, various interested groups, donors and grass root communities across the provinces of Pakistan. It outlines the broad framework and strategy for poverty reduction based on four (04) pillars:

- Accelerating economic growth while maintaining the macro-economic stability;
- Improving the governance;

- Investing in human capital; and
- Targeting the poor and vulnerable.

The PRSP also highlights the programs and policies of the Government under each of these pillars and proposes indicators to monitor the outcome of these policies as well as intermediate indicators for social sectors.[4]

2.2.7 National Forest Policy Pakistan, 2001

This policy covers the Renewable Natural Resources (RNR) of Pakistan i.e. forests, watersheds, rangelands, wildlife, biodiversity and their habitats. The policy seeks to launch a process for eliminating the fundamental causes of the depletion of RNR through the active participation of all the concerned agencies and stakeholders, to realize the sustainable development of the resources. It is an umbrella level policy providing guidelines to the Federal Government, Provincial Governments and territories for the management of their RNR. In consonance with it, the Provincial and District Governments may devise their own policies in accordance with their circumstances.

The goal of this policy is to foster the sustainable development of RNR of Pakistan, for the maintenance and rehabilitation of its environment and the enhancement of the sustainable livelihoods of its rural masses especially women, children and other vulnerable groups.

The elements of the policy are as follows:

- Reducing the impact of socio-economic causes;
- Population planning in critical ecosystems;
- Providing substitutes to firewood in the wooded mountains;
- Reducing poverty, poverty of opportunity and Powerlessness;
- Reducing political interference in the Forestry and Wildlife Departments;
- Renovating and invigorating the institutions of RNR;
- Supporting Local Governments in the sustainable development of their RNR;
- Policies for fragile ecosystems;
- Riverain forests;
- Irrigated plantations;
- Preservation of relict and unique forests;
- Wildlife;
- Rangelands and desert ecosystems; and
- Planting of trees and fodders on farmlands.

2.3 Pakistan Environmental Protection Act (PEPA), 1997

PEPA, 1997 is a fairly comprehensive legislation and provides legislative framework for protection, conservation, rehabilitation and improvement of the environment. It contains concrete action plans and programs for the prevention of pollution and promotes sustainable development. However, after the approval of 18^{th} amendment all the power as delineated and referred in the PEPA, 1997 has been referred to the respective provincial Enviornmental Protection Agencies i.e. Sindh Enviornmental Protection Agency (SEPA) and Environmental Protection Agency (EPA), Punjab for the subject Project. All the relevant portions has or

[4] www.finance.gov.pk

NATIONAL TRANSMISSION AND DESPATCH COMPANY LTD.

±660KV HVDC TRANSMISSION LINE FROM MATIARI TO LAHORE

JULY 2015

Environmental Impact Assessment (EIA) REPORT

Volume 1 of 2 (Main Report)

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HVDC ± 660 KV TRANSMISSION LINE FROM MATIARI TO LAHORE

(DRAFT)

Environmental Impact Assessment (EIA) Report

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Disclaimer:

This report has been prepared based on the Project information provided by the designer to NESPAK dated 15th July, 2015. NESPAK is not responsible or control over the changes in the Project design data which may require update of this report.

LIST OF ABBREVIATIONS

AC	Alternating Current
ADB	Asian Development Bank
AHs	Affected Houses
ALAO	Assistant Land Acquisition Officer
AM	Angle Marker
ANSI	American National Standards for Electric Power Insulators
ASTM	American Standard for Testing Material
BOD	Board of Directors
BOOT	Built Operate Own Transfer
CAS	Compulsory Acquisition Surcharge
CASA	Central Asia, South Asia Regional Electricity Trade Project
CBD	Convention on Biological Diversity
CBOs	Community Based Organizations
CCR	Community Complaints Register
CE	Chief Engineer
CET	China Electrical Power Equipment and Technology Company
COI	Corridor of Impact
CPPA	Central Power Purchasing Agency
CRPEA	Contract Registrar and Power Exchange Administrator
DC	Direct Current
DCR	District Census Reports
DISCOs	Distribution Companies
EA	Environmental Assessment
ECO	Economic Corporation Organization
EHV	Extra High Voltage
EIA	Environmental Impact Assessment
EMF	Electromagnetic Field
EMMP	Environmental Management and Monitoring Plan
EN	Euronorm Standard Specifications
EPA	Environmental Protection Agency
ESA	Environmental Social Assessment
EURONORM	European Legal Requirements to Musculoskeletal Disorders
GDP	Gross Domesatic Product
GENCOs	Generation Companies
GIS	Geographical Information System
GMT	Greenwich Mean Time

GOP	Government of Pakistan
GRC	Grievance Redress Committees
GSC	Grid Station Construction
GSO	Grid Station Operation
HSE	Health Safety and Environment
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
ICB	International Competative Bidding
ILO	International Labour Organization
IEE	Initial Environmental Examination
IGF	Inspector General Forestry
IPPs	Independent Power Projects
KMC	Karachi Metropolitan Cooperation
KV	Kilo Volt
LAA	Land Acquisition Act
LAC	Land Acquisition Collector
LAR	Land Acquisition and Resettlement
LARF	Land Acquisition and Resettlement Framework
LARP	Land Acquisition and Resettlement Plan
M&E	Monitoring and Evaluation
MLO	Martial Law Order
MMM	Mitigation and Management Matrix
MSDS	Material Safety Data Sheet
MVA	Mega Volts Amperes
NCS	National Conservation Strategy
NEPRA	National Electric Power Regulatory Authority
NEQS	National Environmental Quality Standards
NESC	National Electrical Safety Code
NGOs	Non-Governmental Organizations
NOC	No Objection Certificate
NPO	No Project Option
NRP	National Resettlement Policy
NTDC	National Transmission and Dispatch Company
O & M	Operation and Maintenance
OHSW	Overhead Shield Wire
OIC	Organization of Islamic Countries
OPGW	Optic Fibre Ground Wire

PAPs	Project Affected Persons
PC-1 Proforma	Planning Commission Proforma
PD	Project Director
PEPA	Pakistan Environmental Protection Act
PEPC	Pakistan Environmental Protection Councl
pH	Power of Hydrogen
QUAD S/C	Quad Bundle Single Circuit
REA	Rapid Environmental Assessment
RNR	Renewable Natural Resources
ROW	Right of Way
SAARC	South Asian Atlantic Regional Corporation
SDO	Sub-Divisional Officer
SEPA	Sindh Environmental Protection Agency
SI	Survey and Soil Investigations
SPS	Safeguard Policy Statement
SPSS	Statistical Pakage for Social Science
SSR	Sub-Synchronous Resonance
TA	Telegraph Act
T/L	Transmission Line
T/Ls	Transmission Lines
TLC	Transmission Line Construction
TOR	Terms of Reference
TSS	Total Suspended Solid
UC	Union Concil
UNO	United Nations Organization
UTS	Ultimate Tensile Strength
WAPDA	Water and Power Development Authority
XEN	Executive Engineer

EXECUTIVE SUMMARY

Pakistan is facing electricity crisis due to demand and supply short fall as well as ever increasing electricity prices in Pakistan. Moreover, the existing network of National Transmission and Dispatch Company (NTDC) is already overloaded and needs expansion. With the induction of new Power sources, new Transmission Lines (T/Ls) are required for carrying the additional Power to the major electricity distribution centres of the Country.

In order to cope with these crises, Government of Pakistan (GOP) has looked out for various Power Generation options other than Natural Gas and Furnace Oil. In this regard, GOP has planned to generate additional power in the Karachi region and utilize the Coal reserves of Thar, Sindh in Pakistan.

GOP has decided to implement two (02) key options i.e. to have Power generation from Thar coal reserves and have Power Plants based on imported coal to be located in Karachi. Taking a proactive approach, National Transmission & Dispatch Company (NTDC), has accordingly proposed to construct the T/L on BOOT basis from Matiari to Upcountry (Lahore) on priority basis. In order to have this Project implemented, number of tasks including T/L route selection, environmental and resettlement studies and economic and financial analysis of the Project is required. This Report deals with the Environmental Impact Assessment (EIA) of the proposed T/L from Matiari to Lahore.

The proposed T/L is a $\pm$ 660KV High Voltage Direct Current (HVDC) circuit starting from the district Matiari near Hyderabad at a converter Station located in Matiari, Sindh and ending at the Punjab province district Nankana Sahab near Lahore. Figure 1-1 shows the location map of the proposed T/L. Total length of the T/L is about 865.55 km, of which 314.9 km falls in Sindh province and remaining 550.65 km are located in Punjab province. Proposed T/L route passes through twelve (12) districts, out of which five (05) districts are located in Sindh and the remaining seven (07) are located in Punjab province.

Purpose of the Study

The purpose of this study is to assess the positive and significant adverse environmental and social impacts and to suggest mitigation and remedial measures to make the Project environment friendly and achieve sustainability during the construction and operational stages of the Project, prepare Environmental Management and Monitoring Plan (EMMP) with cost estimates and to intiate the NOC process from the concerned provincial EPAs i.e Sindh Enviornmental Protection Agency (SEPA) and EPA, Punjab.

Approach and Methodology

The detailed approach and methodology used for the EIA study is as follows:

- Literature Review;
- Route Optimization Study;
- Review of Environmental Laws and Institutional Requirements;
- Delineation of Corridor of Impact (COI);
- Baseline Survey of COI;
- Analysis of Alternatives;
- Baseline Conditions of the COI;
- Stakeholder Consultations;
- Impact Assessment and Mitigation Measures;
- Environmental Management and Monitoring Plan (EMMP); and,
- Conclusions and Recommendations.

Applicable Polices, Laws and Guidelines

Following are the applicable policies, laws, regulations and guidelines related to the proposed Project:

- National Environmental Policy, 2005;
- National Conservation Strategy, 1991;
- Pakistan Environmental Protection Act (PEPA), 1997;
- Regulations for Environmental Assessment, 2000;
- National Environmental Quality Standards (NEQS), 2000;
- Land Acquisition Act, 1894
- Telegraphy Act, 1910;
- Affected Persons Ordinance, 2001;
- Electricity Act, 1910;
- Provincial Wildlife (Protection, Preservation, Conservation and Management) Acts, Ordinances and Rules (Act, 1972);
- Cutting of Trees (Prohibition) Act, 1975;
- Punjab Plantation and Maintenance of Trees Act, 1974;
- Protection of Trees and Brushwood Act, 1949;
- Provincial Local Government Ordinances, 2001;
- Antiquities Act, 1975;
- Sindh Cultural Heritage (Preservation) Act, 1994;
- Factories Act, 1934;
- Explosives Act, 1884;
- Punjab Wildlife (Protection, Preservation, Conservation and Management) Act, 1974;
- Sind Wildlife Protection Ordinance, 1972;
- Forest Act,1927;
- Pakistan Penal Code,1860;
- West Pakistan Water and Power Act, 1958;
- Guidelines for Sensitive and Critical Areas;
- ADB Safeguard Policy Statement, 2009;
- Convention on Biological Biodiversity, 1994
- Convention on Conservation of Migratory Species of Wild Animals, 1979;
- Rio Declaration, 1992; and,
- Convention on Wetlands (Ramser Convention), 1971.

Project Description

Proposed project have two main components i.e. Converter Stations and T/L.

Converter Stations will be located at each end of the proposed T/L (Matiari and Lahore) to transform the Alternating Current (AC) used in the national networks into Direct Current (DC) for transmission and vice versa. One of the main advantages of DC transmission consists in the savings achieved by not having intermediate Sub Stations along the T/L. Depending on the final design the Converter Stations dimensions will be finalized. T/L main design components are the Towers and the Conductors.

Taking into account the possibility of the transmission of more Power through the proposed T/L in the future years, $\pm$ 660KV Bi-pole Thrasher conductors in quad bundle configuration for the HVDCT/L has been recommended for interconnection. These functional specifications have been prepared at this stage of the Project. It may be added that detailed specifications of the T/L will be based on these functional specifications and will be prepared at a later stage once the Project implementation is finalized.

For Extra High Voltage (EHV) lines, safety considerations are of two types. One is related with the safety of the system, while others are those that are related to the public safety. It is for this reason that NTDC has adopted a 100 m wide (50 m either side from the centreline) corridor as the ROW and 500 m wide (250 m either side from the centreline) corridor as the COI for the T/L. NTDC has planned to implement the Project on BOOT basis.

Analysis of Alternatives

The various alternatives which have been considered during the conduct of the study are:

- No Project Option (NPO);
- Technological System Study of T/L Alternative;
- Alternative Route Alignment selection; and,
- Design Alternatives.

The proposed T/L Project is a cost effective, sustainable and environmental friendly option to dispatch the bulk electricity from Matiari to major electricity supply centres of Pakistan. Based on the facts No Project Option (NPO) if exercised, electricity produced from Karachi and Thar areas cannot be supplied to the national grid hence it will not be available to the consumers. This may result in lost an opportunity to cope with the shortage of Power and boost in the national economy. In light of above situation, NPO is not acceptable for Pakistan.

Two options were considered for the technical comparison as given below for the proposed T/L project:

- Alternative 1: HVDC
- Alternative 2: HVAC

Technical comparison results [1]of both the alternative schemes concluded that HVDC is more economical and technically viable.

Therefore, Alternative-1 is feasible and technically superior.

Baseline Conditions

Following is the brief of the baseline conditions of T/L COI. Principally the whole T/L has been divided into two (02) sections namely Section I&II. Section-I lies in the Sindh Province i.e. from AM #1 to AM #49 while Section-II lies in Punjab Province i.e. from AM #50 to AM #169. Following is the brief of baseline conditions in the COI of the proposed T/L Project:

[1]See Phase-1 Report Vol1 for detailed technical comparison

Physical Environment

Section I:

T/L starts at the Summo village in Matiari district. The whole area is the part of rich fertile land of Matriari district. There exist the orchards of Mango, Guava, and Citrus etc. along with wheat, rice, vegetables due to the avaialbity of irrigation water.

At AM # 8 the proposed T/L enters the Sanghar district. The district does not have any mountain or hill. The district can be divided into two parts: a fertile plain area in the west; and desert area in the east. The T/L passes through eastern desert area as well as the agriculture part of Sanghar district. Most of the area consists of barren tracks of sand dunes covered by thorny bushes.

At AM # 28 district Khairpur starts. The portion where T/L enters the district consists of hills of windblown sand running in parallel rows from north-east to south-east.

From Khairpur T/L enter the Sukkur district at AM # 36. The T/L passes through desert portion of the Salehput sub-division.

T/L passes through the Ghotki district from AM # 41 to AM # 49. T/L passes through the desert area of the district which consists of hills of windblown sand and is part of the Thar Desert.

Table ES-1 below describes the mean daily maximum and minimum temperatures in Summer and Winter seasons of the Meteorological Gauging Stations which represents the climate of Section-I.

Table ES-1: Mean Daily Temperatures at Meteorological Gauging Stations (1981-2010)

Sr. No.	Meteorological Gauging Station	District	Mean Daily Temperature (Summer) °C		Mean Daily Temperature (Winter) °C	
			Minimum	Maximum	Minimum	Maximum
1	Sukkur	Sukkur	34.6	35.6	14.8	16.5
2	Nawabshah	Benazirabad	33.8	35.7	15.4	16.9
3	Hyderabad	Hyderabad	32.4	34.0	18.0	19.6

Source: 1. Pakistan Meteorological Services; and
2. Surface Water Hydrology Project, WAPDA.

Section II

T/L enters the district Rahim Yar Khan at AM # 50. Desert area is called Cholistan. T/L passes through the desert area. The surface of the desert consists of a succession of sand dunes and covered with the vegetation peculiar to sandy tracts.

Bahawalpur district starts at AM # 63 on the desert area known as Cholistan. It extends along the entire eastern boundary of Bahawalnagar district in the north and Rahim Yar Khan district in the south. The surface of the desert consists of a succession of sand dunes. It is covered with the vegetation peculiar to the sandy tracks.

T/L enters Bahawalnager district at AM # 75. The line passes through the irrigated agriculture area. The main source of irrigation in this area is semi-perennial and perennial canals which debouche from Sulemanki Head Works. T/L also crosses the Sutlej River in Bahawalnagar district.

T/L enters Pakpattan district at AM # 95. The area is a flat plain, covered on the north by the old bed of the Bias River. Soil impregnated with soda and other salts is common and known as Kallarathi. The major means of irrigation in the COI are canal and tube wells. Pakpattan canal takes off from Sulemanki Headwork's also cross by the T/L. This canal and its branch namely Khadir branch irrigate a vast area of the district.

T/L enters Okara after AM # 125. T/L is crossed by Depalur canal. T/L crosses the semi-urban area which is rich in agriculture.

T/L enters Kasur district at AM # 151 near village Kitan Kalan and passes through the upland area where T/L also crosses the old bed of Bias River. The soil is sandy. The upland is flat plain sloping from north-east to south-west.

Table ES-2 below shows the mean daily maximum and minimum temperatures in Summer and Winter seasons of the Meteorological Gauging Stations which represents the T/L Section-II.

Table ES-2: Mean Daily Temperatures at Meteorological Gauging Stations (1981-2010)

Sr. No.	Meteorological Gauging Station	District	Mean Daily Temperature (Summer) °C		Mean Daily Temperature (Winter) °C	
			Minimum	Maximum	Minimum	Maximum
1	Khanpur	Rahim Yar Khan	33.1	34.8	13.3	15.1
2	Bahawalpur	Bahawalpur	32.2	35.0	13.5	15.5
3	Bahawalnagar	Bahawalnagar	33.4	35.0	13.3	15.4
4	Faisalabad	Faisalabad	31.4	33.5	11.8	13.7
5	Lahore (PBO)	Lahore	31.3	33.6	13.3	14.8

Source: 1. Pakistan Meteorological Services; and
2. Surface Water Hydrology Project, WAPDA.

Ecological Environment

The proposed Transmission Line (TL) from Matiari to Lahore passes through two main eco-regions i.e. Desert-Xeric shrublands and Sub-Tropical Thorn area. The Desert-Xeric shrubland category includes districts of Sanghar, Khairpur, Sukkur, Ghotki, Rahim Yar Khan, Bahawalpur and Bahawalnagar, and consists of Angle Marks No. 8 to 94. The eco-region of Sub-Tropical Thorn area includes rest of the districts i.e. Matiari, Pakpattan, Okara, Kasur, and Nankana Sahib and stretches over AM-1 to AM-7 and AM-95 to AM-169. However, for the purpose of collection of field data, the proposed T/L route has been split up into two Sections i.e. Section-I (districts falling in Sindh) and Section II (districts falling in the Punjab).

The original flora of the area consists of the tropical thorn vegetation with acacia species predominanting with particular charateristics of thorny hard wooded species of short boles and low branching crowns. Fauna includes mammal species of jackal, rabbit, porcupine and wild boar. Reptiles consist of snakes and small sized lizards. Squirrel and mouse are the basic rodents while frog and toad are commonly found in the Project Area.

Game Reserves, National Parks and Wildlife Sanctuaries

]The proposed T/L will not pass through or cross any protected area i.e. Game Reserves, National Parks, Wildlife Sanctuaries etc. However, proposed T/L passes at a distance of about 12 kilometers from Changa Manga Reserve Forest (RF) at AM-160. Proposed Project, therefore, will not cause any impact on the flora and fauna of the Reserved Forest.

Socio-Economic Environment

To document the socio-economic conditions of the population settled in the COI, socio-economic surveys of the selected households were carried out. One of the major steps after the identification of the villages and their estimated populations was the calculation of sample size. Total 164 villages were found within the T/L COI for Matiari to Nankana Saheb and socio-economic survey was conducted in these villages. Based on the field visit and DCRs of the relevant districts, total number of households and population is estimated along the COI. Based on the estimated population and household sample size of 450 was determined using a statistical formula.

Section-I

T/L in Section-I passes through some semi urban and mostly rural areas. In this section, about 64 village are located along the COI. As per socio-economic survey highest population in this section is residing in Sanghar district and lowest population in Ghotki district because in Ghotki district most of the T/L route is in desert area. 2nd highest population is living in Khairpur district which is 41,600 persons. Total population in the COI of Section-I is 103,855 persons.

Based on the field survey major occupations in the COI are agriculture farming, labour (unskilled workers), service (government or private employ), business (small shop keeper) and livestock rearing (sale and purchase of livestock and dairy products). As per data collected for the baseline, it was noticed that agriculture/farming and unskilled labour is the main source of income for the locals.

The optimum cropping pattern refers to the allocation of the cropped area under different crops during the year in order to attain maximum output within the existing resources. In general, there are four (04) main crops (i.e. wheat, cotton, maize, sugarcane,) being grown in the COI from Matiari to Ghotki.

The results derived based on the 'village profile surveys' shows that out of 64 villages / Goths, 75 to 85 percent population in the COI had access to roads, electricity, fuel wood and schools especially for boys, while the other facilities like health, sui-gas, drinking water and telephones were found with only less than 10 percent population. Drinking water/ water supply schemes were also not available in most of the villages. In the COI from Matiari to Ghotki districts, drinking water is a major issue for the people especially in desert and barren areas of Sanghar, Khairpur and Ghotki where people are forced to use pond water for drinking. The major sources of drinking water in the COI are streams, nullahs, pumps and tubewell etc. In some areas of Sanghar and Ghotki districts, women have to fetch water from far away ponds and dug wells from their houses.

Section-II

As per socio-economic survey, highest population in the COI is calculated as 95,000 persons of Okara district. Due to urban or semi urban area population density is high in Okara. The lowest population is 11,400 persons in Bahawalpur district with most part of TL pass through the rural areas in this district. Total population falling in the COI from Rahim Yar Khan to Nankana Saheb is 297,400.

Saraiki and Punjabi as the mother tongue in the COI of Section-II, however, Balochi and Pashto are also spoken in the few areas.In Rahim Yar Khan and Bahawalpur, Saraiki is dominant language while from Bahawalnagar to Nankana Saheb Punjabi and Urdu are spoken.

Based on the field survey, major occupations in the COI are agriculture / farming, unskilled labour, service, business, shops and livestock rearing. As per data collected for the baseline, it was noticed that agriculture farming and unskilled labour is the main source of the income for the locals.

The optimum cropping pattern refers to the allocation of the cropped area under different crops during the year in order to attain maximum output within the existing resources. In general, there are four (04) main crops (i.e. wheat, cotton, Maize, sugarcane) being grown in the COI from Rahim Yar Khan to Nankana Sahib.

During the field surveys, it was observed that in case of farm households, the major sources of income included the income from crops and livestock (Dairy products). For non-farm or landless households, the main sources of income are the income from off-farm activities, such as business, Govt. or private employment, labour etc.

The survey results derived based on the 'village profile' shows that out of 95 villages, 80 to 90 percent of the villages in the COI had access to roads, electricity, fuel wood and schools especially for boys, while the other facilities like health, sui-gas, drinking water and telephones were found at less than 50 percent villages. Drinking water/ water supply schemes were also not available in most of the villages. The major sources of drinking water are hand pumps, streams, nullahs, pumps and tubewell etc. in the COI. In some areas of Rahim Yar Khan and Bahawalpur districts, women have to fetch water from dug well or water ponds far away from their houses.

Stakeholder Consultation

Stakeholders, especially the local population, involvement is an important feature of the environmental assessment and can lead to a better and more acceptable decision-making regarding the Project design and implementation. As a part of EIA studies consultations with the Proponent (NTDC), government departments such as Sindh, EPA (SEPA), EPA, Punjab, Sind Wildlife and Forest Department, Punjab Wildlife and Forest Department, Archaeology Departments of Sind and Punjab, Irrigation Departments of Sindh and Punjab, Revenue Departments etc., NGOs working in the COI and the potential project affectees were consulted.

Feedback received during public consultation are related to the willingness of people to accept project, compensation for their effected crops, livelihood, electricity and compensation/relocation/resettlement while concerns include drinking water supply and sewerage, health facilities, road infrastructures, education, women issues, agriculture and security.

Numbers of scoping sessions/focus group discussions with the women were also carried out at various locations in the COI. The purpose of focus group discussions was to share information about the Project activities and to analyze the gender related activities.

Project related concerns and feedback by the women in the COI were mostly related to their privacy, benefits associated with the project, any special provision related to jobs for the women in the area.

Impact Assessment and Mitigation Measures

With the implementation of the proposed Project following major positive impacts are foreseen:

- Dispatch of Electricity from Matiari to Lahore;
- Flexibility in the NTDC T/L system;
- Employment Opportunities;
- Infrastructure Development;
- Increase in Land Value; and
- Socio-economic Uplift.

Some of the indirect benefits envisaged due to the increase of electricity in the national grid are as follows:

- Due to the implementation of the Project, increase in the availability of electricity in the national grid will be ensured;
- Expansion of the industrial base is expected due to the availability of electricity in the national grid; and
- Better quality of life will be available for the residents of the Study Area if electricity from the national grid is provided to the locals of COI.

Apart from positive impacts proposed T/L Project also have some potential adverse environmental and social impacts. These are divided into two (02) major components which are given below:

- Transmission Line (T/L); and,
- Converter Stations.

Summary of identified potential significant environmental and social impacts of T/L and Converter Stations along with their mitigation measures are outlined below:

- The proposed T/L will not involve the permanent land acquisition as per NTDC practice in the light of LAA and Telegraph Act, 1910. No permanent land acquisition will be made for the land at the Tower footings as the landowner will be allowed to use the area under the Towers after the installation. T/L Section I and II a is mostly passing over the agriculture land. Some part of Section I and II is also crossing the desert. The Contractors will require temporary land acquisition for the construction camps.

The land for construction camps should be selected and leased prior to the start of construction phase. Land will be directly rented from the private landowners by the Contractors. The provisions of the LAA will not be involved as the acquisition of the land will be temporary and will be covered by short-term lease agreements between the landowners and Contractor. Rental terms should be negotiated to the satisfaction of the concerned landowners and the agreement should be in local language to make the process clear.

- Permanent acquisition of land will be required for the Converter Station at Matiari and at Nankana Sahib near Lahore. Final selection of the sites for the Converter Stations is in process;

Permanent land will be acquired as per LAA and ADB policy requirements for Involuntary Resettlement will also be fulfilled. It is recommended that existing market price of the land should be paid to the landowner. In this regard proper LARP should be prepared and implemented prior to the construction of the Converter Station.

- Ambient air quality will be affected by the fugitive dust and emissions from the construction machinery and vehicular traffic during the construction phase.

The measures such as the use of existing quarries, Concrete batching plants equipped with dust control equipment such as fabric filters or wet scrubbers to reduce the level of dust emissions; periodic tuning of the vehicles; regular sprinkling of water and Haul-trucks carrying sand aggregate and other materials will be kept covered with tarpaulin to reduce the dust pollution, will be adopted.

- Noise generated by the construction machinery during the construction stage is likely to affect the COI particularly the sensitive receptors like nearby schools, hospital etc. This impact will be more pronounced in both the sections however, end of Section II is more sensitive due to proximity to the urban to semi-urban residential areas.

As the proposed T/L route at some locations is passing near houses, so special care must be taken for noise producing activity by providing casing to the noise generating part of the machinery or use of noise absorbing materials. Properly tuned vehicles and oiling of moving part of equipment may also reduce the noise levels. Construction timing should be coordinated with locals. Normally noise generating activities are allowed from 9 AM to 5 PM during day time to avoid disturbance to humans as well as fauna.

- Approximate proposed strength of the labour in all camps is 179 persons for the T/L, Towers and stringing of conductors. These persons will be involved during hauling and installation stage. As a general rule the water consumption will be about 20 gallon/capita/day (75.7 liter/capita/day) and will subsequently generate about 70 to 80% of this water as sewage.

- Approximate proposed strength of the labour in each camp for Converter Station will be about 25 persons which will generate about 1.9 m^3/day of wastewater and about 12.5 kg/day of solid waste. Improper wastewater and solid waste management activities can increase disease transmission, contaminate ground and surface water and ultimate damage to the ecosystem.

Domestic and chemical effluents from the construction camp should be disposed by the development of on-site sanitation systems i.e. septic tanks along with soakage pits. Proper monitoring to check the compliance of NEQS will be carried out. Proper solid and hazardous waste management system should be adopted for camps;

- Construction activities such as clearing and grubbing, excavation, filling, laying down concrete foundation for Towers and setting up construction camps will affect the existing soil condition in the COI.

Good engineering practices will help to control or minimize the soil erosion both at the construction sites and in peripheral areas, particularly at the Tower foundations and along the haul tracks. All the disturbed areas need to be protected against soil erosion by stripping and stockpiling of all the available topsoil for later re-vegetation. Special slope protection measures should be adopted in the sensitive areas i.e. desert or semi-desert areas. Site restoration plan for the Project should be strictly followed.

- Natural streams and irrigation channels mostly in agicultural areas of Sinddh and Punjab may be prone to increase in sedimentation and silt due to excavated material (loose aggregate) with the runoff from the construction area, workshops and equipment washing-yards.

The excavated material will be managed by ensuring proper storage areas located far away from the water bodies. It will not cause the siltation of the irrigation channels. All the areas disturbed due to erosion need to be protected against soil erosion by stripping and stockpiling of all the available topsoil for later re-vegetation. At sand dunes, proper slope protection should be provided to reduce the erosion of the slopes.

- Land may be contaminated due to the spillage of chemicals, fuels, solvents, oils, paints, concrete, solid waste generated at campsites etc. This normally happens when these materials are transported in open or loosely capped containers.

The Contractors will be required to instruct and train their workforce in the storage handling and management of materials and chemicals that can potentially cause soil contamination. Material Safety Data Sheets (MSDS) implementation should be enforced.

- Construction stage of the proposed Project may affect the existing infrastructure within the ROW of the T/L where Towers are to be installed and stringing activities to take place. Estimated list of infrastructure falling within the ROW (100 m) is provided in the report. Exact number will be identified after the availability of project foot / spotting of Towers on ground.

During the detailed design stage, NTDC will coordinate with NHA and local road department/authorities for the installation of the Towers and during stringing of the conductors where the line is crossing the existing roads for the provision of alternate traffic route and management. Special care is required during the construction of Towers as well as stringing of conductors. During the stringing of conductors, temporary shutdown of the existing T/Ls will be ensured to safeguard the workers and the surroundings.

- Surface and groundwater resources may get contaminated by the fuel and chemical spills, or by solid waste and effluents generated by the kitchens and toilets at the construction camp sites. Moreover, runoff from the chemical storage areas may also contaminate the surface water bodies.

As a mandatory step, all the effluents should be disposed as per the requirements of NEQS. Moreover, to reduce the risk of surface and groundwater contamination, good management practices will be adopted to ensure that fuels, chemicals, raw sewage and wastewater effluent are disposed in a controlled manner.

- T/L section passing through agriculture land, where trees have been raised by the farmers along the boundaries of their agricultural fields or along the water channels. Orchards (mostly Mangos, Banana, Guava and Citrus exist) which may have to be removed.

Land holders should be paid reasonable compensation for the loss of their standing trees, in accordance with the prevailing market rates. This will mitigate the financial losses of the land holders. They should be encouraged to plant new trees, outside the ROW of the T/L.

- Based on the Google images and field surveys, the total cultivated area, which will be affected due to this Project, is nearly 16,500 hectares, which forms about 38.8% of the total area coming in the COI. The agriculture of the tract in Sindh and Punjab will receive significant adverse impact due to various operations such as movement of heavy machinery, erection of Towers, dragging, stretching and stringing etc.

Land holders will be paid compensation for the loss of their standing agricultural crops in accordance with the prevailing market rates as per LAA, Telegraph Act, NTDC practices and LARP specific to the Project. The landholders will also be allowed to salvage the agricultural crops and other vegetation from the affected fields.

- The damages may occur to existing crops during the construction stage due to the following activities:
  - Considerable vehicular movement for the transportation of materials/water and steel work will be involved at the time of concreting of Tower foundations. This movement and storage of materials will cause damage to the existing crops; and
  - The stringing of conductors involves movement of equipment and vehicles along the corridor, which may involve the cutting of trees and considerable damage to the existing crops.

Compensation for the loss of crops to the land owners and cultivators as the case may be will be paid, in accordance with the prevailing market prices and uniformity in rates will be ensured within the local areas;

- It is anticipated that local water resources will be utilized to meet the camp and construction requirements, bringing its use into competition with the local use especially in the desert areas of Sindh and Punjab province in Sections I to II where the water availability is limited.

Approval from the local administration and representatives of the concerned irrigation departments or other relevant authorities will be obtained before using the local surface water resources

- During the construction activities of the Tower foundations, erection and stringing of conductor, people will suffer loss in their annual income due to the loss of crops, trees etc. The land under the Towers during the operation stage may also restrict the current land use for agriculture purposes;

Fair, prompt and negotiated compensation for the crops and trees on private land will be provided to the affectees. Generally, in the areas which are devoid of irrigation and very few trees exist along the Project corridor some assistance if seem possible in the form of good compensation rates may be awarded. However, orchards of Mango, Banana, Citrus need special provision for the compensation

- As the Project route is passing through the rural areas of Okara, Pakpattan, Bahawalnagar, Bahawalpur, Rahim Yar Khan and all districts of Sindh from Ghotki to Matiari, women activities in the field may become affected due to the construction activities;

The Contractor have to select the specific timings for the construction activities like Tower footings, erection and stringing of conductors so as to cause least disturbance to the local population particularly women considering their routine movement hours.

- During baseline survey it was identified that, T/L also crosses some houses of vulnerable people in few areas. During the field visit it was also identified that the owners of the affected structures fall below the poverty line. Income of these vulnerable groups may be affected due to the implementation of the Project like crossing of T/L upon their infrastructure, affect of any assets such as houses, tube wells room etc.

LARP provisions should be strictly followed to eliminate the impact on livelihood.

- Occurrence of accidents/incidents during the construction stage is a common phenomenon and workers as well as locals will be more prone to serious accidents. The COI falls in Sindh and Punjab in which area is sensitive from the law and order point of view and the security of the Contractor and Consultant staff will be a major issue.

Special provision of security for all the activities should be kept to deal with any unpleasant incident. To avoid accidents HSE provisions should be strictly followed. Moreover, complying with the safety precautions for the construction workers as per International Labour Organization (ILO), Convention No. 62 as far as applicable to the Project Contract is highly recommended.

- Removal of the infrastructure like buildings, huts, animal sheds, tube wells etc. will cause the loss of community shelters and sources of income. Although the number of public infrastructure fall into the proposed T/L route, no significant relocation is expected as the Project has the flexibility to provide proper horizontal/vertical clearance for safe passage over the existing infrastructure.

In order to mitigate or compensate the impact of land acquisition and resettlement LARP provisions should be followed.

- During the operational stage, electric current (induction) may travel into the Towers due to short circuiting and may become a hazard to the public and livestock.

It is recommended that NTDC at the planning stage of the Project would plan necessary arrangements in the form of Earthling system of the Towers to avoid accidents. As exact location of Towers spotting is not yet finalized at this stage. However, it is recommended that at least two (02) diagonal legs of the Towers should be properly grounded to avoid any such incident.

- The electromagnetic field (EMF) may have significant adverse impacts on the health of locals. EMF due to extra high voltage (EHV) can cause the risk of *leukaemia,* which is a disease in which white blood cells mutate and become cancerous before maturity. These cells are important in fighting against infection in the body. Leukaemia also slows down the production of red blood cells that are needed to carry oxygen in the blood. Leukaemia is the second leading cause of death for children ages 2-15 years.

Since the Project has been planned to pass through the least populated area and the T/L will be kept at least 100 m from the populated areas, effects due to EMF are envisaged to be minimal due to safe distance. Similarly a vertical clearance required as per international standards will also be maintained especially near the populated areas. During operation stage check will be kept by the NTDC that no construction will be allowed within 100 m of the proposed T/L.

- Collapse of the Towers due to the high wind or earthquake will be dangerous for human as well as animal life and can cause loss to property.

The Towers are designed on the basis of proper subsoil investigations and climatic conditions of the area including maximum wind velocity and earthquakes which are normally based on last 50 years data. At the time of detailed survey for fixing the Tower positions proper soil investigations will be carried out to check the presence of collapsible soils and if detected, Engineer will be informed immediately for design change. It will be ensured that no accident due to collapsing of Towers would occur during the life of the Project. Morover, electrode stations are planned to groubd the current in case of any disaster.

Compensation and Resettlement Policy Framework

In order to mitigate the impact of land acquisition, loss of crops, loss of infrastructure, loss of livelihood etc. a compensation and resettlement framework has been developed. The Project is at the feasibility stage and detailed survey along with the spotting of the T/L Towers and their design are still to be finalized. Same in the case with the Converter Stations for the proposed T/L. Only demarcation of the T/L route and AMs has been marked on maps. In the absence of the demarcation of T/L in the field and spotting of Towers, it was very difficult to identify the PAPs within the ROW. The number of affectees will be identified within the ROW when the detailed LARP survey after the spotting of Towers at the site will be available. Occurrence of any public and religious structures such as mosque or graveyard will also be identified/verified at that stage, which may be affected due to the Project implementation.

Major laws related to the compensation and resettlements are Land Acquisition Act, Telegraphy Act, Local Provincial Laws such as Sindh and Punjab Katchi Abadies Act and ADB Policy.

In principle, Pakistan Law and ADB Policy adhere not only to the objective of PAPs compensation, but also to the objective of rehabilitation. However, LAA is unclear on how rehabilitation is to be achieved and in practice the provision of rehabilitation is left to ad hoc arrangements taken by local governments and specific Project Proponents. To clarify these issues and reconcile eventual gaps between Pakistan Law and ADB Policy, the LARF and LARP for the proposed T/L is being prepared as a separate document to ensure compensation at replacement cost of all items, the rehabilitation of informal settlers and the provision of subsidies or allowances for PAPs that may be relocated, suffer business losses, or may be severely affected.

Entitlement provisions for PAPs cover such impacts as land losses, house and buildings losses, crops and trees losses, a relocation subsidy, rehabilitation measures and a business losses allowance based on tax declarations and/or lump sums.

Agricultural land impacts will be compensated based on whether a PAP's access to, or use of, their land is restricted. For PAPs whose access to and use of, agricultural land is not restricted i.e. they can continue to cultivate the land, compensation will be for removed or damaged crops and trees. For PAPs whose access to, or use of, agricultural land is restricted i.e. they cannot continue to cultivate the land compensation will be paid at replacement value in: (i) cash at current market rates plus a 15% compulsory acquisition surcharge (CAS), or (ii) through replacement land equal in value/productivity to the plot lost. When >10% of an PAP's income or agricultural land is affected, AHs (owners, leaseholders and sharecroppers) will get an additional allowance for severe impacts equal to the market value of a year's gross yield of the land lost (inclusive of winter and summer harvest). Eventual transaction taxes/fees will either be paid by NTDC or waived by local governments. Market rates will be assessed through a survey of prevalent land prices, carried out by local government and financing institutions along with involvement of community.

Residential/commercial land will be compensated at replacement value by either (i) land for land or (ii) cash at current market rates free of any deductions. Renters/leaseholders will receive an allowance corresponding to 3 months' rent. However, the land under Towers and line (100 m wide ROW) can be used by the landowner or sharecropper for cultivation.

Houses, buildings, structures will be compensated in cash at replacement cost free of depreciation, salvaged materials and transaction cost deductions. The compensation for houses/buildings will also include the cost of lost water and electricity connections.

Crops: Cash compensation at current market rates for the net harvest actually lost as it may be the winter, the summer crop, or both. Crop compensation will be paid both to landowners and tenants based on their specific sharecropping agreements.

Trees: Cash compensation shall reflect income replacement based on market price.

Businesses: compensation for permanent business losses will be encashed for a 1-year income based on tax declaration or, if unavailable, based on the official minimum salary; compensation for temporary business will be encashed for the period of income interruption (1 to 3 months) based on tax declaration or, if unavailable, official minimum salary.

Business workers and employees: Indemnity for lost wages for the period of business interruption up to a maximum of 3 months.

Agricultural land leaseholders, sharecroppers and workers: Where the access to, or use of, the land is restricted; affected leaseholders will receive either a renewal of the lease in other plots or cash corresponding to the yearly yield of land lost for remaining years of the lease up to a maximum of (3) years. Sharecroppers will receive their share of harvest at market rates (if impact is temporary) or if the land is lost permanently additional compensation for 1 crop. Agricultural workers, with contracts interrupted, will get an indemnity in cash corresponding to their salary in cash and kind for the remaining part of the agricultural year (inclusive of both winter and summer crops).

Community structures and public utilities: These will be fully compensated or replaced/rehabilitated so as to satisfy their pre-Project functions.

Relocation subsidy: PAPs forced to relocate will receive a relocation subsidy sufficient to cover transport costs and living expenses for 1 month.

Framework provides the entitlement matrix and the proposed guidelines for the LARP.

Environmental Management and Monitoring Plan (EMMP)

In the end Environmental Management and Monitoring Plan (EMMP) has been developed. The main objectives of the EMMP are:

- Provide the details of the Project impacts along with the proposed mitigation measures and the corresponding implementation activities;
- Define the role and responsibilities of the Project Proponent, Contractor, Supervisory Consultants and other role players and effectively communicate environmental issues among them;
- Define a monitoring mechanism, reporting frequency and identify monitoring parameters to ensure that all the mitigation measures are completely and effectively implemented; and
- Identify the resources required to implement the EMMP and outline the corresponding financing arrangements.

An Environmental Mitigation & Management Matrix (MMM) for the T/L and Converter Stations are attached in the EMMP, which establishes the linkages between the environmental and social impacts, mitigation strategy and the agencies responsible for execution.

EMMP includes the Monitoring Mechanism, Monitoring Plan, Site Restoration Plan Guidelines, Solid and Hazardous Plan Guidelines, Chance Find Procedures, Tree Plantation

Plan, Documentation Plan, which will ensure that the proper results are achieved by the implementation of measures from concerned entities. The monitoring of environmental and social activities will be carried out by NTDC through Environmental and Social Experts from their Environmental Cell or hired staff by NTDC Internal Monitoring agency. The Environment and Social Expert working under the NTDC field staff will supervise all the activities in the field and will provide assistance to the NTDC staff in this regard. He will also ensure public participation.

Monitoring and evaluation (M&E) is also proposed in the EMMP.

An estimated cost for Environmental Management, Monitoring and Training has also been provided in the EMMP for inclusion in the PC-I or overall Project Cost. It should be noted that as referred earlier the Project is at a preliminary stage and the detailed survey is to be carried out for the Project showing the actual position of the Towers, so at this stage only tentative and lump sum amount has been allocated for the relocation of the infrastructure and the compensation for Land Acquisition and Resettlement is based on the environmental and social field surveys.

As a conclusion of the Study, the proposed Project have positive as well as some significant adverse impacts that can however be managed by proper mitigation and compensation measures and residual adverse impacts will not be of significant nature.

1 INTRODUCTION

1.1 Background

The main sources of the Power generation in Pakistan are based on Fuel Oil and Gas, Hydel and Nuclear Power Plants. Since Pakistan is not an oil producing Country, therefore, the high price of electricity in Pakistan is due to the significant contribution of Thermal Power based on Fuel Oil. Pakistan is facing Power crisis due to demand and supply shortfall as well as ever increasing electricity prices. With the reduction in the gas supply in Pakistan the conditions are further deteriorated. Moreover, the existing network of National Transmission and Dispatch Company (NTDC) is already overloaded and with the potential of induction of new PowerSources, new Transmission Lines (T/Ls) are very much required on urgent basis to despatch the additional planned Power to the major distribution centers of the Country for supply to the consumers.

In order to cope with imminent Power crises and reduce load shedding, Government of Pakistan (GOP) has looked out for various Power Generation options based on Regasified Liquified Natural Gas (RLNG), Imported Coal, Coal reserves of Thar, Solar etc.

Taking a proactive approach, NTDC has proposed to include the T/L from the planned Power Plants near Karachi and Thar region. It is envisaged that a capacity of about 4000 MW would be developed in Thar and Karachi regions in few years and new T/Ls need to be developed for transmitting this quantum of Power to major load center of Pakistan which are located in Upcountry. In order to transmit this Power from Thar and Karachi to Upcountry,a 500 kV collector/switching station is being developed at Matair. In order to evacuate the power at Matari station, T/L needs to be established on the basis of technical studies. A Coverter Station has been proposed at Matiari to collect the power and T/L from Matiari to Lahore has been proposed for the implementation on fast track basis.

It is important to mention here that as per information made available the proposed T/L will be implemented in Built Operate Own and Transfer (BOOT) mode. National Engineering Services Pakistan (Pvt.) Limted (NESPAK) has been assigned the challanging task to complete the Enviornmental Imapct Assessment (EIA) study to fulfil the requirements of Enviornmental Protection Agencies (EPAs) and to initate the proess of NOC. Terms of Reference (TOR) for the study as provided by the NTDC is attached as Annex-I.

Note: This EIA Report comprises two volumes namely, 1 and 2. Volume 1 is the main report while Volume 2 contains maps, annexes and photologs.

1.2 Nature, Size and Location of the Project

The proposed Project is a linear project of T/L from Matiari to Lahore to transfer the Power. The proposed T/L crosses thorugh two provinces i.e. Sindh and Punjab hence the T/L is divided into the two (02) mian sections namely Section-I and II, Section-I, Angle Marker (AM) # 1 to 49 are located in Sindh province and Section-II AM # 50 to 169 are located in Punjab province.Figure 1-1 shows the location map of the proposed T/L. In this report, Sindhand Punjab provinces are used to indicate the T/L route districts falling in the respective provinces. Sindh and Punjab provices hosts large number of districts proposed T/L only passes few of these districts. Figure 1-2 shows the location of T/L in desert of these two provices in Pakistan.

Proposed T/L is divided into AMs, which is the point where the proposed T/L changes its direction (angle).

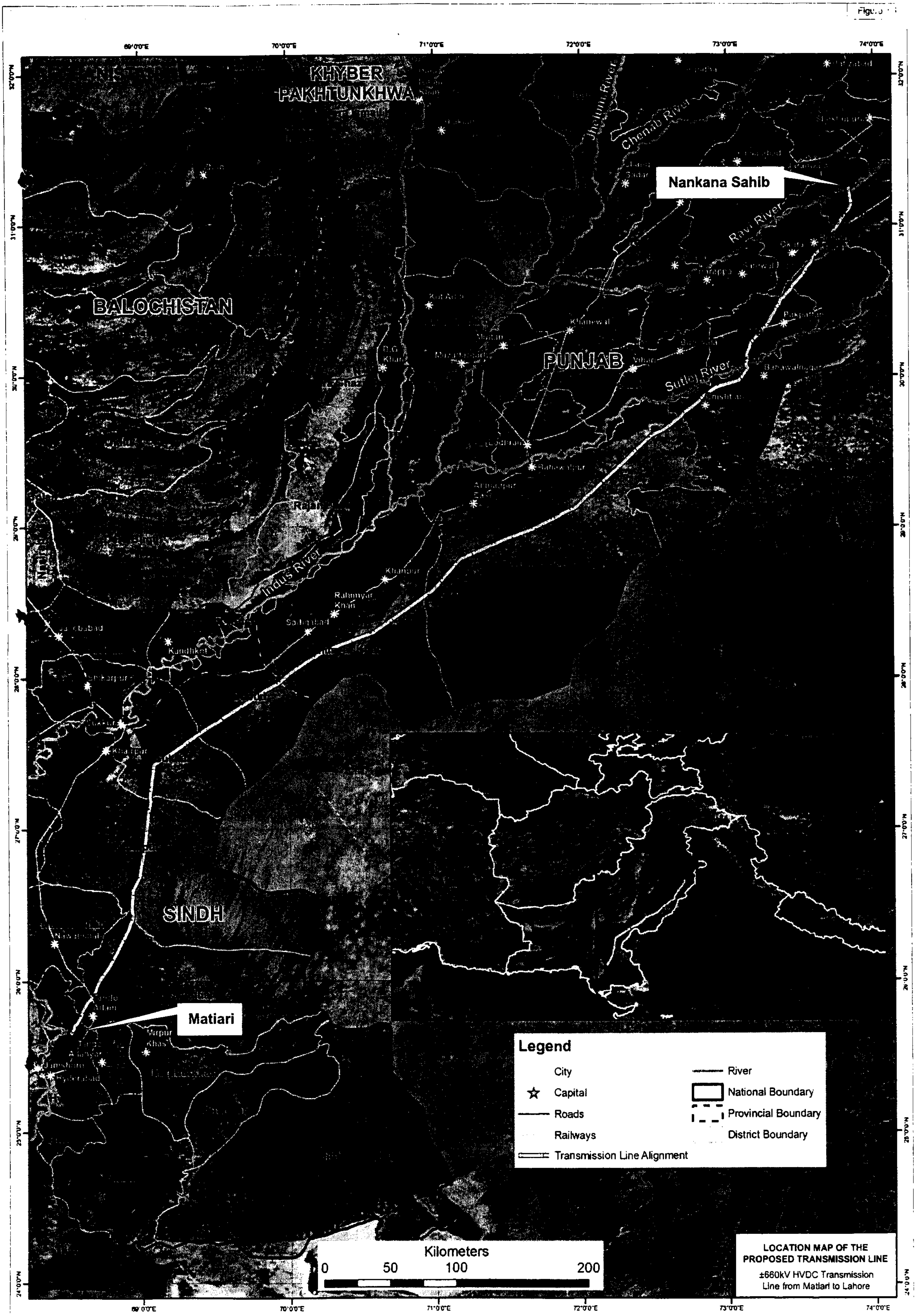
The proposed T/L starts from Matiari district Sindh and finishes in Punjab province in district Nankana Sahib. Length of the T/L is about 865.55 km, of which 314.9km falls in Sindh province and remaining 550.65 km in Punjab province. Proposed T/L route passes through total twelve (12) districts, of which five (05) districts are located in Sindh and the remaining seven (07) are located in Punjab. Figure 1-3 a&b shows the map of Sindh and Punjab provinces showing the districts being crossed by the proposed T/L. Proposed. T/L Section-I and II mostly crosses the rural agriculture and some desert areas in Sindh province, while as it enters Punjab province at Sadiqabad, some Part of Section-II alos crosses over desert in Rahimyar Khan and Bahawalpur districts and some part in the semi-urban to urban areas of Okara and Kasur districts.

1.3 Project Objectives

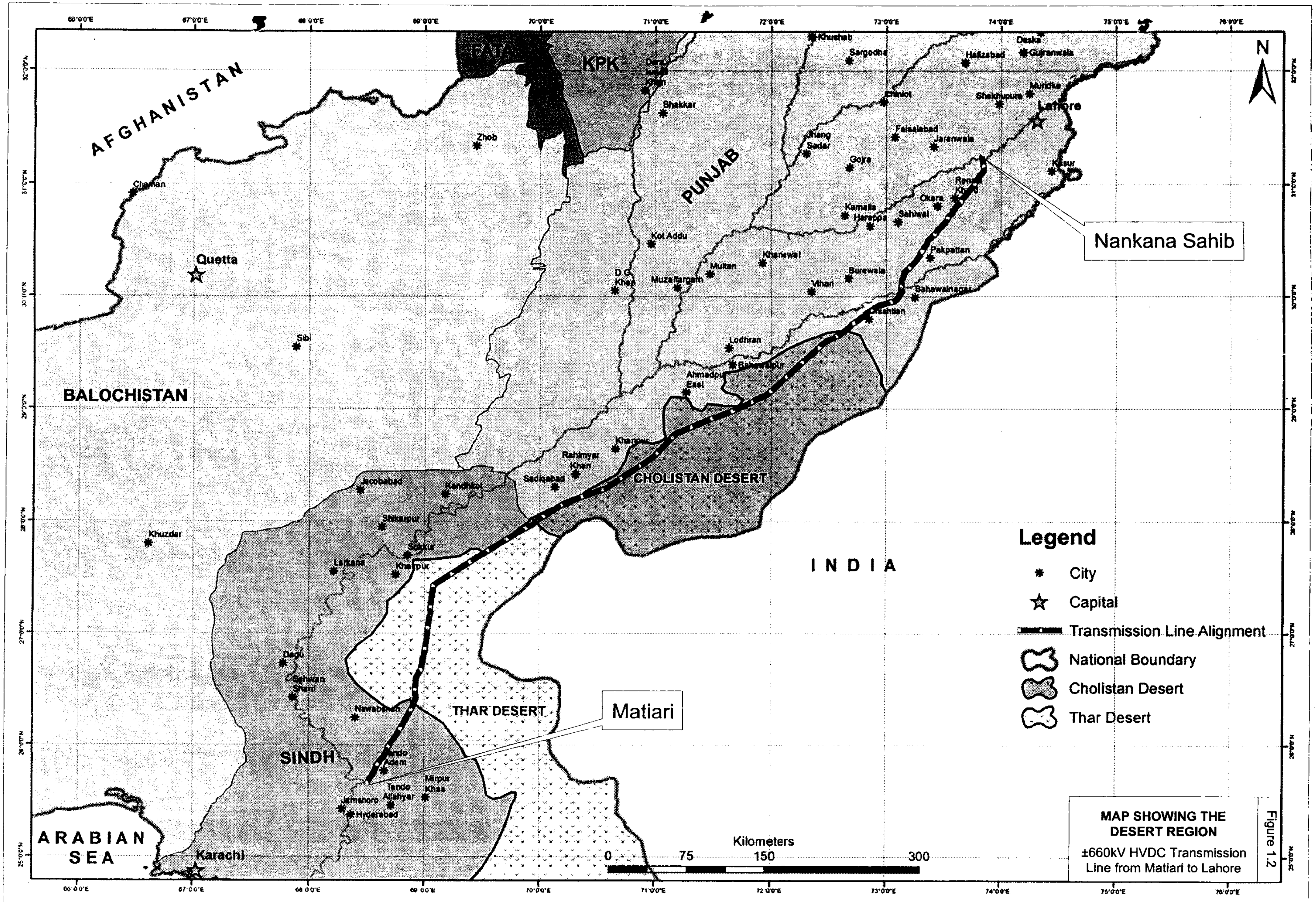
Considering the increasing demand of energy and current shortfalls, Government is planning to install new Power Plants and additional T/Ls and Grid Stations which are required to meet the growing demand of transmission and to strengthen the existing NTDC transmission system. The proposed Project is the part of NTDC Power Sector Expansion Program. The main objectives of NTDC's program is to provide adequate facilities for reliable and stable transmission of electrical Power, keeping in view the growing demand of domestic, commercial, industrial and agricultural customers of Pakistan Water and Power Development Authority (WAPDA).

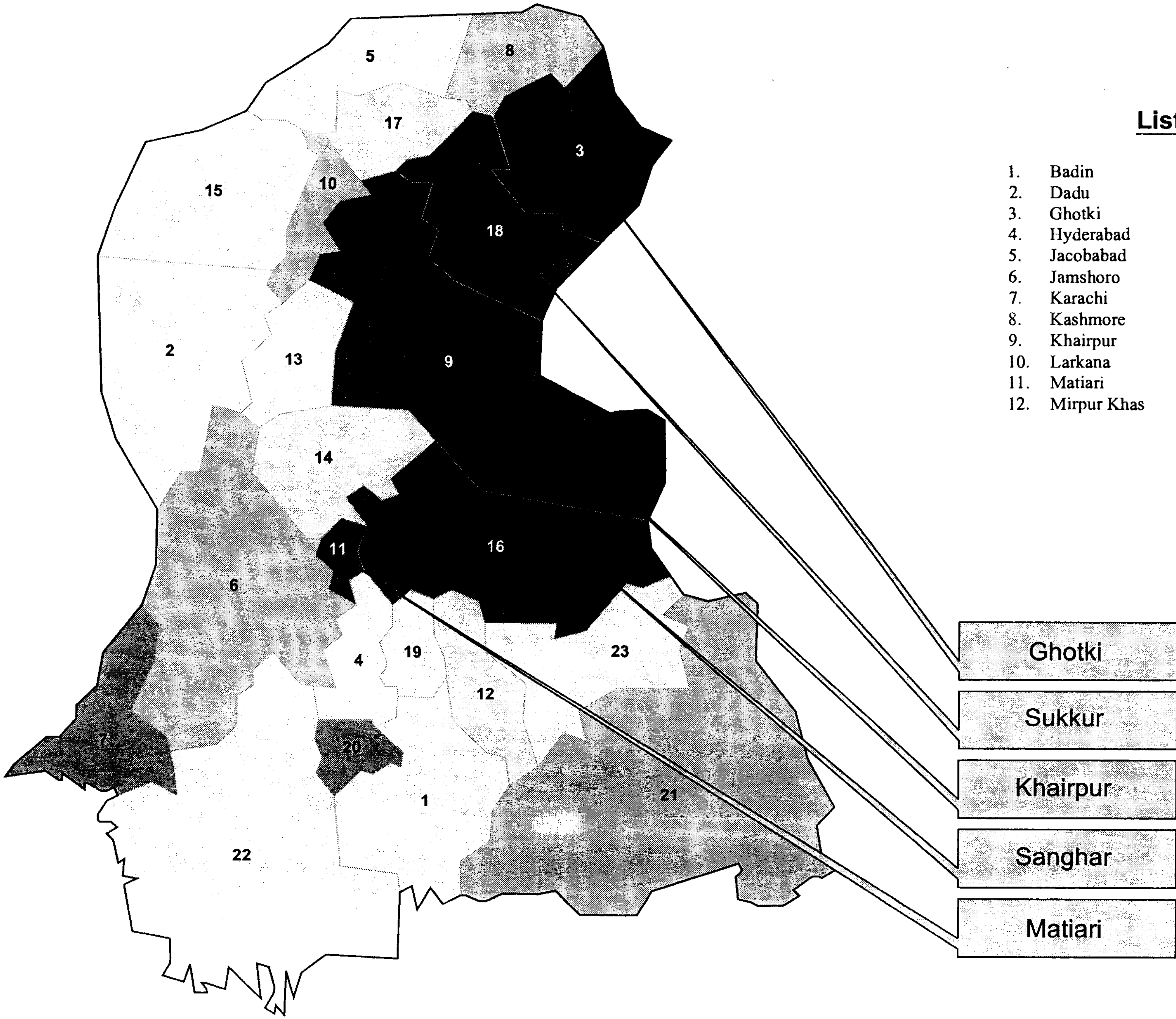
WAPDA's Power Wing has been unbundled and corporative into Distribution Companies (DISCOs), Generation Companies (GENCOs) and NTDC. Main objective of NTDC is to procure Power from GENCOS, IPPs and WAPDA's Hydro Wing on behalf of DISCOs and to deliver it to the networks of DISCOs through integrated system of 500 KV and 220 KV T/Ls and Sub Stations.

As the major Hydro Resources are located in the northern areas of the country and thermal generation facilities are concentrated in southern parts, a large and extensive Power transmission network consisting of 500, 220, 132 and 66 KV T/Ls and Grid Stations was built for delivering Power to the main distribution centers which are also located mostly in the middle part of the country. Further expansion in this transmission network is being constantly carried out in line with the plan for expansion of generation schemes for system improvements.



KHYBER PAKHTUNKHWA
BALOCHISTAN
PUNJAB
SINDH
Nankana Sahib
Matiari
Jhelum River
Chenab River
Ravi River
Sutlej River
Indus River
Khanewal
Multan
Lodhran
Bahawalpur
Rahimyar Khan
Khanpur
Sadiqabad
Kandhkot
Khairpur
Mirpur Khas
Hyderabad
Legend
City
Capital
Roads
Railways
Transmission Line Alignment
River
National Boundary
Provincial Boundary
District Boundary
Kilometers
0
50
100
200
69°0'0"E
70°0'0"E
71°0'0"E
72°0'0"E
73°0'0"E
74°0'0"E
32°0'0"N
31°0'0"N
30°0'0"N
28°0'0"N
27°0'0"N
26°0'0"N
24°0'0"N
LOCATION MAP OF THE PROPOSED TRANSMISSION LINE
±660kV HVDC Transmission Line from Matiari to Lahore


AFGHANISTAN
FATA
KPK
PUNJAB
BALOCHISTAN
SINDH
INDIA
ARABIAN SEA
CHOLISTAN DESERT
THAR DESERT
Quetta
Karachi
Lahore
Zhob
Chaman
Sibi
Khuzdar
Bhakkar
Kot Addu
Multan
Muzaffargarh
Khanewal
Vihari
Burewala
Lodhran
Bahawalpur
Ahmadpur East
Khanpur
Rahimyar Khan
Sadiqabad
Jacobabad
Kandhkot
Shikarpur
Sukkur
Larkana
Khairpur
Dadu
Sehwan Sharif
Nawabshah
Tando Adam
Tando Allahyar
Mirpur Khas
Jamshoro
Hyderabad
Khushab
Sargodha
Hafizabad
Daska
Gujranwala
Chiniot
Sheikhupura
Muridke
Faisalabad
Jaranwala
Jhang Sadar
Gojra
Kasur
Renala Khurd
Okara
Kamalia
Harappa
Sahiwal
Pakpattan
Bahawalnagar
Chishtian
Nankana Sahib
Matiari
Legend
City
Capital
Transmission Line Alignment
National Boundary
Cholistan Desert
Thar Desert
Kilometers
0 75 150 300
MAP SHOWING THE DESERT REGION
±660kV HVDC Transmission Line from Matiari to Lahore
Figure 1.2



List of Districts

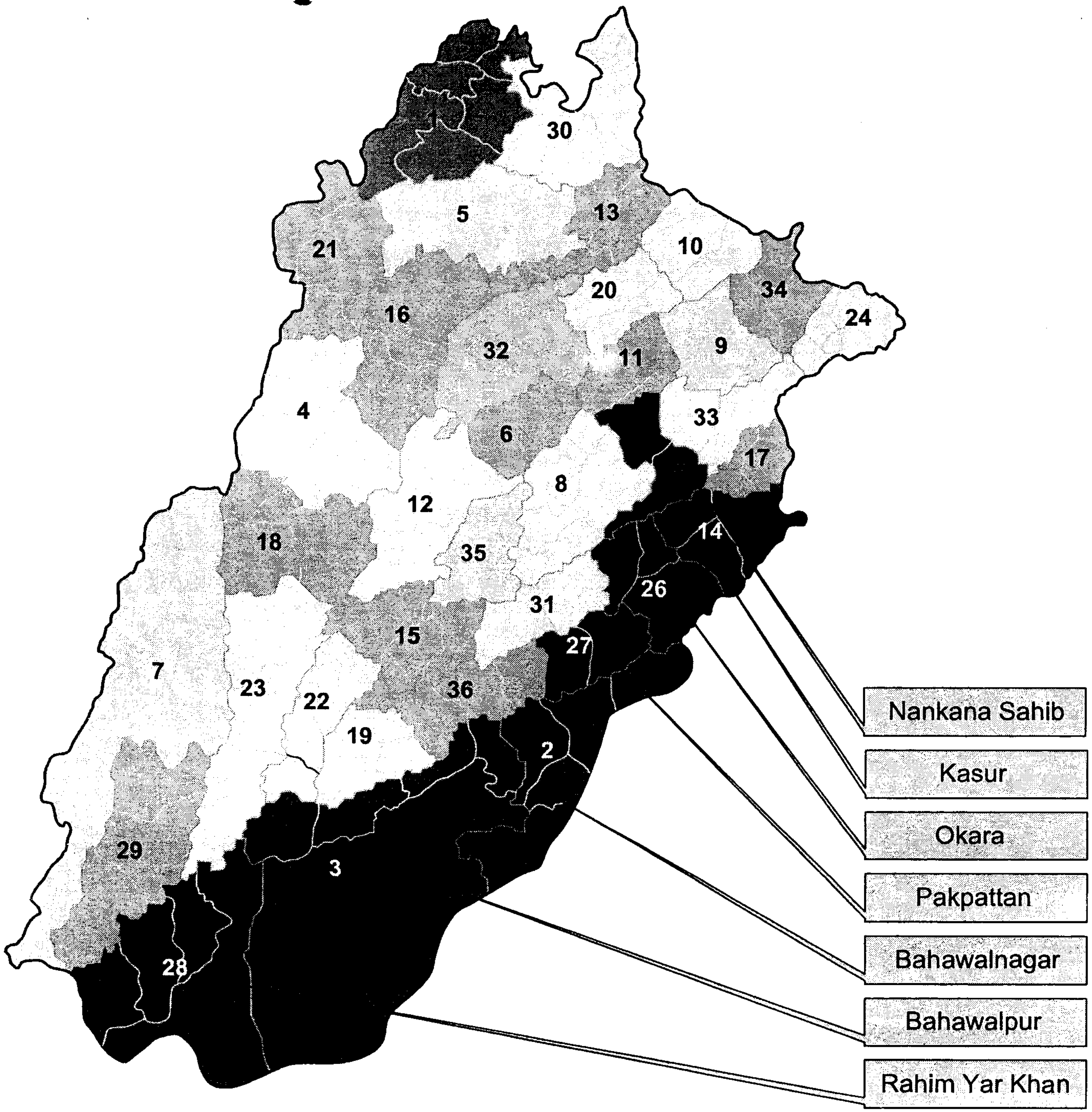
1. Badin
2. Dadu
3. Ghotki
4. Hyderabad
5. Jacobabad
6. Jamshoro
7. Karachi
8. Kashmore
9. Khairpur
10. Larkana
11. Matiari
12. Mirpur Khas
13. Naushahro Feroze
14. Shaheed Benazirabad
15. Qambar Shahdadkot
16. Sanghar
17. Shikarpur
18. Sukkur
19. Tando Allahyar
20. Tando Muhammad Khan
21. Tharparkar
22. Thatta
23. Umerkot

- Not to Scale

MAP OF SINDH PROVINCE

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 1.3a



- Not to Scale

List of Districts

1. Attock
2. Bahawalnagar
3. Bahawalpur
4. Bhakkar
5. Chakwal
6. Chiniot
7. Dera Ghazi Khan
8. Faisalabad
9. Gujranwala
10. Gujrat
11. Hafizabad
12. Jhang
13. Jhelum
14. Kasur
15. Khanewal
16. Khushab
17. Lahore
18. Layyah
19. Lodhran
20. Mandi Bahauddin
21. Mianwali
22. Multan
23. Muzaffargarh
24. Narowal
25. Nankana Sahib
26. Okara
27. Pakpattan
28. Rahim Yar Khan
29. Rajanpur
30. Rawalpindi
31. Sahiwal
32. Sargodha
33. Sheikhupura
34. Sialkot
35. Toba Tek Singh
36. Vehari

MAP OF PUNJAB PROVINCE

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 1.3b

The proposed Project aims to meet not only incremental demand for Power but also overcome voltage problems and enhance reliability of Power supply in service areas of DISCOs. The Project will also reduce overloading on existing 220/132 KV transformers. Finally, the Project may reduce transmission losses to about 20.22 MW.[2] Immediate objectives of the proposed Project can briefly be summarized as under:

- Dispatch Power from Matiari nearby areas to the major load distribution center of the Country to reduce the existing shor falls;
- Improvement in the voltage profile of Grid Stations;
- Reduction in T/L losses;
- Improvement in the NTDC System reliability; and
- Socio-economic uplift of the T/L route areas.

1.4 Scope of the Study

Consultants have envisaged the following Scope of Work (SOW) related to environmental and resettlement studies in the light of Terms of Reference (TOR) and discussions held with the NTDC:

- Review of national and local guidelines, laws and policies;
- Review of all relevant existing data, studies, reports and drawings;
- Minimize and avoid the environmental and resettlement effects during design;
- Identification of the most environmentally and socially feasible T/L route;
- Collection of baseline data related to Physical, Ecological and Social/Cultural environmental aspects;
- Identification, evaluation and categorization of the potential significant adverse physical, ecological and socio-economic impacts on the local environment during the construction and operational stages of the proposed T/L;
- Recommend appropriate environmental and social mitigation measures for the identified adverse impacts and monitoring plans to address them;
- Review the capability of the NTDC staff for the development of the Environmental Management and Monitoring Plan (EMMP);
- Preparation of EMMP;
- Determine the regulatory procedures and protection measures needed to obtain environmental and forestry clearances from the concerned departments;
- Provide technical assistance to NTDC for the issuance of No Objection Certificate (NOC) from the concerned EPAs; and
- Prepare future line of action/further studies required such as Land Acquisition and Resettlement Framework (LARF), Land Acquisition and Resettlement Plan (LARP) etc.

Copy of TOR's relevant portion is attached as Annex-I.

1.5 Purpose of the Report

The purpose of this EIA Report is to assess whether or not significant adverse environmental and social impacts are anticipated and to suggest mitigation and remedial measures to make the Project environmental friendly and sustainable during the construction and operational stages of the Project and to initiate the process of NOC from the concenred EPAs. In order

[2] EIA Report of Lahore New Grid Station Project

to implement the proposed mitigation measures, an EMMP with cost estimates has been developed. EMMP also provides the environmental management capability and recommends institutional strengthening measures of the management units of NTDC.

1.6 Extent of the Study

As per PEPA, 1997 and Pak-EPA (Review of IEE and EIA) Regulations, 2000, Schedule-II, T/L of 11 KV and above requires an EIA study.

According to the PEPA, 1997 & EPA Regulations, 2000 a separate EIA, study is required for the Converter Stations. At this stage these stations are considered as a part of the Project, but at the time of Project implementation a separate environmental study would be carried out for the proposed Sub Stations and Converter Stations.

This EIA study covers the environmental impacts of the proposed T/L, Converter Stations comprising the physical, ecological and socio-economic aspects. A minimum strip of 100 m (50 m on either side from the centerline) was delineated as Right of Way (ROW) in which direct impacts of the proposed T/L are envisaged due to the implementation. However, for indirect impact related to physical, ecological and social domains, a COI of 500 m on each side of transmission centerline was considered as project corridor or COI.

It is worth to mention here that the location of spotting of Towers and the material quarry sites is not finalized yet. Project foot print has not been made available on ground. Therefore, their general anticipated impacts are identified. The site specific comments will be taken up after the finalization of the spotting and marking of related sites. This study also suggests the mitigation measures and describes the institutional arrangements and the Mitigation Management Matrix (MMM) with cost estimates.

1.7 Project Proponent

Ministry of Water and Power of Pakistan's is managing the Power sector with the crisis management objectives to improve the efficiency of the Power sector and to meet customers' electric energy requirements on a sustainable and environment friendly basis. The specific objectives are:

- Stop load shedding;
- Constructing new Grid Stations;
- Reducing line losses; minimizing tripping and theft control;
- Revamping of generation units and to improve customer services; and
- Development of an integrated automated Power planning system for generation, transmission and distribution to ensure system stability, fault isolation and upgrade relying, metering and tripping system at NTDC as well as DISCOs levels.

NTDC under the Ministry of Water and Power is the Project Proponent of the proposed T/L. NTDC operates under WAPDA. It commenced commercial operation on December 24, 1998 after incorporation on November 6, 1998. It was organized to take over all properties, rights and assets obligations and liabilities of 220 KV and 500 KV Grid Stations and T/Ls network owned by WAPDA. NTDC operates and maintains nine (09) 500 KV Grid Stations, 4,160 km of 500 KV T/Ls and 4,000 km of 220 KV T/Ls in Pakistan. NTDC was granted a transmission license on December 31, 2002 by National Electric Power Regularity Authority (NEPRA) to engage in the exclusive transmission business for a term of thirty (30) years, pursuant to Section 17 of the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997. NTDC's headquarter is situated at WAPDA House Lahore[3] with details as given below.

National Transmission & Dispatch Company Limited (NTDC)

[3] NTDC Official Website

Room # 414, WAPDA House

Shahrah-e-Quaid-e-Azam, Lahore

Tel: 92 (042) 99202229

Fax: 92 (042) 99200894

E-mail: ceo@ntdc.com.pk

1.8 Approach and Methodology

The detailed approach and methodology used for the EIA study is as follows:

1.8.1 Literature Review

Before mobilization, Consultants carried out a desk study through collection and review of guidelines, data and reports related to the Project that included (a) review of National Environmental Legislations and international best practices related to Environmental and Social Assessment Guidelines/Safeguards; (b) Google Earth Satellite Imagery; (c) Relevant District Census Reports (DCR) and any other relevant documents/drawings; and (d) Reference documents such as HVDC/HVAC T/L from Thar to Lahore, Thar to Matiari and Peshawar to Tajikistan (CASA Project), T/L from Iran to Pakistan to Import 1000 MW, Lahore New Grid Station and Allied T/Ls and other projects.

1.8.2 Route Optimization Study

Judicious route selection is the most cost effective method of reducing the environmental and social impacts of the construction and operation of the T/L and other linear infrastructure. Consequently, the identification and optimization of the route was the most critical phase of the present Feasibility Study.

The objective of this work was to obtain first-hand overview of the Project environmental and social setting and to conduct an initial analysis of the physical, biological and social constraints posed within the proposed T/L route.

A map was prepared by digitizing the Google Imageries over which the existing Sub Stations and T/Ls along with the proposed tentative route for the proposed T/L from Matiari to Lahore was marked by CET with NTDC. This tentiave route was handed over to NESPAK experts by NTDC for further route optimization. NESPAK experts based on the GIS and existing information and experience developed a critiera for route optimization. Efforts were made to optimize the route in such a way as to avoid environmentally sensitive areas such as protected areas, game reserves, lakes, archaeological and historical sites, settlements etc. The objective of route optimization was to propose an initial corridor that will minimize technical and environmental constraints.

An initial assessment of the infrastructure, types of land and the settlement pattern were also made based on the preliminary plans. The existing main towns and villages were identified along the proposed Project alignment through which accessibility to the proposed alignment was made.

The following environmental criteria were used in addition to technical and design considerations for the proposed T/L route.

- Avoid towns/populated areas;
- Avoid indigenous or tribal settlements;
- Avoid cultural, religious and historical buildings;
- Maintain minimum disturbance to the natural habitat and vegetation;
- Maintain appropriate distance from the sensitive receptors (500 m);
- Avoid large water bodies like lakes, rivers or streams; and

- Avoid airports and other such facilities.

After the marking of proposed T/L route based on the above criteria, route optimization was carried out jointly by the design and environmental teams of NESPAK and route was send to CET for finalization.

1.8.3 Review of Environmental Laws and Institutional Requirements

National laws, legislations, guidelines as well as ADB Safeguards and Policies/Guidelines in the absence of local laws related to resettlement along with relevant international protocols were reviewed.

1.8.4 Delineation of Corridor of Impact (COI)

COI/Study Area include the actual Project Right of Way (ROW) as well as the area in the surroundings in which positive and adverse impacts may be foreseen due to the implementation of the proposed Project was marked based on the .

Based on the available tentative T/L route marked at Google Earth, a route optimization of the T/L was made by a team of experts to highlight any potential sensitive physical, ecological and socio-economic constraints in and along the proposed T/L route. Based on the above considering the urgency and short time avaialble, a maximum COI of 500 m with 250 m on each side from the centerline was selected as COI for the baseline survey.

1.8.5 Survey of COI

A team of environmental and social experts including surveyers, ecolgists, land experts, valuation experts, enumerators etc. carried out the environmental and social survey of the COI to familiarize themselves with the local conditions and the environmental settings. During the survey, the information regarding the topography, soils, rock, surface water, groundwater, flora and fauna, wetlands, forested areas, social settings and villages/towns along the COI was observed.

1.8.6 Analysis of Alternatives

The analysis of different alternatives was carried out during the selection of the most feasible T/L route of the study in consultation with NTDC and CET staff in order to select the most viable route keeping in view the environmental, economic and social constraints.

It is an international practice for the preparation of EIA that the proposed Project is compared with other alternative arrangements that could be developed to meet the objectives for which the proposed Project has been planned.

An analysis was carried out in consideration of technical and environmental aspects. Moreover, No Project Option (NPO) was also considered with reference to the effect on the Country's economics. This exercise provides justification for the need of the proposed Project.

The following alternatives were considered for the Project:

- NPO;
- Technological System Study of T/L Alternatives;
- Route Alignment Alternatives; and
- Design Alternatives.

1.8.7 Environmental Baseline Survey of the Project

After the selection of the most feasible route for the T/L based on satellite images and the delineation of COI, detailed environmental survey was carried out within the COI. The T/L route has been divided into two (02) Sections based on provincial boundaries. Detailed investigations/surveys were carried out on all the T/L sections for environmental parameters on which any adverse or positive impacts were envisaged by the implementation of the Project. Baseline surveys were carried out during the month of June and July, 2015.

Prior to the start of field activities, comprehensive checklists, proformas and maps were developed covering the following main parameters:

1.8.7.1 Physical Environment

The information needed for the preparation of physical environment included the following main parameters:

- Land resources (including landuse pattern, soil composition, contamination of soil and soil erosion etc.);
- Water (including available surface and groundwater resources and natural streams, hydrology, spring water, water supply, water contamination etc.);
- Climate (including temperature, rainfall, humidity, wind speed and direction etc.);
- Ambient air quality and noise Level;
- Existing solid waste management and effluents disposal practices and storm water drainage;
- Buildings, including residential, commercial and animal shed for complete/partial relocation;
- Cultural properties (mosques, shrines, graveyards);
- Archaeological monuments; and
- Other private/public infrastructures such as roads, telephone poles, hand pumps, tubewells etc.

1.8.7.2 Ecological Environment

- Flora (including vegetation cover, trees, shrubs and grasses, valuable or rare trees and their loss due to implementation of the Project etc.);
- Fauna (including wildlife, avifauna, domestic animals etc.);
- Reserved forests and wildlife sanctuaries in COI;
- Wetlands;
- Migratory birds corridors; and
- Endangered species (both flora and fauna).

1.8.7.3 Socio-Economic Environment

A sample survey was carried out within the COI in order to develop the socio-economic baseline information of the general settled population. There are 164 villages/settlements located in the COI of the proposed T/L in twelve districts. Based on the statistical sampling methodology, 450 households were interviewed and consulted for the collection of baseline socio-economic data.

The following major aspects were covered in the socio-economic baseline survey of the sample population settled along the COI:

- Demographic characteristics;
- Literacy status/ education;
- Nature of business/occupation;
- Livelihood/income;
- Living standard of the population;

- Access to credit;
- Social Infrastructure available;
- Gender issues;
- Pressing needs of the people;
- Community perception about the Project etc.; and
- Other aspects.

Checklists and Proformas which are used during the baseline surveys for the EIA study are attached as Annex-II.

1.8.8 Stakeholder Consultations

The Consultants identified Project stakeholders and held meetings with them during the surveys to receive feedback on the expected environmental issues related to the Project impacts and suggested mitigation measures. Meetings were carried out with the Project affectees, relevant departments including Wildlife, Agriculture, Fisheries, Provincial EPAs, Irrigation and Power Departments, WAPDA, NTDC, Non-Governmental Organizations (NGOs) etc. to discuss the issues/constraints and get their views and feedback to mitigate the potential environmental impacts associated with the implementation and operation of the Project. All in all more than 67 consultations/group discussions with the locals residing in the COI were carried out along the T/L route at various locations.

Based on the above, letters were also written to the concerned Wildlife and Forest Departments regarding the occurrence of any protected areas. The copies of the letters are attached as Annex-III. The proceedings of the consultations/meetings along with the photographs and list of participants are documented in Chapter 6.

1.8.9 Impact Assessment and Mitigation Measures

A logical and systematic approach was adopted for impact identification and assessment. The process began during the screening and continued through scoping which identified the key issues and classified them into different categories. The tools, which were used for impact assessment, are:

- Checklists;
- Matrices; and
- Overlays.

Identification of potential environmental and social impacts in terms of their nature, magnitude, extent, location, timing and duration were carried out. The impacts were correlated to the Project location, design stage, construction stage and operation stage. Based on the impacts prediction methods and as a result of public/stakeholder consultations, the Consultants screened the adverse environmental impacts for inclusion in the mitigation measures and environmental management plan. The same process was followed for the identification of social impacts. Public consultations (which provided feedback of the impacts from the stakeholder's viewpoint) were used to screen out the insignificant impacts. Matrices and overlays were used for the evaluation of temporal and spatial impacts respectively.

The Consultants proposed practicable, economically feasible and socially acceptable mitigation measures for the significant adverse environmental and social impacts. These measures were based on exploring the ways to achieve the Project objectives causing least disturbance to the existing environment by alternative ways, proposing changes in the Project design (ROW, height of the T/L Towers and sitting of facilities), through improved monitoring and management practices (storage of construction materials, labour camps, waste disposal, disposal of construction debris etc. or through monitory compensation).

1.8.10 Environmental Management and Monitoring Plan (EMMP)

An EMMP has been prepared to ensure the adequacy and effectiveness of the proposed protocol by clearly identifying the roles and responsibilities of the agencies responsible for implementation, monitoring and auditing of EMMP activities, existing and suggested framework, necessary approvals, training needs and the required further studies. EMMP also include organizational setup, a monitoring mechanism, monitoring plan, environmental and social parameters to be monitored with their frequency. Similarly, costs for environmental monitoring and social component/social mitigation measures were also included as part of the EMMP. Environmental monitoring, evaluation, auditing and reporting mechanism were also proposed in the EMMP.

1.8.11 Conclusions and Recommendations

Based on the baseline conditions, identified impacts and suggested mitigation measures and proposed environmental cost, conclusions are made. Based on the conclusions, recommendations regarding the future plan of action and outcome of the EIA report are provided.

1.9 Report Structure

The EIA report has been structured into following chapters:

Chapter-1 provides the Project background and nature, size and location of the Project, Project objectives, Project Proponent followed by scope of the study, purpose of the study and its approach, extent of the study and the report structure.

Chapter-2 provides a brief about national environmental policies, legal and administrative frameworks applicable to the Project together with the applicable International Safeguards/Guidelines and international protocols.

Chapter-3 provides the analysis of alternatives considered for the proposed Project so far.

Chapter-4 presents description of the Project including Project components, approvals and implementation schedule for Project and other information available so far.

Chapter-5 explains in detail the existing environmental baseline conditions of the Study Area considering the physical, ecological and social environment.

Chapter-6 depicts the consultations carried out with the stakeholders to know the concerns and issues.

Chapter-7 exhibits the environmental and social impacts assessment with the proposed mitigation measures during the design, construction and operation stages of the Project.

Chapter 8 presents the compensation and resettlement framework for the loss of assets by the erection of the line with an estimate of the budget and a schedule of actions to be implemented to make the inventories and the monitoring of the compensations.

Chapter-9 provides an overall approach for managing and monitoring the environment related issues and describes the institutional framework and resource allocations to implement the EMMP along with the environmental monitoring plan.

Chapter-10 provides the major conclusions in the light of the available Project plans, field surveys and impacts assessment; mitigation measures; and necessary recommendations.

2 POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK

2.1 General

This chapter provides an overview of the official policy framework and legislation that applies for controlling the environmental consequences of the Project implementation and operation. The Project is expected to comply with all the policies, laws, guidelines, acts and legislations of the Pakistan and other related environmental aspects.

2.2 National Policy Framework

Following elements of national policy framework are relevant to this Project:

2.2.1 National Conservation Strategy, 1992

The Pakistan National Conservation Strategy (NCS), which was approved by the federal cabinet in March 1992, is the principal policy document on environmental issues in the Country (EUAD/IUCN, 1992).

The NCS outlines the Country's primary approach towards encouraging sustainable development, conserving natural resources and improving efficiency in the use and management of resources. The NCS has 68 specific programs in 14 core areas in which policy intervention is considered crucial for the preservation of Pakistan's natural and physical environment. The core areas that are relevant in the context of the proposed Project are pollution prevention and abatement, restoration of rangelands, increasing energy efficiency, conserving biodiversity, supporting forestry and plantation and the preservation of the cultural heritage.

2.2.2 National Environment Policy, 2005

The national environmental policy 2005 aims to protect, conserve and restore Pakistan's environment in order to improve quality of life of the citizens through sustainable development. The main objectives of the policy are:

- Conservation, restoration and efficient management of the environmental resources;
- Integration of the environmental considerations in policy making and planning process;
- Capacity building of government agencies and other stakeholders at all levels for the better environmental management;
- Meeting international obligations effectively in line with the national aspirations; and
- Creation of a demand for environment through mass awareness and community mobilization.

2.2.3 National Climate Change Policy, 2012

The National Climate Change Policy provides a framework for addressing the issues that Pakistan faces or will face in future due to the changing climate. In view of Pakistan's high vulnerability to the adverse impacts of climate change, in particular extreme events, adaptation effort is the focus of this policy document. The vulnerabilities of various sectors to climate change have been highlighted and appropriate adaptation measures spelled out.
The policy covers measures to address issues in various sectors such as water, agriculture, forestry, coastal areas, biodiversity and other vulnerable ecosystems.

Notwithstanding the fact that Pakistan's contribution to global greenhouse gas (GHG) emissions is very small, its role as a responsible member of the global community in combating climate change has been highlighted by giving due importance to mitigation efforts in sectors such as energy, forestry, agriculture and livestock.

Furthermore, appropriate measures relating to disaster preparedness, capacity building, institutional strengthening; technology transfer; introduction of the climate change issue in higher education curricula; ensuring environmental compliance through Initial Environmental Examinations (IEE) and Environmental Impact Assessments (EIA) in the development process; addressing the issue of deforestation and illegal trade in timber; promoting Clean Development Mechanisms (CDM); and raising Pakistan's stance regarding climate change at various international forums, have also been incorporated as important components of the policy.

The policy thus provides a comprehensive framework for the development of Action Plans for national efforts on adaptation and mitigation. This policy document is a 'living' document and will be reviewed and updated regularly to address emerging concepts and issues in the ever-evolving science of climate change.

2.2.4 National Disaster Risk Reduction Policy, 2013

Disasters have an enormous and significant adverse impact on the development of key sectors of economy like agriculture, infrastructure, housing, health, and education and above all the environment, they result in a serious social and economic set-back to the sustainable development. Disasters also pose threat to increasing poverty and resultantly backslide the national development targets set to achieve the Millennium Development Goals (MDGs). Climate change induced disasters pose even greater threat to sustainable development in developing country like Pakistan which is ranked quite amongst the most vulnerable countries. Continuous floods of 2010, 2011 and 2012 are seen as an indication of more intense and frequent extreme events in the future.

Disaster risk reduction interventions were being carried out in the country till date by different departments / agencies in isolation at national, province and district levels. There was a strong need to give them directions and sound guidelines to align their activities in line with the true spirit of National Disaster Management Act, 2010 to counter the threats of disasters faced by the country. NDMA, being the lead focal agency for disaster preparedness and management, has therefore, embarked upon formulation of a comprehensive National Disaster Risk Reduction Policy through wider consultations with all stakeholders including all provinces, state of AJ&K and regions. This policy covers disasters risk reduction in a more holistic way and introduces a proactive and anticipatory approach by laying special emphasis on risk assessment and prevention.

2.2.5 Pakistan Labor Policy, 2010

The main objective of the Labour Policy, 2010 is the social and economic well-being of the labour of Pakistan. The Labour Policy, 2010 has following four (04) parts:

i) Legal Framework;
ii) Advocacy: rights of workers and employers;
iii) Skill development and employment; and
iv) Manpower export.

2.2.6 Poverty Reduction Strategy Paper, 2003

The full Poverty Reduction Strategy Paper of Pakistan (PRSP), prepared after a long consultative process involving the ministries, provincial and district governments, civil society, various interested groups, donors and grass root communities across the provinces of Pakistan. It outlines the broad framework and strategy for poverty reduction based on four (04) pillars:

- Accelerating economic growth while maintaining the macro-economic stability;
- Improving the governance;

- Investing in human capital; and
- Targeting the poor and vulnerable.

The PRSP also highlights the programs and policies of the Government under each of these pillars and proposes indicators to monitor the outcome of these policies as well as intermediate indicators for social sectors.[4]

2.2.7 National Forest Policy Pakistan, 2001

This policy covers the Renewable Natural Resources (RNR) of Pakistan i.e. forests, watersheds, rangelands, wildlife, biodiversity and their habitats. The policy seeks to launch a process for eliminating the fundamental causes of the depletion of RNR through the active participation of all the concerned agencies and stakeholders, to realize the sustainable development of the resources. It is an umbrella level policy providing guidelines to the Federal Government, Provincial Governments and territories for the management of their RNR. In consonance with it, the Provincial and District Governments may devise their own policies in accordance with their circumstances.

The goal of this policy is to foster the sustainable development of RNR of Pakistan, for the maintenance and rehabilitation of its environment and the enhancement of the sustainable livelihoods of its rural masses especially women, children and other vulnerable groups.

The elements of the policy are as follows:

- Reducing the impact of socio-economic causes;
- Population planning in critical ecosystems;
- Providing substitutes to firewood in the wooded mountains;
- Reducing poverty, poverty of opportunity and Powerlessness;
- Reducing political interference in the Forestry and Wildlife Departments;
- Renovating and invigorating the institutions of RNR;
- Supporting Local Governments in the sustainable development of their RNR;
- Policies for fragile ecosystems;
- Riverain forests;
- Irrigated plantations;
- Preservation of relict and unique forests;
- Wildlife;
- Rangelands and desert ecosystems; and
- Planting of trees and fodders on farmlands.

2.3 Pakistan Environmental Protection Act (PEPA), 1997

PEPA, 1997 is a fairly comprehensive legislation and provides legislative framework for protection, conservation, rehabilitation and improvement of the environment. It contains concrete action plans and programs for the prevention of pollution and promotes sustainable development. However, after the approval of 18th amendment all the power as delineated and referred in the PEPA, 1997 has been referred to the respective provincial Enviornmental Protection Agencies i.e. Sindh Enviornmental Protection Agency (SEPA) and Environmental Protection Agency (EPA), Punjab for the subject Project. All the relevant portions has or

[4] www.finance.gov.pk

being transformed for each province. However, the core legislation and spirit remains the same.

The law Stipulates:

- No Proponent of a Project shall commence construction or operation unless he has filed with the Government Agency designated by Pak-EPA or Provincial EPAs an EIA and have obtained an NOC;
- Establishment and Formation of the Pakistan Environmental Protection Council;
- Powers and Functions of the Federal and Provincial EPA;
- Prohibition of certain discharges or emissions;
- National Environmental Quality Standards (NEQS), for wastewater, air emissions and noise; and
- Law also emPowers Federal Government to issue notices and to enforce them for the protection of the environment.

For the effective implementation of the provisions of PEPA 1997, Pak-EPA headed by a Director General has been constituted. On the same pattern, EPAs have established in all the provinces.

The capability of regulatory institutions for environmental management largely achieves the success of environmental assessment for ensuring that development Projects are environmentally sound and sustainable.

2.3.1 Pak EPA Regulations, 2000

Under Section 12 (and subsequent amendment) of the 1997 Act, a Project falling under any category specified, in Schedule II, requires the Proponent to file an IEE or EIA with the Agency. Within ten (10) working days of the submission of IEE or EIA, the Agency will confirm that the document submitted is complete for the purpose of review. During this time, should the federal agency require the Proponent to submit any additional information; the IEE or EIA will be returned to the Proponent for revision, clearly listing those aspects that need further discussion. Subsequently, the Agency shall make every effort to complete an IEE review within forty five (45) days and an EIA review within ninety (90) days of filing of the complete information of report.

As per PEPA, 1997 and EPA (Review of IEE and EIA) Regulations, 2000, Schedule-II, an EIA study is required for the 11 KV and above T/L. In accordance with the requirements of the TOR, the EIA will include the assessment of T/L route with regard to interference with the protected areas, recommendation of mitigation measures and its cost estimate, review of regulatory measures, development of environmental monitoring and management plans and recommendations to enhance the institutional capability of NTDC.

It is also worth mentioning here that the Pak-EPA has delegated Powers to the provincial EPAs to enforce the provisions of the 1997 Act, an EIA will be submitted to the following agencies, if part of the proposed Project is falling in their respective domains:

- Sindh Environmental Protection Agency (SEPA); and
- Environmental Protection Agency(EPA) Punjab.

Therefore, this EIA report needs to be submitted to the SEPA as well as EPA, Punjab for the issuance of NOC from both the agencies.

2.4 Guidelines for Environmental Assessment

Pak-EPA has published a set of environmental guidelines for conducting environmental assessments and the environmental management of different types of development Projects. The guidelines that are relevant to the proposed Project are listed below.

- Guidelines for the Preparation and Review of Environmental Reports, Pakistan Environmental Protection Agency, 1997;
- Guidelines for Public Consultation, Pakistan Environmental Protection Agency, May, 1997; and
- Sectoral Guidelines: Pakistan Environmental Assessment Procedures, Pakistan Environmental Protection Agency, October 1997.

2.5 Guidelines for Critical and Sensitive areas

Protected areas are of crucial and growing importance. Properly managed protected areas are based on the establishment of a system, which aims to:

- Safeguard the earth's precious biodiversity;
- Protect outstanding areas of natural beauty; and
- Conserve areas of cultural significance.

In Pakistan, there exists a system of protected areas for the protection of endangered species, habitats, ecosystems, archaeological sites, monuments, buildings and other cultural heritage. The threats to protected areas in Pakistan are commercial-industrial pressures including mining, logging, overgrazing, cutting wood for fuel, development Projects and mismanaged tourism. Protected areas in Pakistan can be broadly categorized into two groups; i.e.

- Ecosystems; and
- Archaeological and cultural sites.

There is no central or federal level legislation for Wildlife conservation in Pakistan. However, each province has its own laws covering protected areas. There are separate Wildlife departments in the provinces that administer protected areas.

It should be noted that the above legislation consists of complicated, lengthy and legal documentation. Logically, only the relevant conservation authorities are in a position to provide the Proponent or Consultant with the most appropriate technical, scientific, administrative and regulatory assistance relating to the different legislations.

The GOP in the past years has taken some concrete steps to preserve, conserve and manage our national heritage, fauna and vegetation through the establishment of protected areas. This is being done through legislation, scientific research and education. In all the four (04) provinces, there are statutes that provide for creation and management of national parks, wildlife sanctuaries and game reserves.

The official classification of notified protected ecosystems in Pakistan consists of wildlife sanctuaries, national parks and game reserves.

In addition, there are protected forests, reserved forests, village forests/guzara forests, state forests and range lands. The relevant conservation authorities supply information on these areas to the Proponent or Consultant. In planning and sitting a Project, the Proponent needs to focus on being sensitive to the particular values of the relevant ecosystem or archaeological and cultural sites.

2.5.1 Checklist of Procedure for Environmental Assessment

Prior to any Environmental approval being granted by the responsible authority, the following steps should be undertaken:

- First of all the Proponent should identify whether the site for the proposed development is within the precincts of a protected ecosystem, cultural and archaeological sites. For this the Proponent should refer to the list of notified ecosystem, archaeological and historical sites. This list was last updated in April 1997. If the proposed site is not located in a notified area and there are no apparent ecological or cultural values associated with the site, take no further action;

- If the Proponent, or Consultant identifies an ecological site that appears to be of importance, but the site is not listed, they should discuss the site with the relevant conservation authority;
- If the site falls within the boundaries of a protected ecosystem, the relevant conservation authority in each province should be contacted for advice about the extent to which the development may be allowed and with what conditions. Certain protected areas may have total prohibition of development while others may allow controlled development;
- The relevant conservation authority should inform the responsible authority of their assessment of the significance of the likely impacts of the proposed development early in the process in order for the responsible authority to determine the level of documentation required. The Provincial EPA's will then be in a position to review the level of reporting required in the light of the advice from the conservation authorities; and
- During the review of the environmental report, the responsible authority will liaise with the Conservation Authority to ensure that the impacts and mitigation measures detailed in the environmental report are well based to frame environmental approval conditions, which protect the values of the listed area.

2.5.2 Protected Areas Clearance Procedure

Protected areas help maintain the integrity and diversity of eco-systems, protect flora and fauna and facilitate ecological processes such as water flows, soil regeneration, nutrient cycling and so on, which is vital for all life.

The Guidelines for Sensitive and Critical Areas have described the procedure for the clearance of the Forestry and Wildlife departments in case of the Project lies into the protected areas.

The Secretary Forestry and Wildlife department at the provincial level will be involved in the comment and recommendation for EA that are related to ecosystems. The Proponent or consultant for a proposed development in a protected area will be required to contact the Secretary Forestry and Wildlife departments in Punjab, Sindh, KPK, Baluchistan, Azad Jammu and Kashmir (AJK), or Northern Areas.

At the federal level, the office of the Inspector General Forestry (IGF) will be the central and national coordinator for the Provincial Wildlife department in the EA report review. The IGF office has on-going responsibilities for policy formulation, implementation, embedding process, monitoring, technical assistance and Research and Development (R&D) assistance if required. Finally, the IGF will need to be involved to assist in any dispute between the provincial Wildlife departments and the Proponent/consultant which they cannot resolve themselves.

The EA report should not be finalized and submitted to the responsible authority (i.e. provincial EPA's) until there is consultation with the provincial Wildlife departments and their comments and recommendations are taken into consideration as part of the mitigation and control measures.

These guidelines are expected to be included by the Federal IGF Office in the refinement of their current Forestry Master Plan for upto year 2017. The involvement of the provincial Wildlife departments and Federal IGF in the EA report review will become a critical part of the process for Project review and approval, for development in or vicinity of protected ecosystems.

While the provincial Wildlife Conservation Departments and the Federal IGF will provide this technical and specialized expertise in the review process, the review of the environmental reports and the provision of any Environmental approval will be undertaken by the responsible authority, as provided for in the Act and elsewhere in the package.

2.6 Pakistan Environmental Impact Assessment Procedures

These are descriptive documents guidelines the format and content of IEE/EIA reports to be submitted to Federal and Provincial EPA for obtaining NOC. Following are the major areas, which are covered by these guidelines:

- The EA report formation (scope, type and category of Project, description of Project, alternatives, site selection, baseline data);
- Assessing impacts (identification, analysis and significance);
- Mitigation and impact management and preparing an EMP;
- Reporting (format, main features, shortcomings, other forms of presentation);
- Review and decision making (role, steps, remedial options, checks and balances);
- Monitoring and auditing (systematic follow up, effective data management); and
- Project management (inter-disciplinary teams, programming and budgeting).

2.7 Guidelines for Public Consultation

The Pak-EPA published these guidelines to deal with possible approaches to public consultation and techniques for designing an effective program of consultation that reaches out to all major stakeholders and ensures the incorporation of their concerns in any impact assessment study. These guidelines cover:

- Consultation, involvement and participation of stakeholders;
- Effective public consultation (planning, stages of EIA where consultation is appropriate); and
- Facilitation involvement (including the poor, women and NGOs).

2.8 National Environmental Quality Standards (NEQS)

The NEQS, 2000, specify the following standards:

- Maximum allowable concentration of pollutants (32 parameters) in municipal and liquid industrial effluents discharged to inland waters, sewage treatment facilities and the sea (three separate sets of numbers);
- Maximum allowable concentration of pollutants (16 parameters) in gaseous emissions from industrial sources;
- Maximum allowable concentration of pollutants (two (02) parameters) in gaseous emissions from vehicle exhaust; and
- Maximum allowable noise levels from vehicles;

The NEQSs for motor vehicle exhaust and noise was approved in 2009. These NEQS specify the exhaust and noise standards for in use vehicles and new vehicles (Petrol and Diesel vehicles).

The NEQSs for ambient air quality, drinking water quality and noise has been approved in 2010. These NEQS specify the following:

- Maximum allowable concentration of pollutants (nine (09) parameters) for ambient air;
- Maximum allowable concentration of pollutants (35 parameters) in drinking water; and
- Maximum allowable noise levels during day and night time for residential area, commercial area, industrial area and silence zones.

2.9 National Resettlement Policy and Ordinance

As referred above, at present the only legislation relating to land acquisition and compensation is the Land Acquisition Act (LAA) of 1894. Experience with large-scale infrastructure development projects implemented by institutions such as WAPDA has demonstrated the need for a cohesive national policy for resettlement. Following a national consultative process, a national resettlement policy and a related ordinance were drafted known as Draft Resettlement Policy, 2002 which still has to be approved by the Government.

2.10 Other Environment Related Statutes

This section outlines the other statutes apart from PEPA, 1997, which are relevant to the project.

2.10.1 The Land Acquisition Act, 1894

At this point, the only legislation relating to land acquisition and compensation is the LAA of 1894. The LAA is, however, is limited to a cash compensation policy for the acquisition of land and built-up property and damage to other assets, such as crops, trees and infrastructure. The LAA does not consider the rehabilitation and resettlement of disrupted populations and the restoration of their livelihoods.

2.10.2 The Telegraph Act, 1885

This Act was promulgated for installation of telegraph poles and stringing. This Act makes a provision of installing poles/Towers without acquiring any land. However, provision is there for temporary acquisition of land during the construction period. As such, compensation is made for the loss of crop for a specific period.

2.10.3 Pakistan Penal Code, 1860

The Pakistan Penal Code deals with offences where public or private property and/or human lives are affected due to the intentional or accidental misconduct of an individual or body of people. In the context of environment, the Penal Code emPowers the local authorities to control noise, noxious emissions and disposal of effluents. The NEQS enforced by the EPAs supersede the application of this legislation on industries and municipalities.

2.10.4 Affected Persons Ordinance, 2001

This Ordinance was promulgated in 2001 by the federal government to provide relief to persons or households affected by any Project due to loss of land or displacement. The Project under review is not affected by the provisions of this law as no displacement of population is expected to occur.

2.10.5 Electricity Act, 1910

The Act provides a legal basis for distribution of Power. It enables a licensee to conduct operations for supply of electricity and binds the license to payment of compensation in respect of any damages caused during the construction, operation and maintenance of Power distribution facilities.

2.10.6 The West Pakistan Water and Power Act, 1958

This Act authorizes WAPDA to construct and operate electrical T/Ls with Powers and obligations of a license under the Telegraph Act, 1910. This Act also establishes policy for land acquisition and compensation, as well as the degree of liability of WAPDA for damages sustained by landowners or others.

2.10.7 The Forest Act, 1927

The Forest Act emPowers provincial governments to prohibit the clearing of forest for cultivation, grazing, hunting, removing forest produce; quarrying and felling, lopping and toping of trees, branches in reserved or protected areas.

2.10.8 Provincial Wildlife (Protection, Preservation, Conservation and Management) Acts, Ordinances and Rules (Act, 1972)

In addition to emPowering the provincial Wildlife departments to establish game reserves, parks and Wildlife sanctuaries, these Acts regulate the hunting and disturbance of Wildlife.

2.10.9 Sindh Wildlife Protection Ordinance, 1972

The Sindh Wildlife Protection Ordinance was approved in pursuance of the Martial Law Proclamation of 25th March, 1969. Under this Ordinance, three types of protected areas viz. National Park, Wildlife Sanctuary and Game Reserve have been notified for protection, conservation and preservation and management of Wildlife.

2.10.10 Punjab Wildlife (Protection, Preservation, Conservation and Management) Act, 1974

This Act was enacted in 1974 for the regulation of activities relating to protection, conservation and management of Wildlife in the province. Enabling rules were notified in the same year to enforce the Act.

2.10.11 Punjab Plantation and Maintenance of Trees Act, 1974

The provincial government enacted this law in 1974 to regulate tree plantation and enforce measures for the protection of tree plantations in the province.

2.10.12 Cutting of Trees (Prohibition) Act, 1975

The Act was enforced in 1975 to place restrictions on cutting of trees in order to restrain unchecked trend of tree felling without replacement plantations.

2.10.13 Protection of Trees and Brushwood Act, 1949

The Protection of Trees and Brushwood Act, 1949 prohibits cutting or chopping of trees and brushwood without prior permission of the relevant department in the provincial government.

2.10.14 Provincial Local Government Ordinances, 2001

These ordinances, issued following the devolution process, establish regulations for landuse, the conservation of natural vegetation, air, water and land pollution, the disposal of solid waste and wastewater effluents, as well as matters related to public health and safety.

2.10.15 Antiquities Act, 1975

The Antiquities Act relates to the protection, preservation and conservation of archaeological/historical sites and monuments.

2.10.16 Sindh Cultural Heritage (Preservation) Act, 1994

This provincial Act emPowers the Government of Sindh to preserve and protect any premises or objects of archaeological, architectural, historical, cultural, or national interest in Sindh by declaring them protected.

2.10.17 Explosives Act, 1884

Under the Explosives Act, the Project Contractors are bound by regulations on handling, transportation and using explosives during quarrying, blasting and other purposes.

2.11 ADB Safeguard Policy Statement, 2009

ADB affirms that environmental and social sustainability is a cornerstone of economic growth and poverty reduction in Asia and the Pacific. ADB's Strategy 2020 therefore emphasizes assisting DMCs to pursue environmentally sustainable and inclusive economic growth. In addition, ADB is committed to ensuring the social and environmental sustainability of the projects it supports. In this context, the goal of the SPS is to promote the sustainability of project outcomes by protecting the environment and people from projects' potential adverse impacts.

The objectives of ADB's safeguards are to:

- avoid adverse impacts of projects on the environment and affected people, where possible;
- minimize, mitigate, and/or compensate for adverse project impacts on the environment and affected people when avoidance is not possible; and
- help borrowers/clients to strengthen their safeguard systems and develop the
- Capacity to manage environmental and social risks.

ADB's SPS sets out the policy objectives, scope and triggers, and principles for three key safeguard areas:

- environmental safeguards;
- involuntary resettlement safeguards; and
- Indigenous Peoples safeguards.

To achieve the policy objectives and deliver the policy principles, ADB carries out the actions described in the following subsection ("B. Policy Delivery Process"). To help borrowers/clients and their projects achieve the desired outcomes, ADB adopts a set of specific safeguard requirements that borrowers/clients are required to meet in addressing environmental and social impacts and risks. ADB staff, through their due diligence, review, and supervision, will ensure that borrowers/clients comply with these requirements during project preparation and implementation. These safeguard requirements are as follows:

- Safeguard Requirements 1: Environment (Appendix 1);
- Safeguard Requirements 2: Involuntary Resettlement (Appendix 2);
- Safeguard Requirements 3: Indigenous Peoples (Appendix 3); and
- Safeguard Requirements 4: Special Requirements for Different Finance Modalities (Appendix 4).

As per ADB requirement the subject Project requires an IEE study. However, in the absence of any national level resttlement policy and framework, ADB SPS has been included to take care of the compensation and rehabilitation rights of the affectees.

2.12 International Protocols and Obligations

As Pakistan is a member of a number of international organizations like United Nations Organization (UNO), Organization of Islamic Countries (OIC), South Asian Atlantic Regional Corporation (SAARC), Economic Corporation Organization (ECO) etc., so it has to follow the international protocols and obligations related to the environment. The protocols and obligations related to the proposed project are as under:

2.12.1 Convention on Biological Diversity, 1994

The Convention on Biological Diversity (CBD), known informally as the Biodiversity Convention, is an international legally binding treaty. The Convention has three main goals:

- Conservation of biological diversity (or biodiversity);
- Sustainable use of its components; and
- Fair and equitable sharing of benefits arising from genetic resources.

In other words, its objective is to develop national strategies for the conservation and sustainable use of biological diversity. It is often seen as the key document related sustainable development.

2.12.2 The Convention on Conservation of Migratory Species of Wild Animals, 1979

The Convention requires the countries to take action to avoid damage to endangering migratory species. Species covered in the Convention should be given special attention during EA and monitoring and any impacts identified should be mitigated to acceptable levels.

2.12.3 The Rio Declaration, 1992

The Rio Declaration comprises 27 principles which address important issues such as; sustainable development to integrate environmental protection into the development process; common but differentiated responsibilities to conserve, protect and restore the earth's ecosystems; public participation and information access at the national level, reduce and eliminate unsustainable patterns of production and consumption.

2.12.4 Convention on Wetlands (Ramsar Convention), 1971

The broad aim of the Convention on Wetlands (Ramsar, Iran, 1971) is to halt the worldwide loss of wetlands and to conserve those that remain through wise use and technology transfer. Contracting Parties have made commitments to:

- Designate at least one site that meets the Ramsar criteria for inclusion in the list of wetlands of international importance;
- Protect the ecological character of listed sites;
- Include wetlands conservation within their national land-use planning; and
- Establish nature reserves on wetlands and promote wetland training.

2.13 NTDC Safety Considerations

NTDC Design Directorate has issued safety considerations which must be borne in mind during selection of route for a T/L. The main points of the guidelines are:

- Operation in environmentally sensitive areas with special respect for fragile ecosystems and their inherent biodiversity are to be avoided to the extent possible;
- Similarly, ROW for a T/L through natural features like mountains, hilly terrain susceptible to landslides, large lakes, reservoirs, marshes, human habitations and reserved forests or national parks are to be avoided to the extent possible;
- ROW is selected after due consideration for location of telecommunication lines and railway circuits to avoid electrical interference due to mutual induction;
- Residential structures are kept a minimum of 12 m out from the plumb line of the outer conductor in the ROW. However, in the absence of an alternative alignment, an exception can be made for farm buildings and single floor factory buildings, provided neither is used for purposes of residence;
- Innovative technologies and latest equipment must be adopted or used to abate pollution in construction activities and operations;
- Routes of T/Ls are avoided to the maximum extent through areas of cultural or historical importance and religious places;
- Tubewells and open wells using a surface pump are not permitted under high voltage conductors as piping and cranes used to recondition such wells could make contact with high voltage conductors;
- Existing orchards can remain within the ROW although Towers are kept out of orchards wherever possible. Orchards are to be over-sailed by a clearance of six (6) m above the height of a mature orchard whereas all other trees are to be removed;

- Brick kilns should be kept at 30 m outside the centerline of ROW;
- Alternative route alignments should be used if any school, rural dispensary, mosque or local shrine (ziarat) falls within 200 m of the centerline of a planned route;
- Existing open wells and hand pumps can remain under high voltage conductors, provided open wells are capped;
- Selection of sites for Tower foundation and Tower erection is made consciously on stable surfaces and by rejecting sites susceptible to erosion, slips and landslides;
- Alignment of the T/L is made by NTDC after discussions with key persons of the area and by avoiding properties and infrastructure to the extent feasible;
- Spacing between Towers/poles may not be uniform and ranges could vary for physical and other considerations, such as crossing of main roads, residential areas, streams and canals and trees and for avoiding graveyards and big ditches in between Towers/poles;
- The route alignment of the T/L, location of the Towers/poles and the corridors are identified by NTDC;
- The main consideration relating to public safety is a safe horizontal and vertical distance of conductor from ground level to prevent electrocution of people or animals under the T/L. A corridor having a minimum width of 30 m, clear of all obstructions, is provided for extra high voltage (500 KV and 220 KV) T/Ls (half on either side from the centerline). However, general farming within this corridor is allowed and tree plantations that do not exceed a height of one and a half (1.5) meter are also allowed to remain under the lines. Similarly, open wells, including Persian wheels, can remain under T/Ls. Tubewells and pumps are not permitted under high voltage conductors, because piping and cranes used to refurbish such wells may come into contact with the lines; and
- No residential or other public buildings such as factory, school, hospital and mosque, except for graves/graveyards, are permitted within the corridor. However, farm buildings which are used for residential purposes may remain under extra high voltage lines, provided vertical clearance of at least eight m is maintained. The height of Towers can be increased to accommodate such buildings.

3 ANALYSIS OF ALTERNATIVES

3.1 General

This Chapter deals with an analytical overview of the different alternatives that have been considered in the Project. The analysis has been carried out critically so as to justify the need of the Project and the selected options. Besides the economic viability, environmental sustainability and social soundness, the proposed Project was considered for various alternatives. The various alternatives which have been considered during the Feasibility Study are:

- No Project Option (NPO);
- Technological System Study of T/L Alternatives;
- Route Alignment Alternatives; and
- Design Alternatives.

3.2 No Project Option (NPO)

Pakistan is facing acute shortage of Power due to increase in population and industrial development, which has created a huge gap between the demand and supply of electric Power. Currently being utilized Power generating sources are not sufficient to meet the electricity demand of today and obviously insufficient to meet the future ever increasing demand. Currently the resources whih are being utilized are mostly based on the imported fuel oil which prove to be the most expensive one. Hence GOP has to spend millions of foreign exchange to import fuel to run these Power Plants. According to the available data, the installed power generation capacity in Pakistan is estimated to be about 22,104 MW including 8,793 MW and 5,458 MW from thermal private and public generating units respectively, 7,097 MW from hydro, 650 MW from nuclear and 106 MW from wind[5]. The gap between supply and demand in the PEPCO's system went over 6,000 MW[6] mark, it remained around 4,000 to 5,000 MW for most part of the year. The gap representing about one third of the total demand in PEPCO's system, forced one third of the electricity consumers to remain without electricity over a twenty-hour period. Further reduction in supply due to constraints in the transmission and distribution networks led to load shedding of up to 12 hours in urban areas.

This has caused inflationary pressure on the general public. Inflationary pressure created a social instability and misconception among the masses towards the Government. At present, there is a dire need for commissioning additional Power generation resources to overcome the shortage of electricity.

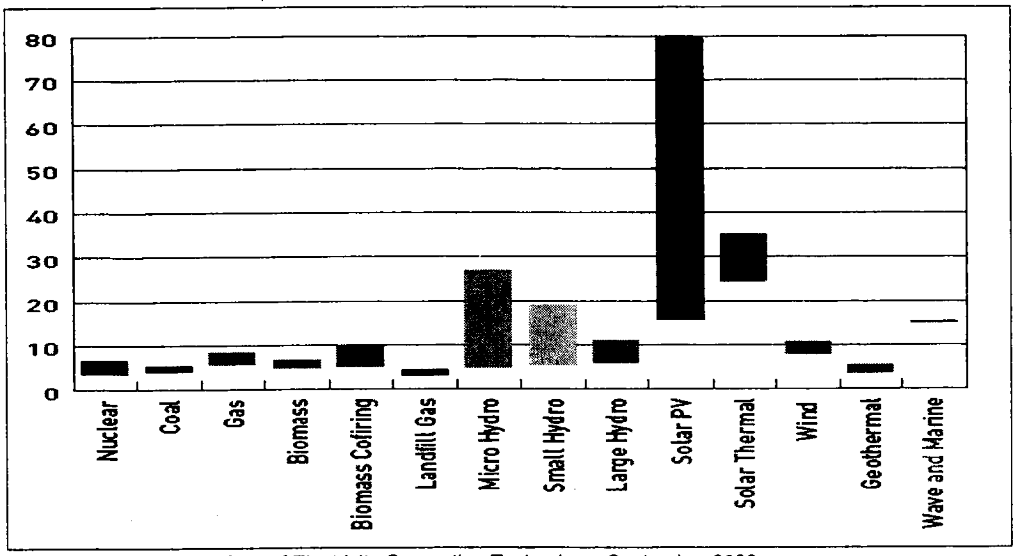
Figure 3-1 shows the relative costs comparison of different electricity generation technologies. Graph reveals that energy generation from coal and nuclear energy are competitive with (or better than) other conventional energy generation (gas, hydro etc.), although there is some variance while solar is the most expensive. The electricity produced through renewable sources i.e. Hydel, Solar and Wind is environment friendly, but these energy generation Projects demands higher capital cost and long time to complete.

Electricity demand and supply gap is increasing annually and causing a great economic loss to the Country. According to estimates[7], for example energy deficit for the year 2010 has given Rs. 45 billion blow to the economy of Pakistan. This is, however, a high time to exploit other resources including the coal resources of the Country to for power generation. Thar coal has great potential for mining and Power generation. Thar Coal presents an electricity

[5] Power System Statistics, 2013-2014, NTDC
[6] State of Industry Report, 2013, NEPRA
[7] WAPDA Official Website

generation potential of more than 20,000MW[8]. Moreover, Karachi and adjoin regions can be utilized to install power plants based on the imported coal due to the avaialbity of shore line.

Figure 3–1: Relative Costs of Electricity Generation Technologies (2003 Canadian cent per Kilowatt hour)[9]



Source: CERI, Relative Cost of Electricity Generation Technology, September 2006

In order to cope with eminent Power crises and to reduce crunch of load shedding, the GOP has also decided to generate energy from the sources other than fuel oil. In this regards varous options are being considered and being implemented. A status summary of planned Power generation from the Thar and Karachi is given below in Table 3-1:

Table 3–1: Status Summary of Planned Power Generation [10]

Sr. No.	Company / Project Developer	Generation Capcity	Participants
1	EngroThar Coal Power Plant	2×330MW	The Employer is Sindh Engro Coal Company. China Machinery Engineering Corporation participated in thewayofEPC.
2	SSRLThar Coal Block-I Mine Mouth Power Plant	2×660MW	China Power International Development Limited exploited in the holding way of BOO.
3	Port Qasim Coal Power Plant	2×660MW	Power Construction Corporation of China, Ltd exploited in the holding way of BOO.
4	Hubco Coal Power Plant	1×660MW	The Employer is Hubco Electric Power Company. Power Construction Corporation of China,Ltd participated in the exploiting.
	Total	**3,960 MW**	

[8]Thar Coal Development Authority Official Website

[9]http://www.cna.ca/curriculum/cna_world_energy_res/comparison-eng.asp?bc=Comparison%20of%20Electrical%20Generation&pid=Comparison%20of%20Electrical%20Generation

[10]Thar Coal and Energy Board

It is envisaged that about 4,000MW capacity of Power Projects will be installed in Karachi and Thar regions with a potential of future expansion and T/L need to be established for transmitting this quantum of Power from these area to Upcountry.

The existing NTDC Grid map of 500 and 220 KV systems is attached as Figure 3-2. The Southern and Northern line diagrams of NTDC system are shown as Figures 3-3 and 3-4. The existing grid station at Jamshore cannot tap this anticipated capacity of power, hence a coverter station at Matiari is being proposed. Similalry to despatch this power from Matiari to the load distribution ceters of NTDC grid, T/L is required which can carry bulk power. Keeping in view the existing system, NTDC has proposed a new T/L to transmit the Power from these areas to Upcountry. The T/L will be established on BOOT basis after technical, economical and environmental consideratoins.

As electricity is pivotal for running all sectors and directly influences the economy. The economic progress is hampered due to the shortage of electricity. One important factor of lower GDP and inflation of commodity prices in recent years is attributed to shortfalls in electricity supply. Electricity cannot be used until or unless the electricity is supplied to the national grid. Hence to utilize the generated electricity, T/Lneed to be established to the major load distribution centers of Pakistan.

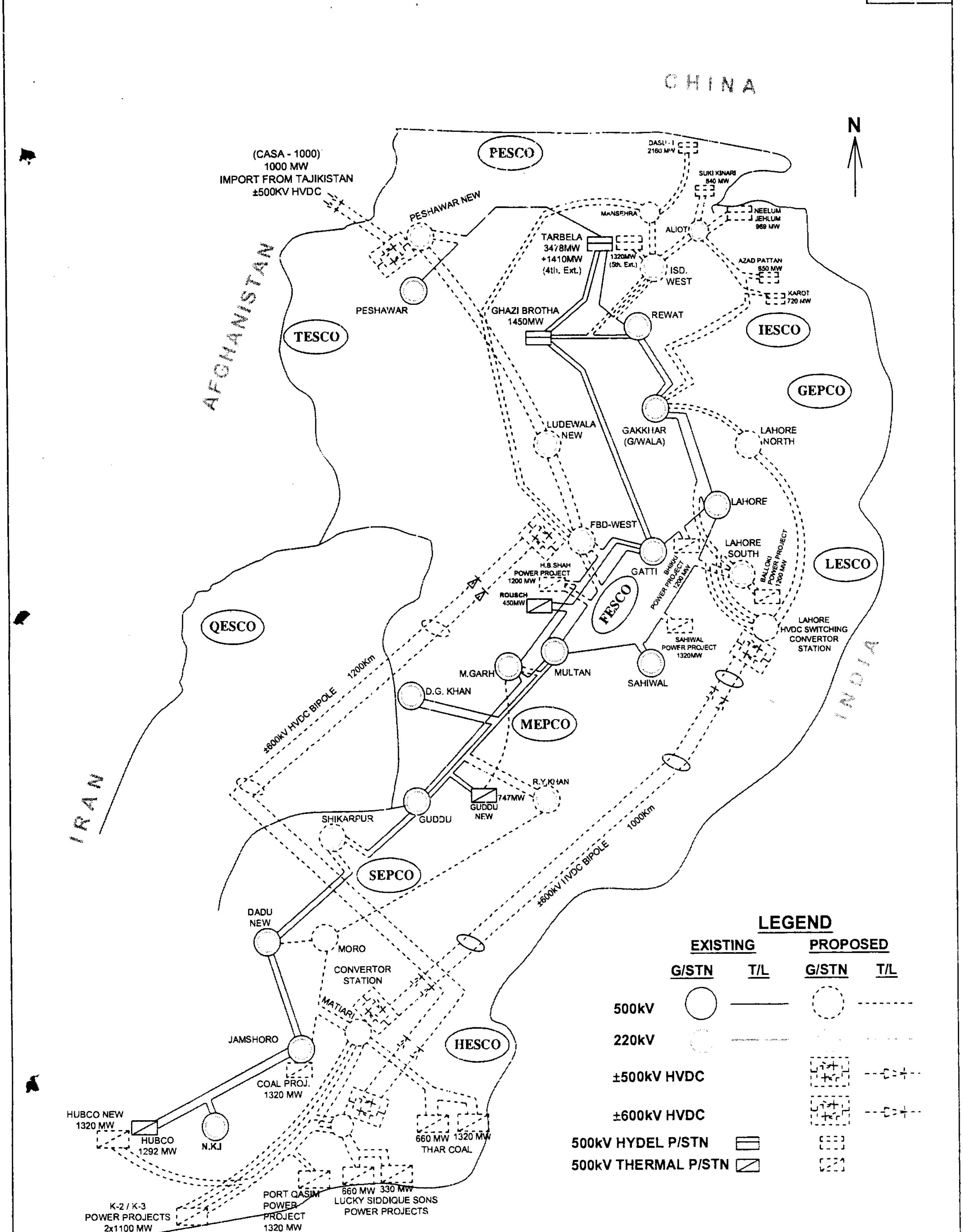
The proposed T/L Project is a cost effective option to dispatch the bulk electricity from Matiari to major electricity supply centers of Pakistan. Based on the facts mentioned above, NPO, if exercised, electricity produced from Karachi and Thar areas cannot be supplied to the consumers which may push Pakistan to further increase shortage of electricity and willcause losses to national economy. In light of above situation, NPO is not acceptable.

3.3 Study of T/L Potential Route Corridors

A T/L is a linear severance of the landscape, similar to a highway or railway line. However, the environmental impact is usually significantly less than that of a highway or railway line. This is mainly due to the fact that permanent contact with the ground is limited to the Towers, at approximately 400m intervals along the line route as compared to a highway or railway, which have continuous ground contact and act as a barrier for people and animals.

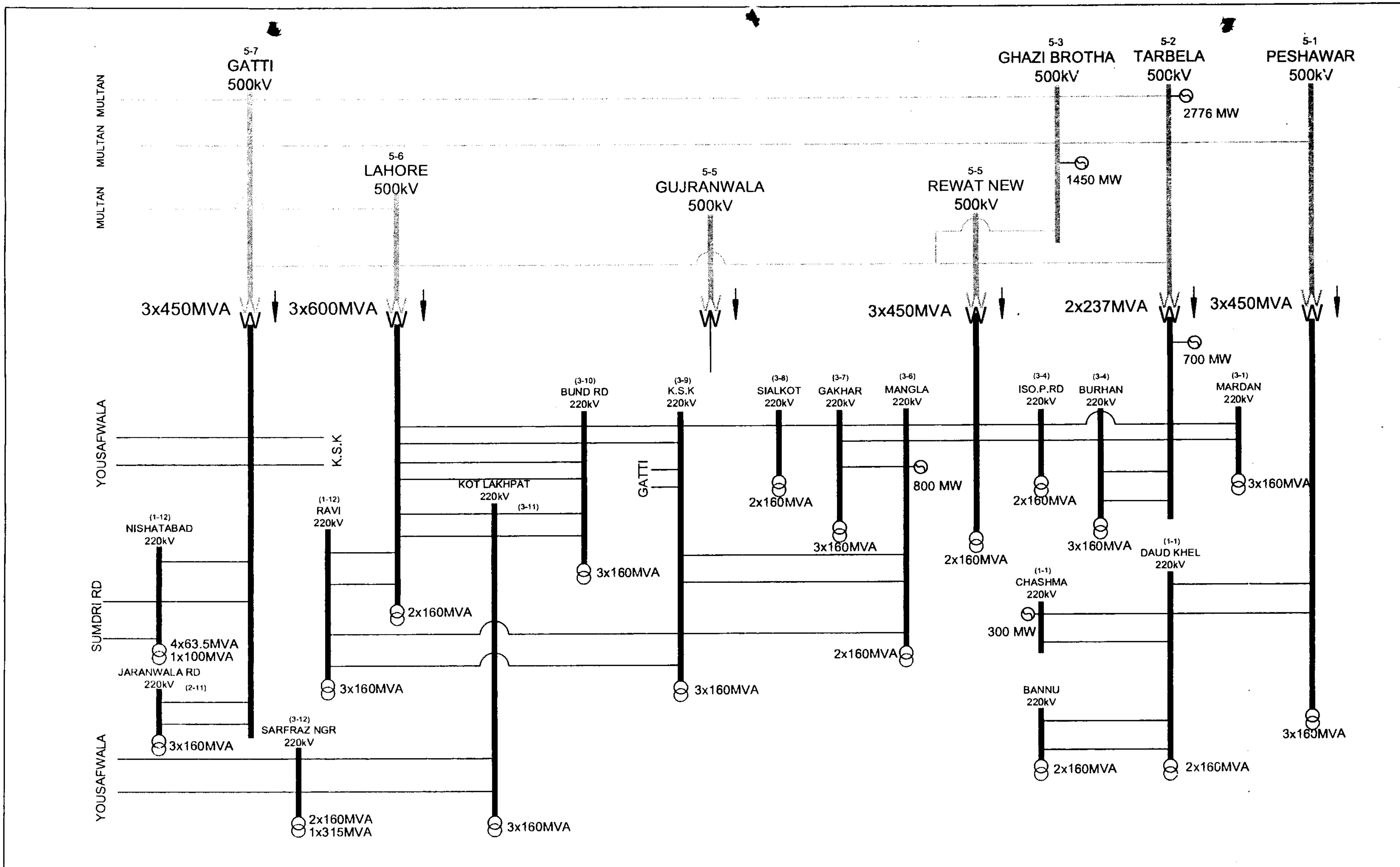
In order to find the potential route corridors of the T/L existing generation points, sub-stations and terminal points were studied. Based on the study, proposed routes of the T/L in segments which join the generation point, Sub Stations and terminal points are summarized below in Table 3-2:

Figure 3.2



EXISTING NTDC GRID MAP OF 500 AND 220KV SYSTEM

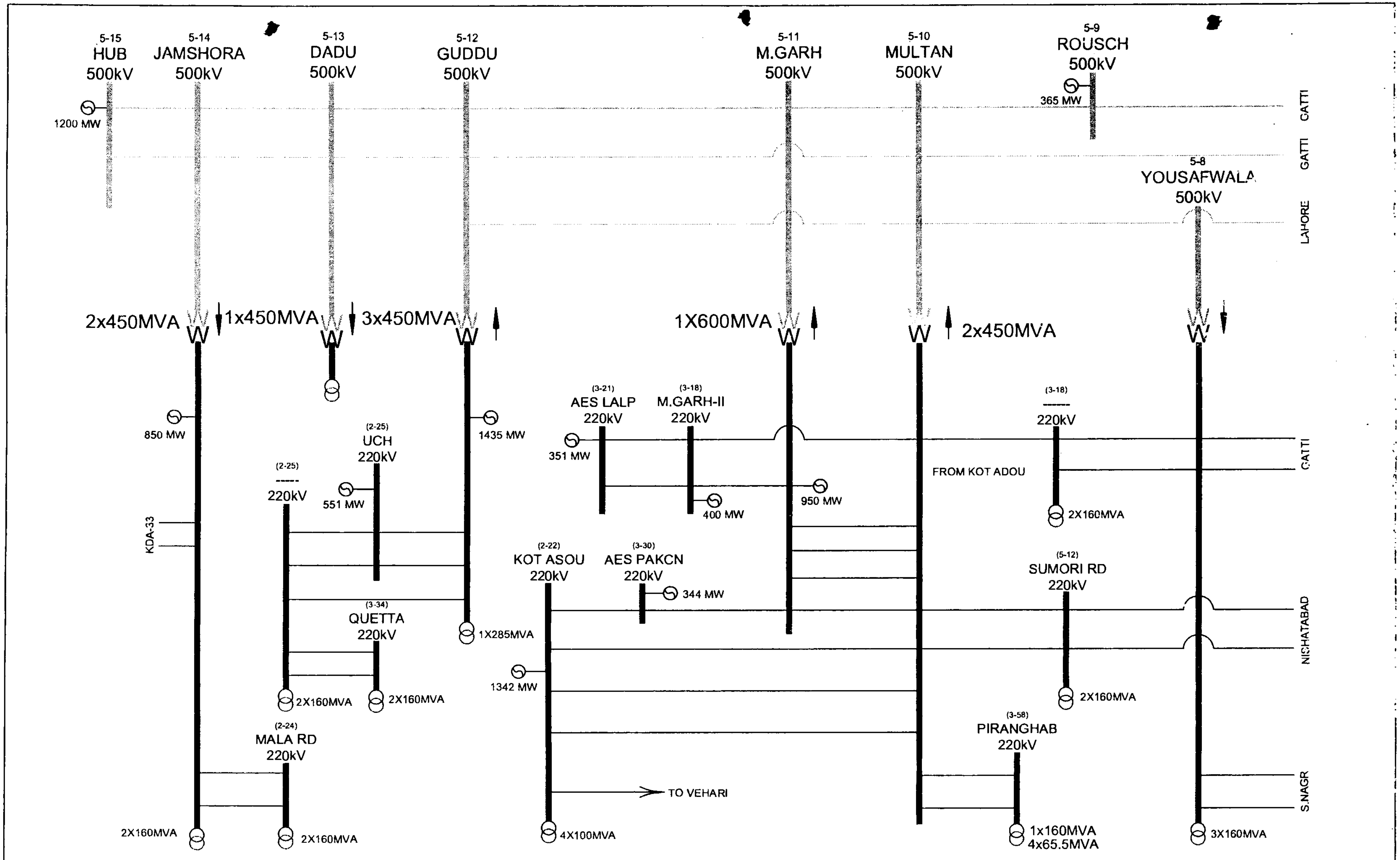
±660kV HVDC Transmission Line from Matiari to Lahore



NTDC 500/220KV SYSTEM SOUTHERN LINE DIAGRAM

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 3.5



NTDC 500/220KV SYSTEM NORTHERN LINE DIAGRAM

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 3.4

Table 3–2: Proposed T/L Routes

Sr. No.	Route Description	Length (Km)
1	±600KV HVDC Bipole from Thar Coal to Lahore (S), Circuit-I	1020
2	±600KV HVDC Bipole from Thar Coal to Lahore (S), Circuit-II	1020
3	±600KV HVDC Bipole from Thar Coal to Faisalabad (W), Circuit-I	980
4	±600KV HVDC Bipole from Thar Coal to Faisalabad (W), Circuit-II	980
5	±660KV HVDC Bipole from Thar Coal to Faisalabad (W), Circuit-II	880
6	±660KV HVDC Bipole from Matiari to Lahore	870

The selection of an appropriate route corridor of the above mentioned T/Ls was critical as the environmental and resettlement issues as well as existing infrastructures, such as roads and railway lines crossings, protected areas etc. need to be taken into account. The cost of the construction of T/L is a critical factor that needs to be considered. In order to minimize the construction cost, the Consultant has adopted efficient approach for avoiding steep slopes, forested land protected/sensitive areas etc.

3.4 T/L Route Alignment Criteria

Consultant considered the environmental and resettlement issues associated with the proposed T/L routes for the comparison of different options. The Consultant developed the Route Alignment Criteria based on the technical as well as critical environmental and social including resettlement parameters in order to minimize the impacts to the extent possible.

The following criteria were developed for the selection of T/L route considering physical, ecological and socio-economic environments:

- Avoid densely populated areas/towns;
- Avoid indigenous or tribal settlements;
- Avoid cultural, religious and historical buildings;
- Minimize disturbance to the natural habitats of flora and fauna;
- Avoid major birds migratory routes;
- Avoid Wildlife sanctuaries, national parks and game reserves;
- Avoid potentially security vulnerable areas;
- Appropriate distance from the sensitive receptors (for instance, minimum 500m);
- Avoid crossing large water bodies like lakes, rivers or streams; and
- Avoid crossing airports, railway tracks and other similar structures and facilities.

3.4.1 Routing of T/Ls and Converter Stations

After studying potential T/L corridor, one potential route after considering different routes i.e. Route A was considered for further studies. Figure 3-5 shows the Route A marked on satellite imagery.

Initially Route A was identified by the CET design team and marked on the imagery. The details of Route A are given in Table 3-3. Subsequently, NESPAK team evaluated this route by identifying various kinds of features (natural as well as manmade) with the major emphasis on settlements and ecological sensitive areas. Large number of settlements, along with the crossings on protected forests, wetlands, agriculture land was identified during the route alignment study. These limitations were marked on the route map and a constraint map was developed. Later, Route A was modified to minimize these identified constraints.

This route was marked as Route B. Route B was marked on the satellite imagery to meet the route alignment criteria.

With this alignment the effected settlements were considerable reduced.Details of Route B are given below in Table 3-3. Based on the desk studies, information collected through available documents/imageries etc. and in the light of identified significant features, the Route B was considered for route optimization. Figure 3-5 shows the Route A & B.

Route Optimization

The route optimization was carried out by the team of experts along with the environmental and resettlement experts to optimize the Route B by physical observations at the site. The route optimization survey was started from Matiari to Lahore. The team adopted the same approach as described in the route alignment criteria to minimize the environmental and resettlement issues. Based on the findings of route optimized survey, Route B was further modified to further minimize the issues and was finalized as Route C. A comparison of Route A, B and C is shown in Table 3-3.

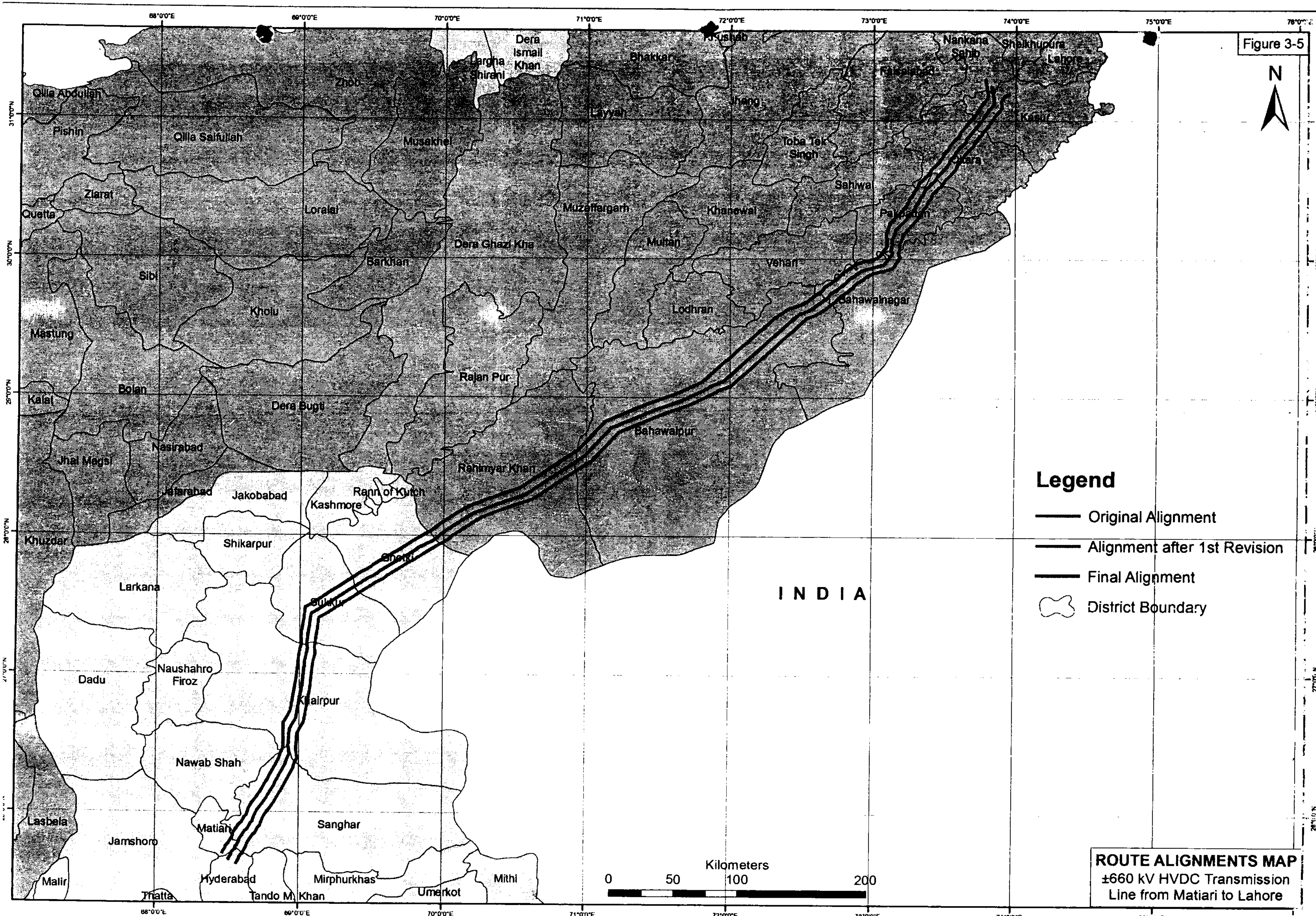


Figure 3-5
N
Legend
Original Alignment
Alignment after 1st Revision
Final Alignment
District Boundary
INDIA
Kilometers
0 50 100 200
ROUTE ALIGNMENTS MAP
±660 kV HVDC Transmission
Line from Matiari to Lahore
Qilla Abdullah
Pishin
Qilla Saifullah
Zhob
Musakhel
Dera Ismail Khan
Bhakkar
Layyah
Jhang
Toba Tek Singh
Nankana Sahib
Sheikhupura
Lahore
Kasur
Okara
Sahiwal
Pakpattan
Ziarat
Quetta
Loralai
Muzaffargarh
Khanewal
Multan
Vehari
Dera Ghazi Khan
Barkhan
Sibi
Kholu
Lodhran
Bahawalnagar
Mastung
Rajan Pur
Bolan
Kalat
Dera Bugti
Bahawalpur
Nasirabad
Jhal Magsi
Rahimyar Khan
Jafarabad
Jakobabad
Kashmore
Khuzdar
Shikarpur
Ghotki
Larkana
Sukkur
Dadu
Naushahro Firoz
Khairpur
Nawab Shah
Sanghar
Matiari
Lasbela
Jamshoro
Hyderabad
Mirphurkhas
Mithi
Umerkot
Malir
Thatta
Tando M. Khan

Figure 3–5: Alternative Routes of Proposed T/L

Table 3–3: Summary of the T/L Route Options

Sr. No.	Parameter	Option A	Option B	Option C
1	Settlements	>350	<240	<170
2	Wildlife sanctuaries, national parks and game reserves	5	3	0
3	Forests	4	2	2
4	Airports and other similar structures	>5	<4	<1
5	Large water bodies like lakes, rivers or streams;	2	2	2
6	Infrastructure like roads, railway crossings etc.	>175	<150	<75

Based on the comparison Route C was finally selected based on technical we well as environmental grounds.

3.5 Technological Alternatives

To find the most economical and environmental friendly technology to dispatch the electricity, various technological options were considered. In principle alternatives are available for the transmission of Power i.e. through High Voltage Alternating Current (HVAC) and High Voltage Direct Current (HVDC). Apart from the choice between AC and DC, selection of 500, 660 and 765 KV circuits is also available. All these alternatives were considered for the proposed T/L Project.

The first electric generator was the direct current (DC) generator and hence, the first T/L was constructed with DC. The basic discoveries of Galvani, Volta, Oersted, Ohm and Ampere were in the DC field. Thomas A. Edison built the first electric central station in the world in 1882, on the Pearl Street, in the New York, which was the DC current. Despite the initial supremacy of the DC, the alternating current (AC) supplanted the DC for greater uses. This is because of the availability of the transformer, the induction motor and polyphase circuits in the 1880s and 1890s.

The transformer is a very simple device and easy to operate to change the voltage level for the transmission, distribution and use. The induction motors are the workhorse in the industries and work only with AC. That is why AC has become very useful for the commercial and domestic uses. But for the transmission of electricity over long distances, DC is still more favourable than AC because of its economical, technical and environmental advantages, such as decrease need for new Power stations, reduced ROW and less visual impacts. High voltage DC (HVDC) Transmission system consists of three basic parts: 1) Converter Station to convert AC to DC 2) T/L or conductor 3) second Converter Station to convert back to AC. HVDC transmission systems can be configured in many ways on the basis of cost, flexibility and operational requirements.

Current and voltage limits are the two important factors of the high voltage T/L. The AC resistance of a conductor is higher than its DC resistance because of skin effect and eventually loss is higher for AC transmission. The switching surges are the serious transient over voltages for the high voltage T/L, in the case of AC transmission the peak values are two or three times of normal crest voltage but for DC transmission it is 1.7 times normal voltage. HVDC transmission has less corona and radio interference than that of a HVAC T/L. The total Power loss due to corona is less than 5 MW for a ± 450 KV and 895 km HVDC T/L.

These alternatives were based on the following data obtained from the NTDC Planning Department.

- Load Forecast upto 2030;
- Generation Plans upto 2030; and
- Transmission Plans upto 2017-18.

To evolve the most feasible T/L route, the analysis was focused on the ultimate spot year of the study i.e. 2030. The overall quantum of targeted Power to be transferred from south to Upcountry by the year 2030 as per the information provided by NTDC is given below in Table 3-4:

Table 3–4: Proposed Power Generation Plan

Sr. No.	Power Plant	Location	MW
1	Imported Coal (Public Sector)	Karachi	1,000
2	Imported Coal (IPP)	Karachi	1,200
3	IPP	Thar	1,200
4	Public Sector	Thar	1,200
5	Additional IPPs	Thar	2,600
6	Nuclear	Karachi	1,000
7	Nuclear	Karachi	1,000
8	Sub-total		9,200
9	Additional IPPs	Thar	15,000
	Total		**24,200**

It is clear from above table that the significant component of proposed Power addition in South will be obtained from the Thar and Karachi regions. The system conditions of low water of January 2030 based on available climate change predictions have also been simulated based on the data received from NTDC. Hence based on the above HVDC T/L is considered most appropriate for the bulk despatch of power.

3.6 Converter Station Site Selection Guidelines

Since, the Project is being implemented on urgent basis and the detailed topographic survey and design of the Converter Stations is yet to be carried out, the following points will be taken care of at a later stage:

- To minimize the resettlement, relocation of the existing infrastructure like roads, railways, cultural and religious sites etc. and alignment will be adjusted during the detailed survey;
- To avoid the cutting of fruit trees like apple and peach, alignment might be adjusted. However, an alternative for provision of Towers with maximum height to achieve the minimum required clearance will also be considered especially at sites where change of alignment is not possible;
- Adjustment of Towers to provide the minimum required vertical clearance at crossing points of roads; and
- Based on the site conditions, Towers with adequate height will be used to provide the required clearance;

- Ease of acceccibility from main road;
- Proximity to the major disaster and emergency management authorities;

Note: These alternatives considered in this chapter are indicated for comparison purpose only.

4 PROJECT DESCRIPTION

4.1 General

This Chapter provides an overview of the Project including the proposed T/L route, Converter Stations, and their design construction aspects. The chapter provides details of project type, design considerations, construction aspects, construction procedures, and Operation and Maintenance. For in-depth technical details, reference to the Desing Document is recommended.

4.2 Type of the Project

The proposed Project is essentially a linear T/L Project with some components which are of non-linear nature such as Converter Stations, etc.

The proposed Project comprises following two (02) major components:

i. Transmission line; and
   a. Conductors; and
   b. Towers.

ii. Converter Stations.

Schematic diagram of the proposed T/L is shown in Figure 4-1. These are detailed below:

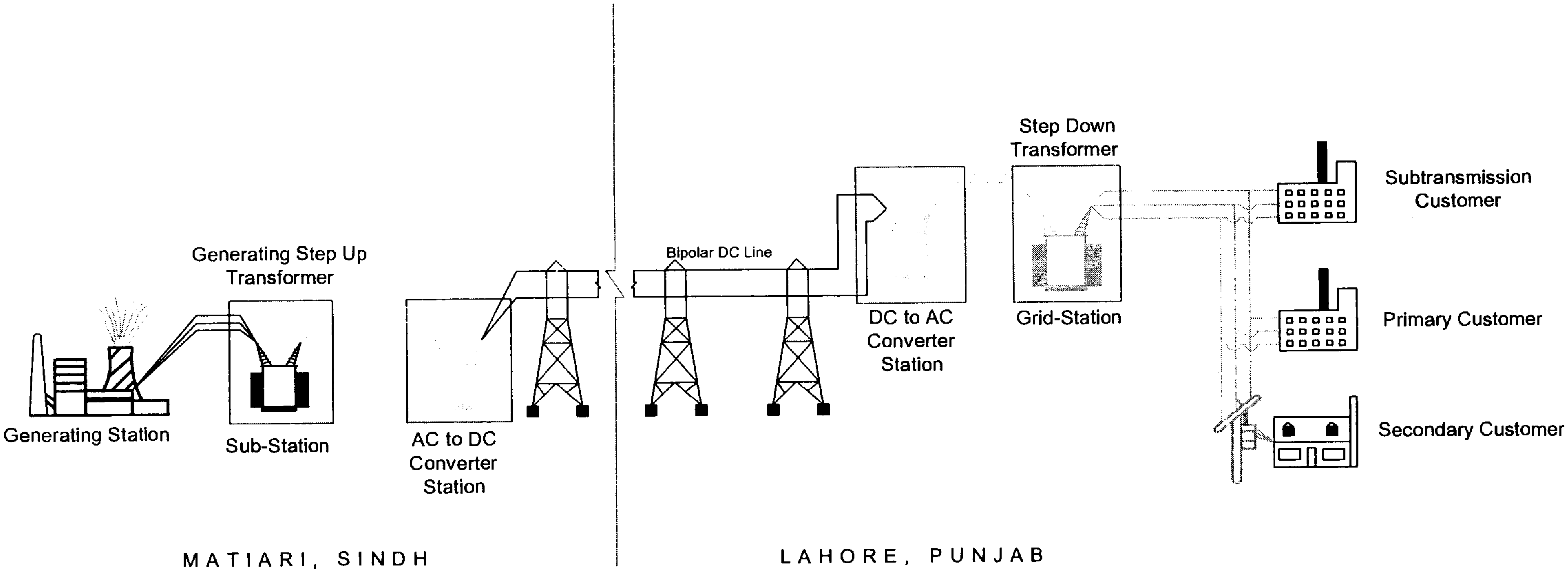
4.2.1 Transmission Line

The length of the proposed T/L route is about 865.55 km, out of which about 314.9 km lies in Sindh province, while the rest of 550.65 km is located in Punjab province.

The T/L route passes through plain sandy and alluvial lands in Sindh and Punjab provinces. During selection of the alignment of the proposed T/L, efforts were made to avoid the existing settlements, infrastructure and other features by following the criteria mentioned in Chapter 3.

Total numbers of AMs in the proposed T/L are about 169 in number. Out of total, 49 AMs falls in Sindh province while rest are located in Punjab province. Total Towers in the proposed line from Matiari in Sindh to Lahore in Punjab are estimated to be about 1898 in number. Out of these, about 681 Towers will be erected in Sindh while the remaining towers are to be raised in Punjab. The spacing between the Towers shall not be uniform because of the physical and other considerations like crossing of main roads, railway line, canals etc. for avoiding houses, infrastructure and cultural properties. However, average distance between Towers can vary from 275 to 340 m considering the topography and land use of the areas. Considering comprehensive carrying capacity, electromagnetic environment, mechanical property, tower load, economy, conductor manufacture, stringing construction, operating maintenance etc. and nature condition, steel reinforced aluminum conductor 4×JL/G3A-1000/45 is adopted in this project. For coastal areas, considering the anticorrosion requirement, all aluminum alloy conductor 4×JL/LHA1-745/335 is adopted. In budgetary estimates of this project, steel reinforced aluminum conductor 4×JL/G3A-1000/45 is considered.

According to the requirement of communication, there are two OPGW optical fiber cable in this project. Considering electrical, mechanical and lightning proof factor, OPGW-150 is recommended in this phase.



COLOR KEY:

Black: Generation

Blue: Transmission

Sub-station at Thar

Sub-station at Lahore

SCHEMATIC DIAGRAM OF PROPOSED T/L

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 4.1

4.2.2 Converter Stations

Converter Stations, a type of Sub Station, convert the generated electricity from HVAC to HVDC and vice versa.

For the planned T/L from Matiari to Lahore, as a part of this Project a Converter Station near the proposed Sub Station at Matiari and a Converter Station near proposed Lahore Sub Station are proposed. After passing through the Converter Station ±660 KV HVDC T/L will despatch the electricity to Converter Station located near Lahore to connect it to Lahore Sub Station (refer to Schematic Diagram Figure 4-1). From new Sub Station electricity will be transferred to the national grid.

Converter Stations generally have switching, protection and control equipment and transformers. In a large Converter Station, circuit breakers are used to interrupt any short circuits or overload currents that may occur on the network. Smaller distribution station may use reclose or fuses for protection of distribution circuits. Converter Stations themselves do not usually have generators, although a Power Plant may have a Converter Station nearby. Other devices such as capacitors and voltage may also be located at a Converter Station.

Converter Stations may be on the surface in fenced enclosures, underground, or located in special-purpose buildings. Where a Converter Station has a metallic fence, it must be properly grounded to protect people from high voltages that may occur during a fault in the network. Earth faults at a Converter Station can cause a ground potential rise. Currents flowing in the earth's surface during a fault can cause metal objects to have a significantly different voltage than the ground under a person's feet; this touch potential presents a safety hazard due to electrocution.

The new Converter Stations sites have been identified in the vicinity of Matiari area to ease the inter-connection of the incoming and outgoing T/Ls for Power dispersal.

Similarly for Lahore, potential site for the Converter Station has been identified in the area outside the Lahore city to ease the connection of the incoming and outgoing T/Ls for Power dispersal. Its location will, however, be finalized in consultation with NTDC. Converter stations potential sites locations are shown in Figure 4-2 (a) and (b).

4.3 Design Aspect

Following is the brief description of the design aspects of the proposed T/L, Converter Stations and Towers:

4.3.1 Transmission Line

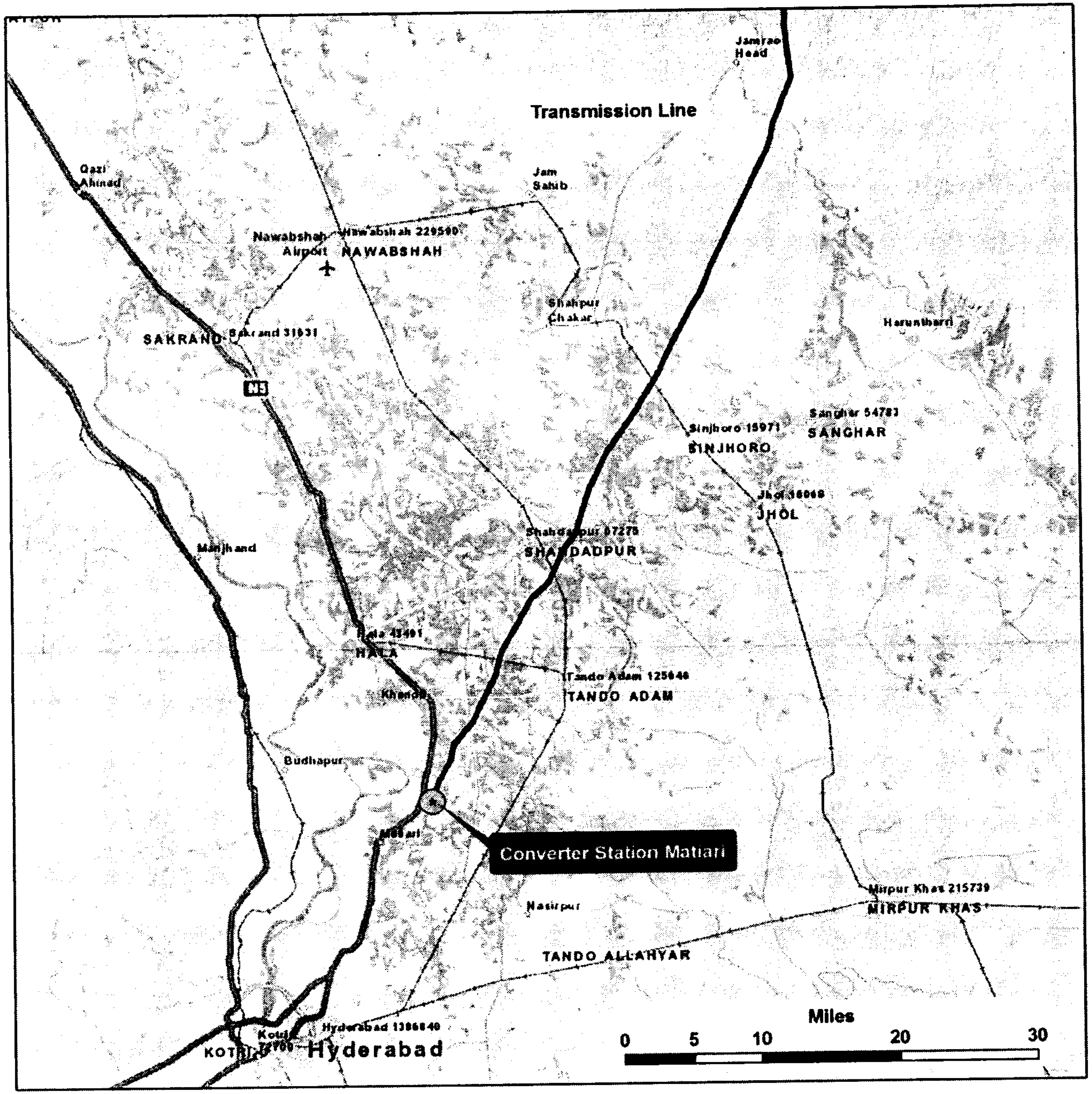
Electric-Power transmission is the bulk transfer of electrical energy, from generating Power Plants to electrical substations located near demand centers. This is distinct from the local wiring between high-voltage substations and customers, which is typically referred to as electric Power distribution. T/Ls, when interconnected with each other, become transmission networks.

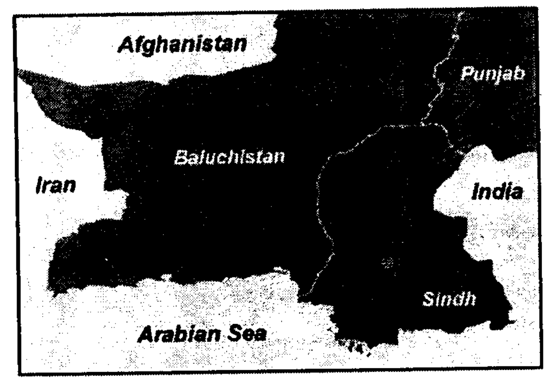
Historically, transmission and distribution lines were owned by the same company, but starting in the 1990s, many countries have liberalized the regulation of the electricity market in ways that have led to the separation of the electricity transmission business from the distribution business[11].

Most T/Ls use high-voltage three-phase AC, although single phase AC is sometimes used in railway electrification systems. HVDC technology is used for greater efficiency in very long distances (typically hundreds of miles (kilometres), or in submarine Power cables (typically longer than 30 miles (50 km). HVDC links are also used to stabilize against control problems in large Power distribution networks where sudden new loads or blackouts in one part of a network can otherwise result in synchronization problems and cascading failures.

[11] http://en.wikipedia.org/wiki/Electric_power_transmission#cite_note-femp01-0

Electricity is transmitted at high voltages (110 kV or above) to reduce the energy lost in long-distance transmission. Power is usually transmitted through overhead Power lines. Underground Power transmission has a significantly higher cost and greater operational limitations but is sometimes used in urban areas or sensitive locations.





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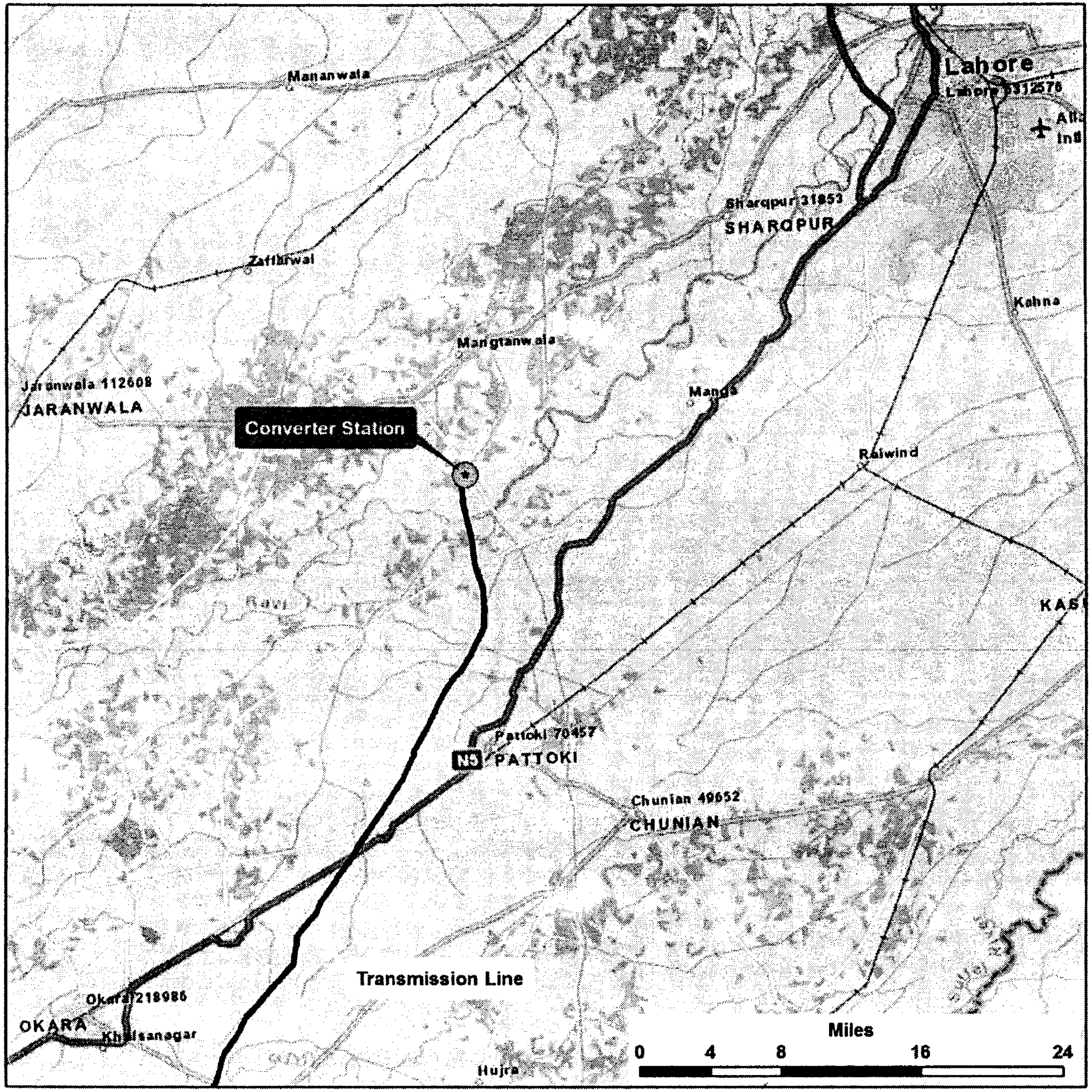
PROPOSED LOCATION OF CONVERTER STATION NEAR MATIARI

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 4.2a



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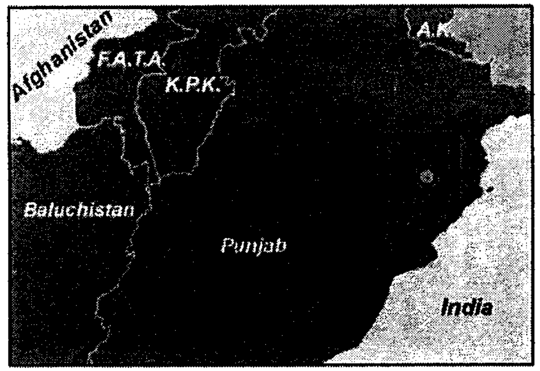


PROPOSED LOCATION OF CONVERTER STATION NEAR LAHORE

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 4.2b

A key limitation in the distribution of electric Power is that, with minor exceptions, electrical energy cannot be stored, and therefore must be generated as needed. A sophisticated control system is required to ensure electric generation very closely matches the demand. If the demand for Power exceeds the supply, generation plants and transmission equipment can shut down which, in the worst cases, can lead to a major regional blackout. To reduce the risk of such failures, electric transmission networks are interconnected into regional, national or continental wide networks thereby providing multiple redundant alternative routes for Power to flow should (weather or equipment) failures occur. Much analysis is done by transmission companies to determine the maximum reliable capacity of each line (ordinarily less than its physical or thermal limit) to ensure spare capacity is available should there be any such failure in another part of the network.

Taking into account the possibility of higher export of Power through the line in future years, ±660 KV Bi-pole conductors in quad bundle configuration for the HVDC T/L has been recommended for interconnection. These functional specifications have been prepared at this stage of the Project after considering all essential parameters. It may be added that detailed specifications of the T/L will be based on these functional specifications and will be prepared at a later stage once the Project implementation is finalized. The parameters considered for the system and human safety are described below in detail.

Considering the location of Sending end Supporting Power Source, the condition of 500kV existing power evacuation networkin Sindh,the collection of power sources, connection of converter station, and minimize the length of DC line, the site of DC delivery point converter station will be near Matiari which is the north part of Hyderabad.

Connection of Delivery Point Converter Station

The delivery point converter station is π connected into Jamshoro~Moro 500kV line.

There are eight 500kV circuits going out from delivery point converter station. One returns to Jamshoro; one returns to Moro; other 6 return to power sources.

Delivery Point Power Source

The Hubco Coal Power Plant and Port Qasim Coal Power Plant will be connected to converter station by two 500kV lines respectively; Engro Thar Coal Power Plant and SSRL Thar Coal Block I Mine Mouth Power Plant will be connected to converter station by one 500kV line respectively, and these two power plants will be connected by one 500kVAC line.

The scheme of connection system was agreed by Pakistan side. The investment and construction will be finished by Pakistan side.

Access System of Receiving End Converter Station

Receiving end Converter Station

According to the analysis of power market, DC project should be located in Punjab and Islamabad area. According to the scheme, the load of Islamabad is satisfied by hydropower from north. This project is considered to be located at the main load center of Punjab which is Lahore area.

Connection of Sending-end Converter Station

The receiving end converter station is double π connected into Lahore~Lahore South 500kV double circuit line; new converter station~Lahore North~Gujranwala 500kV double circuit line.

There are six 500kV circuits going out from receiving end converter station. Two return to Lahore; two return to Lahore South; two return to Lahore North.

a) **Climatic Consideration**

Local climatic conditions, i.e. the temperature, wind velocity, thunder storm levels, relative humidity etc., control the selection of materials to be used for T/Ls. The following climate parameters considered in the design criteria are based on the data collected from the various meteorological stations at an evaluation of 50 m of.

- Maximum Conductor Temperature 50°C
- Minimum Conductor Temperature -5.0°C
- The Annual Average Temperature 25°C
- 10-Minute Average Wind Speed 32.3m/s
- The Annual Average Thunderstorm Days 4.4~38days
- The Annual Average Relative Humidity(UTC 0am) 72.5~74.2%
- Years of Average Rainfall 112.0~679.7mm
- Current Rating of Conductor 1673A

b) **Conductors and Line Configurations**

The selection of conductor is based on electrical, mechanical and atmospheric pollution considerations. The size of conductor is determined such that the corona and radio interference levels are within the internationally acceptable limits.Considering comprehensive carrying capacity, electromagnetic environment, mechanical property, tower load, economy, conductor manufacture, stringing construction, operating maintenance etc. and nature condition, steel reinforced aluminum conductor 4 × JL/G3A-1000/45 conductor has been selected. For coastal areas, considering the anticorrosion requirement, all aluminum alloy conductor 4×JL/LHA1-745/335 is adopted. In budgetary estimates of this project, steel reinforced aluminum conductor 4×JL/G3A-1000/45 is considered.

According to the requirement of communication, there are two OPGW optical fiber cable in this project. Considering electrical, mechanical and lightning proof factor, OPGW-150 is recommended in this phase.

Studies and economic analysis will be carried out by the Consultant to determine the optimum size of the conductor. The conductor in the phase shall be placed in horizontal formation for the single circuit Towers. The phase spacing at Towers, as well as at mid span, has been determined by taking into account the following restrictions:

- Minimum conductor-to-leg clearance of 6.4 m under extreme wind conditions;
- Space to accommodate insulator V-String; and
- Space to provide between cross-arms of two phases of single circuit type Towers.

The ultimate tensile strength (UTS) limits for conductor tension will be as given below:

- 17% of UTS under no wind conditions, every day stress at every day temperature, final conditions;
- 50% of UTS under full wind load (44.7 m/sec) at every day temperature, final condition;
- 30% of UTS under no wind load condition at minimum temperature, initial condition; and
- Maximum wind pressure of 175kg/m² on conductors, 190 kg/m² for Optical Fibber Ground Wire (OPGW) and Overhead Shield Wire (OHSW) and 240kg/m² for insulators have to be adopted.

4.3.1.1 Towers

a) Tower Structures

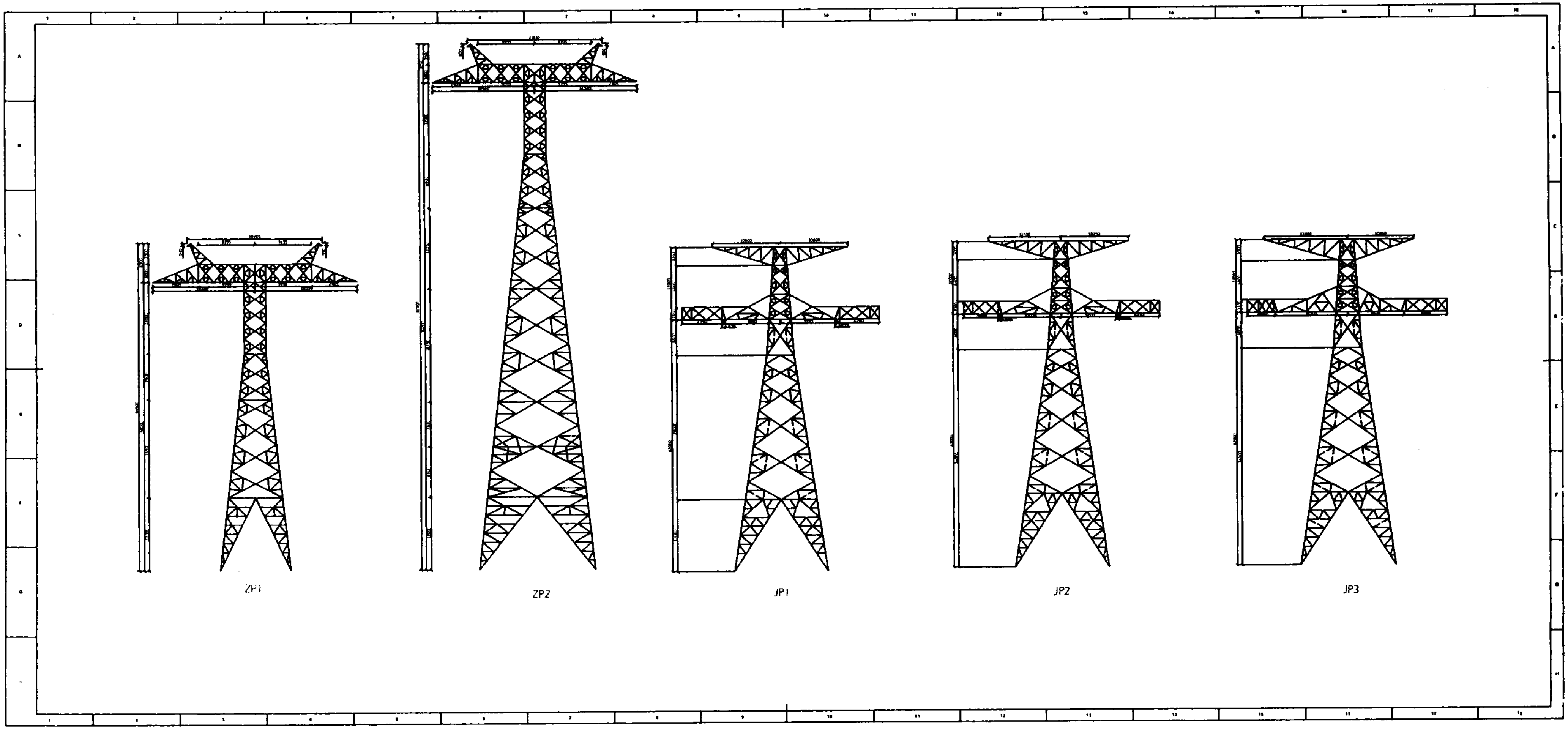
All the Towers shall be self-supporting type, lattice steel structures, fabricated from galvanized structural steel shapes. Outline diagram of tower is shown in Figure 4.3.The steel employed will be in accordance with the latest edition of the following standards:

- EN 10025: EURONORM Standard Specifications for Structural Steel; Rolled Steel, Steel Sheets and Plates etc.;
- ASTM A36: Standard Specifications for Structural Steel; and
- ASTM A572: Grade 50/60/65 Standard Specifications for High Strength Low-alloy Columbium-Vanadium Steels of Structural Quality.

Horizontal configuration has been used for single circuit Towers. Three types of Towers will be used in the system. These include "Suspension", "Medium Angle" and "Heavy Angle/Dead End". Table 4-1 to Table 4-4 provide the details of outline of Tower types to be used along with their wind and weight spans capabilities. The detailed Tower design will be carried out by the CET during Project implementation.

Table 4-1: Current-Carrying Capabilities of Different Conductors

Sr. No.	Conductor type	JL/G3A-1000/45	JL1/LHA1-745/335	JLHA3-1050
1	Number of bundle conductors	4	4	4
2	Outside diameter(mm)	42.10	42.84	42.13
3	DC resistance at 20°C(Ω/km)	0.02890	0.02780	0.02880
4	Temperature coefficient of resistance	0.00407	0.00385	0.0038
5	The maximum carry current of polar conductor A	3837.8	3945.8	3870.2
6	Maximum transmission capacity MW	5065.83	5208.40	5108.62
7	Meeting the normal transportation capacity(true or false)	true	true	true
8	Meeting the overload transportation capacity(true or false)	true	true	true
9	Nominal current-carrying conductor temperature°C(ambient temperature 25°C)	49.03	48.70	48.95
10	Nominal current-carrying conductor resistance (Ω/km)(ambient temperature 25°C)	0.0323	0.0309	0.0320



OUTLINE DIAGRAM OF TOWER

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 4.3

Table 4-2: Resistance Power Losses of Different Conductors

Sr. No.	Conductor type	JL/G3A-1000/45	JL1/LHA1-745/335	JLHA3-1050
1	Number of bundle conductors	4	4	4
2	Aluminium-sectional area of sub-conductor/mm^2	1000	1080	1050
3	Aluminium-sectional area of polar conductor /mm^2	4000	4320	4200
4	Polar conductor resistance with nominal current-carrying capacity (Ω/km)	0.0081	0.0077	0.0080
5	Nominal current density (A/mm2)	0.75	0.69	0.71
6	Nominal resistance loss power (kW/km)	145.41	138.92	143.86
7	Nominal line loss rate	3.22%	3.07%	3.19%

Note: The year-round average milieu temperature 25°C is used to calculate conductor resistance in operation.

Table 4-3: Electric Energy Losses of Different Conductors

Sr. No.	Conductor type	JL/G3A-1000/45	JL1/LHA1-745/335	JLHA3-1050
1	Number of bundle conductors	4	4	4
2	Annual resistive loss (10000kwh/km) τ=4500	65.44	62.52	64.74
3	Annual resistive loss (10000kwh/km) τ=5600	81.43	77.80	80.56
4	Annual resistive loss (10000kwh/km) τ=6000	85.61	81.78	84.69
5	Annual resistive loss (10000kwh/km) τ=6500	94.52	90.30	93.51
6	Outside diameter(mm)	42.10	42.84	42.13
7	corona loss(kW/km)	6.04	6.02	6.04
8	Annual corona loss (10000kwh/km)	5.29	5.27	5.29
9	Corona loss power/Resistance loss power	4.15%	4.33%	4.20%
10	Annual electric energy loss (10000kwh/km) τ=4500	70.73	67.79	70.03
11	Annual electric energy loss (10000kwh/km) τ=5600	86.72	83.07	85.85
12	Annual electric energy loss (10000kwh/km) τ=6000	90.90	87.06	89.98
13	Annual electric energy loss (10000kwh/km) τ=6500	99.81	95.57	98.80

Table 4-4: Mechanical Properties of Different Conductors

Sr. No.	Conductor type	JL/G3A-1000/45	JL1/LHA1-745/335	JLHA3-1050
1	Section surface mm^2	1043.20	1083.33	1048.41
2	Diameter mm	42.10	42.84	42.13
3	Piece weight kg/m	3.10	3.00	2.90
4	Elastic coefficient N/mm^2	60600	55000	55000
5	Thermal expansion coefficient $10^{-6}/°C$	21.50	23.00	23.00
6	T:rated tensile strength kN	220.93	223.30	239.04
7	Breakdown stress N/mm^2	201.19	195.82	216.60
8	Maximum working stress N/mm^2	80.48	78.33	86.64
9	Average operating stress N/mm^2	50.30	48.95	54.15
10	Control state	average temperature	average temperature	average temperature
11	Actual safety coefficients	3.64	3.59	3.53
12	Average percentage of stress	25%	25%	25%
13	High-temperature sag at average span m	16.0	15.46	14.19
14	Sag difference m	0.00	-0.51	-1.78
15	Overload capacity under the gale m/s	61.3	60.67	62.25
16	Nominal height m	42	42	41
17	Number of bundle conductors	4	4	4
18	Vertical load without ice%	100%	97%	94%
19	Horizontal load under the gale %	100%	102%	100%
20	Longitudinal load %	100%	103%	109%

b) Tower Spotting

Tower spotting will be done considering the following factors:

- Selection of proper Tower type and positioning at optimum location;
- Achievement of economical Tower heights with safe clearance from ground and nearby objects;
- Assurance of compliance with design load criteria;
- Location of Towers to minimize risk of foundations being damaged by flood, erosion, shifting of sands etc.;
- Providing a minimum clearance of 20 m from the outer conductor to the nearest conductor of another Power line, existing or planned;
- Avoiding interference with or obstruction to any roadway or track being regularly used by wheeled vehicles, animals or pedestrians;
- In areas of shifting sands, extra ground clearance will be needed to ensure that movement of the sand dunes will not reduce conductor ground clearance below the minimum safe value; and
- The requirements of the relevant authorities regarding distance of Towers from the roadways and railways.

NTDC will provide the final route of the T/L to the Contractor. Contractor will carry out the detailed surveys including preparation of plan and profile drawings and Tower staking in the field.

c) Tower Foundations

American Concrete Institute (ACI), IEEE Guideline for Transmission Structure Foundation Design and Testing (IEEE Standard 691-2001) will be used for Towers Foundations.

All the Tower foundations will be designed as individual leg footings, with 4 legs per Tower. The following foundation types will be considered depending upon the results of the soil investigations.

- Shallow Foundation (Square);
- Dry;
- Semi-submerged;
- Submerged;
- Deep Foundation; and
- Piles.

Depending on the engineering parameters of the soils under various conditions (based on the geotechnical results which are in process), different types of foundations will be recommended. Final choice will be made after the Contractor has carried out soil investigations at the time of construction.

The foundations will be about 2.5 to 4 m below the natural surface level with only Tower footings protruding up to 0.45 m above the ground. The general steel structure of the Tower will have a clearance of 4 to 8 m from the natural ground. This will allow the farmers to utilize the ground underneath the Tower.

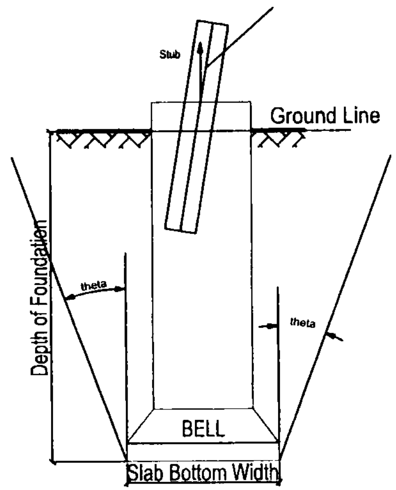
Pile foundation is considered for Tower locations at nullah/stagnant/flash flood area at places where the soil condition do not permit the use of shallow foundations. The exact number of pile foundations will depend on subsurface investigations at the Tower locations at the time of construction. Outline diagram of foundation is attached as Figure 4.4

The concrete grade shall be of C-15, C-25, C-30 etc. while steel grade shall be HPB 300, HRB 400. Equivalent quality materials meeting above specifications can also be used.

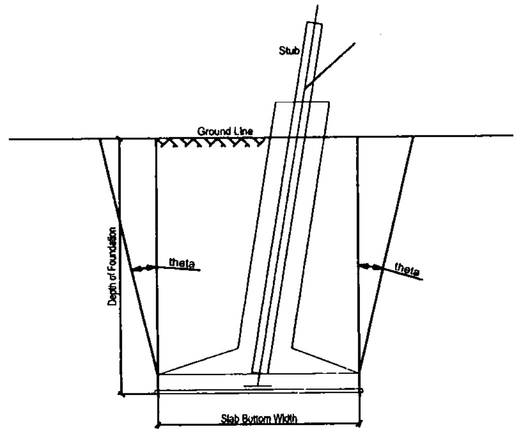
4.3.1.2 Insulation

T/L has been provided with appropriate insulator assemblies. These have been determined based on the degree of contamination in air, Power frequency, operative voltage, switching and lighting surge voltage under the particular service conditions of the line. The type of insulators, creepage distance and shed diameter has been selected in accordance with the existing international standards for similar voltage level.

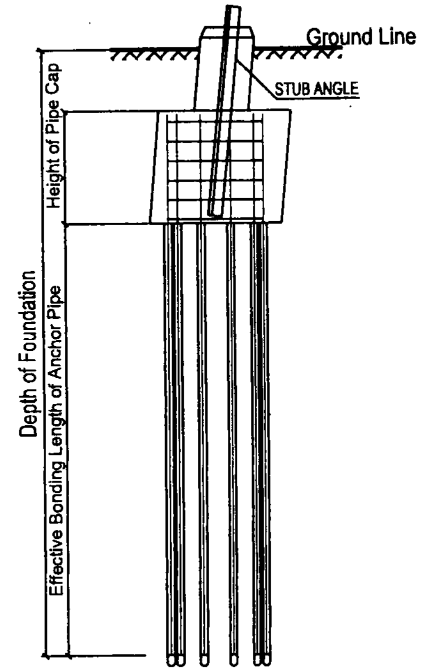
- ANSI C29.1: American national standards for electric Power insulators;
- IEC Publication 383: Insulators of overhead lines with a normal voltage above 1000 V;
- IEC 575: Thermal-Mechanical performance test on string-insulator units; and
- Other relevant ANSI, ASTM and IEC Standards.



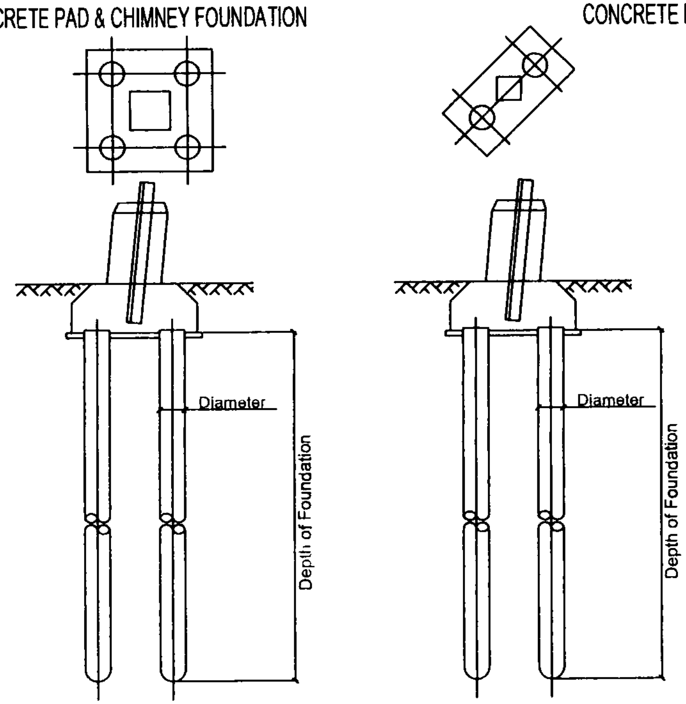
CONCRETE PAD & CHIMNEY FOUNDATION



CONCRETE PAD & CHIMNEY FOUNDATION



Hard Rock Foundation



Pile Foundation

OUTLINE DIAGRAM OF FOUNDATION

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 4.4

4.3.1.3 Safety Parameters

For Extra High Voltage (EHV) lines, safety considerations are of two types. One is related to the safety of the system, while others are those that are related to the public. It is for this reason that NTDC has adopted a 100 m wide (50 m either side from the center line) corridor as the ROW for the proposed T/L. The aspects to be considered in this regard are as under:

(a) System Safety

Conductor to Tower Clearance: For the safety of the system, it is imperative that any factor that may interrupt the Power supply should be considered in the design. The clearance of the conductor from Tower legs and trusses is of prime importance. Therefore, in the design, a minimum clearance of 6.4 m has been adopted under extreme wind conditions. This is based on minimum requirements of National Electric Safety Code (NESC) (ANSI C2). With this clearance, there is 99% probability of withstanding switching surge of 3-sigma margin due to maximum over voltage under adverse climatic conditions.

Earthing of the System: Every Tower is connected to an earthing system. This is to keep Tower footings resistance at a level lower than 10 Ohms. For this, two (02) earth electrodes of copper-clad steel rods are sunk vertically into the ground to a minimum depth of 3 m and at the locations where the required resistance is not achieved crow footing will be done.

Lightning Performance: The Tower geometry, clearance and insulation of the system are designed to perform safely within the permitted lightning intensities. In this respect, consideration has been given to the Tower footing resistance and Isokeraunic level of the area. The accepted level is one trip out/ 100 km/ year due to lightning.

(b) Public Safety

General Aspects: In view of public safety, NTDC has adopted a policy of keeping a 100 m wide corridor clear of all obstructions for ±600 KV T/L (50 m on either side from the center line). However, NTDC allows general farm practices within this corridor, but tree plantation that exceeds a height of 2.5 m is not allowed. As such, the existing orchards having fruit trees with a height of not exceeding 2.5 m are allowed to remain under the lines. Similarly, open wells, including Persian wheels, are allowed to remain under the T/Ls. However, tube wells and peter pumps are not permitted under the high voltage conductors. This is for the reason that piping and cranes used to refurbish such wells could come in contact with the lines.

No residential or other public buildings like factory, school, hospital etc., are permitted within the corridor. However, farm buildings, which are not used for residential purposes are allowed to remain under the high voltage lines, provided a 10.2 m minimum clearance is maintained. The height of the Towers can be increased to accommodate such buildings.

Conductor to Ground Clearance: The conductor to ground clearance is desirable to be worked out based on over voltage due to switching surge. In this consideration, safe clearance is required to be provided for moving objects under the line with a height of 6.0 m, withstanding switching surge of 3-sigma margin with 99.7% probability under adverse atmospheric conditions. This should keep the maximum voltage gradient at ground level and maximum current induced in a person less than the internationally allowable values. As such, the total conductor to ground clearance shall in no way be less than 10.2 m.

The specific standard accepted is that of the NESC, currently applicable in the United States. The permissible conductor clearances (at a maximum temperature of 75°C) are given in

Table 4-5.

Table 4-5: Permissible Conductor Clearances

Sr. No.	Description	Clearance (m)
1	Cultivated land traversed by vehicles	11.5
2	Road and Streets	13.0

Sr. No.	Description	Clearance (m)
3	Highways	15.0
4	Railroads	14.0
5	Electrified Railroads Trolley Wire	6.0
6	River at High Flood Level	9.5
7	Places Accessible to Pedestrians only	12.0
8	Buildings Roofs not accessible to people	10.0
9	Tops of Trees (Orchards)	6.0
10	Canals	11.0

NESC, Rev.12

4.3.2 Converter Stations

Converter Stations will be located at each end of the proposed T/L (Matiari and Lahore) to transform the Alternate Current (AC) used in the national networks into Direct Current (DC) for transmission and vice versa. One of the main advantages of DC transmission is the savings achieved by not having intermediate Sub Stations along the T/L. General Layout of Converter Stations are attached as Figure 4.5 (a) (b).

Depending on the final design, the Converter Stations will measure approximately 200 to 300 acres (0.8 to 1.5 Km^2).

Converter Station at Matiari

Converter station is located at Matiari. The recommended site is an alluvial plain which has quite leveled and smooth surface. The main land use of the recommended piece of land is agriculture. Fields of wheat and orchards of banana, mango, etc. are being cultivated on this land. Land is highly fertile and gives excellent yields.

There are no large active faults in the nearby area and the seismic basic intensity is 7.There are two to three mud houses of the tenants and the traffic intensity is very low. Site is easily accessible from N-5 (National Highway) through accessible road. Condition of accessible road is good. Ground water table is quite shallow and will be utilized for the Converter Station requirements.

Matiari converter station's coordinate is E68 ° 30' 32", N25 ° 38' 25" and is proposed by NTDC. The grounding electrode's coordinate is E68 ° 41' 9.82", N25 ° 18' 29.94".

The scale of DC construction

One circuit 660kV/4000MW, One circuit completed in this project.

The scale of 500kV AC outgoing line

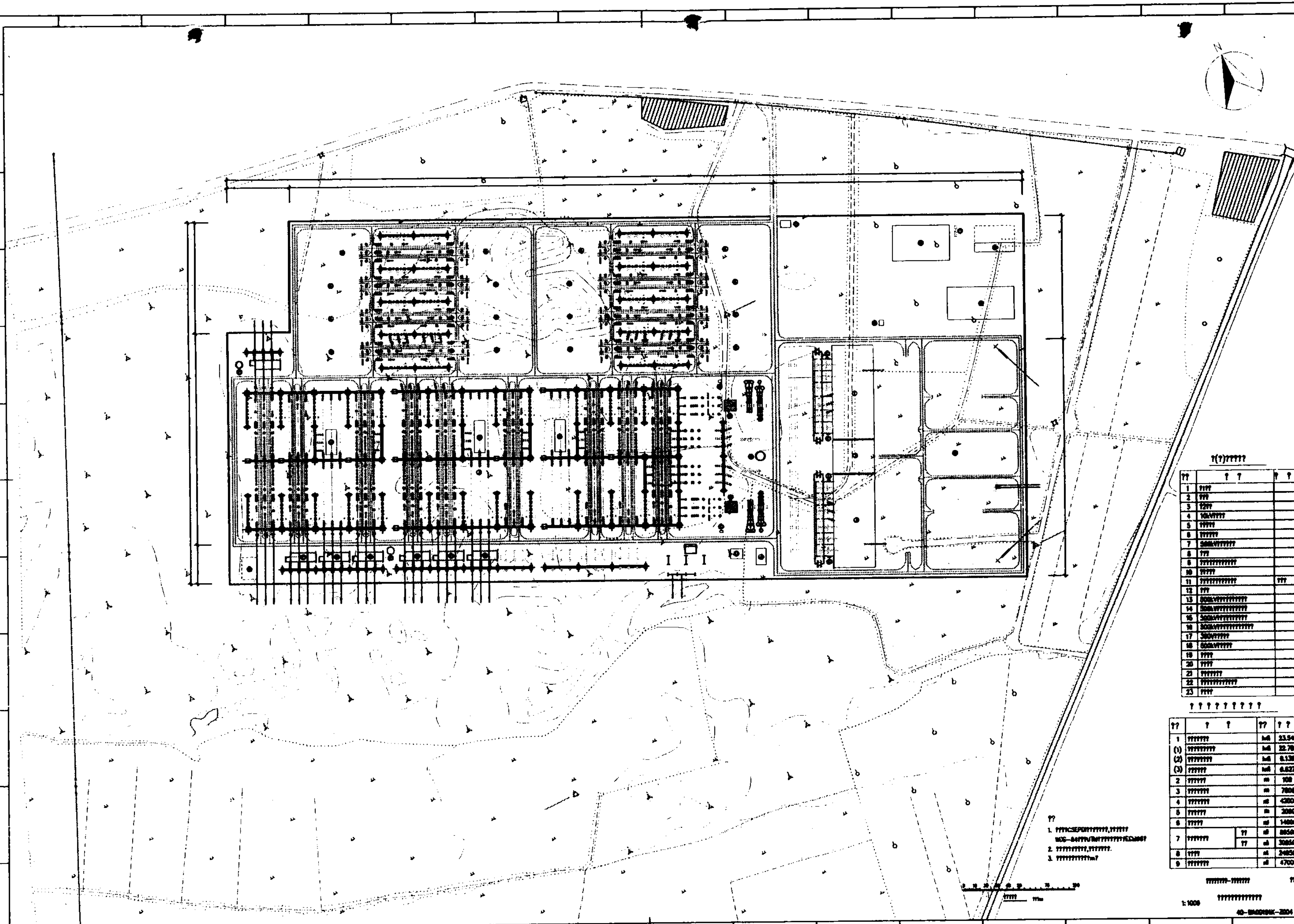
12 AC outgoing circuits in the future, 8 circuits completed in this project.

The scale of AC filter

Total capacity of capacitive reactive compensation is 2400-2600Mvar, in four large groups and 18 or 20 small groups. Each small group holds 120-140Mvar.

Converter Station at Lahore

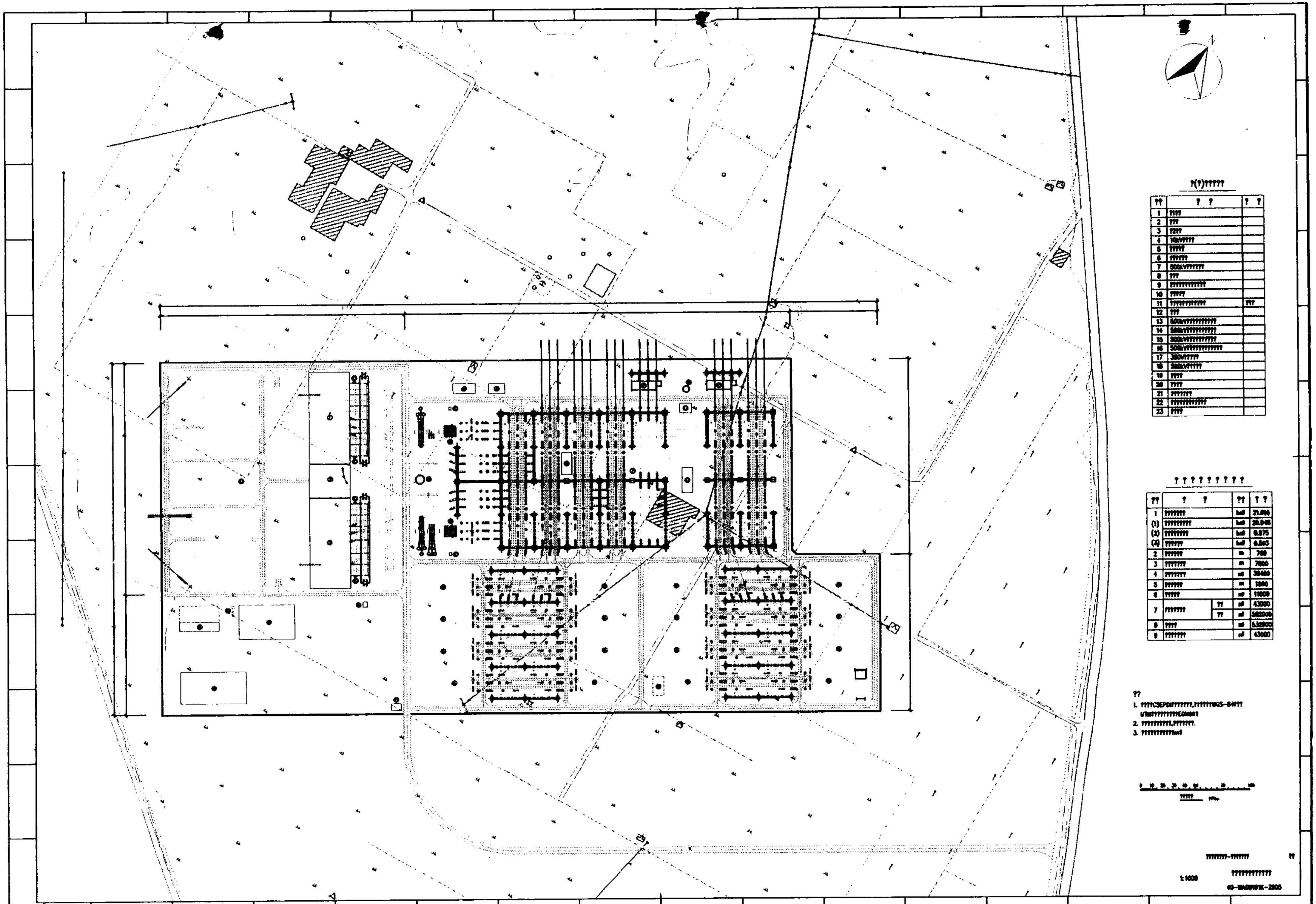
The recommended site for the Converter Station at Lahore is quite leveled and has smooth surface. The main land use of the area is agriculture. Fields of wheat and few fruit trees can be seen at the site.There are no large active faults nearby and the seismic basic intensity is 7.There are three 500kV substations nearby which will be an added advantage for connecting the Converter Station with NTDC system.



GENERAL LAYOUT OF LAHORE CONVERTER STATION

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 4.5a



GENERAL LAYOUT OF LAHORE CONVERTER STATION

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 4.5b

Ground water quality and quantity is feasible and will be utilized for the proposed Station.

Lahore converter station's coordinate is E73 ˚50' 18", N31 ˚15' 13" proposed by NTDC.

The grounding electrode's coordinate shall be chosen from; (a) E73 ˚52' 17.28", N30 ˚52' 12.55", (b) E73 ˚32'15.67", N31 ˚8' 10.07", (c) E73 ˚33' 56.97", N31 ˚12' 54.81".

Each Converter Station will have the following key components:

- **The valve hall:** this building houses the thyristor valves, the electronic component at the heart of the AC-DC conversion process;
- **The control building:** this structure encases all the control, protection and telecommunication equipment as well as the operator's office and computer stations; and
- **The outdoor switchyard:** the switchyard will contain the Power transformers, auxiliary supplies and harmonic filters.

The AC side of the Converter Stations will be connected to the local AC network at a local Sub Station via overhead or underground cable. The DC side is connected directly to the proposed T/L.

Main Electrical Connection

- The valve is bipolar and each electrode contains a 12 pulsation connection line.
- At the 500kV AC side, 3/2 breaker connection is adopted.
- The three-phase winding of converter transformer is YNy0 connection and YNd11 connection, single phase with double winding. Its AC side is connected with AC 500kV bus line with AC 500kV distribution apparatus.
- The DC side is typical bipolar DC connection. At the DC side of converter station, according to electrode, there are smoothing reactor, DC passive filter, DC voltage measurement device, DC current measurement device, DC disconnector, high-speed switcher, neutral point device and voltage protector.
  - DC filters are large AC filter groups.

System Communication

On the DC line between Matiari converter station and Lahore converter station, there are one 24-core OPGW fiber cable. The length is about 878km.

There is an optical communication repeater station near Rahim Yar Khan and Hāsilpur respectively. All repeater stations are regarded as under tower, it is necessary to consider new communication machine room and external power source, and installed with optical communication equipment and communication power supply etc. The main power of repeater station is from reserve power of 11kV substation nearby. Emergency power supply is solar power hybrid generating. The external power source of repeaterstation will be constructed by the employer.

The length of DC line is 878km in this project, and the length of optical fiber is 920km. The longest distance of SDH 2.5G system in China is 397km, which is Jiuquan~Hunan ultra-high voltage project using ultra-low-loss fiber and ROPA technology. We will arrange at least two repeater stations.

PLC repeater station is usually in the middle of the line. In this project, PLC repeater station can be constructed with Rahim Yar Khan OPGW repeater station. Rahim Yar Khan repeater station is 385km from Matiari converter station and 493km from Lahore converter station. PLC repeater station should contain primary equipment like DC isolation filter, coupling capacitor, DC line trap, combining and processing equipment and power line carrier equipment etc.

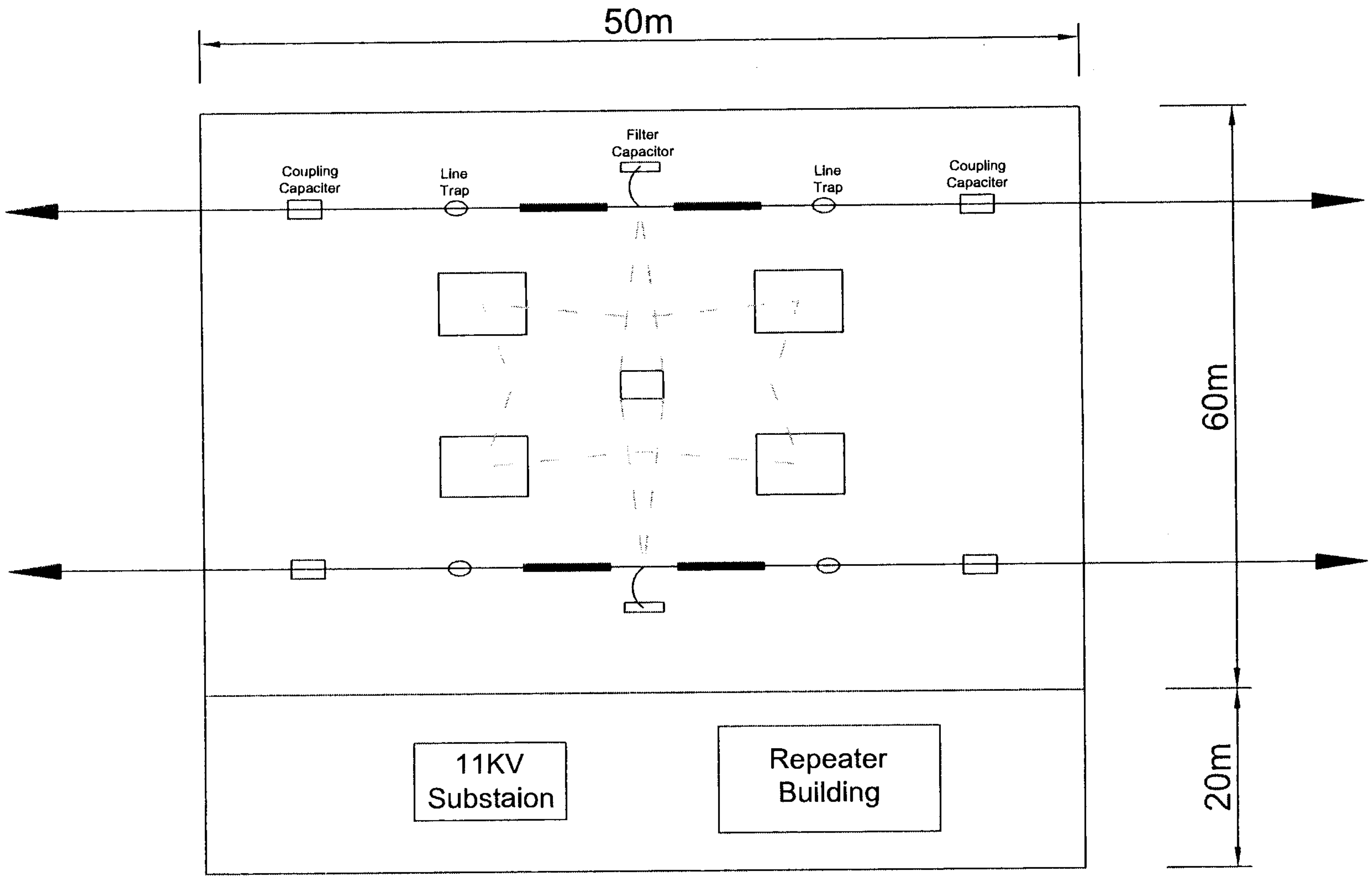
For Rahim Yar Khan OPGW and PLC repeater station, the total area is about 4500m^2, and building area is 150m^2. Its coordinate is E70°26' 18.48601", N28°14' 58.41340". (Transmission tower No. G808). Typical PLC repeater station layout is attached as Figure 4.6.

An OPGW repeater station is arranged at Hāsilpur, the total area is about 1000 m^2, and building area is 120 m^2. Its coordinate is E72°29' 2.70", N29°36' 23.20".

The conceptual arrangement of HVDC power line carrier channels is shown on Figure 4.7 and configuration is elaborated in Table 4-6.

Table 4-6: Configuration of HVDC Power Line Carrier Channels

Sr. No.	Name	Standard	Unit	Matiari	Repeater Station	Lahore	Total
1	DC line trap	4000-2.0/63	Set	4	4	4	12
2	Combining and processing equipment	Bipolar coupling	Set	1	2	1	4
3	Coupling capacitor		Set	2	4	2	8
4	DC isolation filter		Set	4	2	4	10
5	Carrier	80W	Set	8	16	8	32
6	Connection protection		Set	2		2	4
7	Monitoring system of carrier system		Set	1	1	1	3
8	Instrument of carrier system		Set	1	1	1	3
9	Dispatch program-control exchanger	48 door	Set		1		1
10	High-frequency cable	SYV-75-9	Km	1	1	1	3
11	Copper bar	120mm2	Km	1	0.5	1	2.5
12	Total						

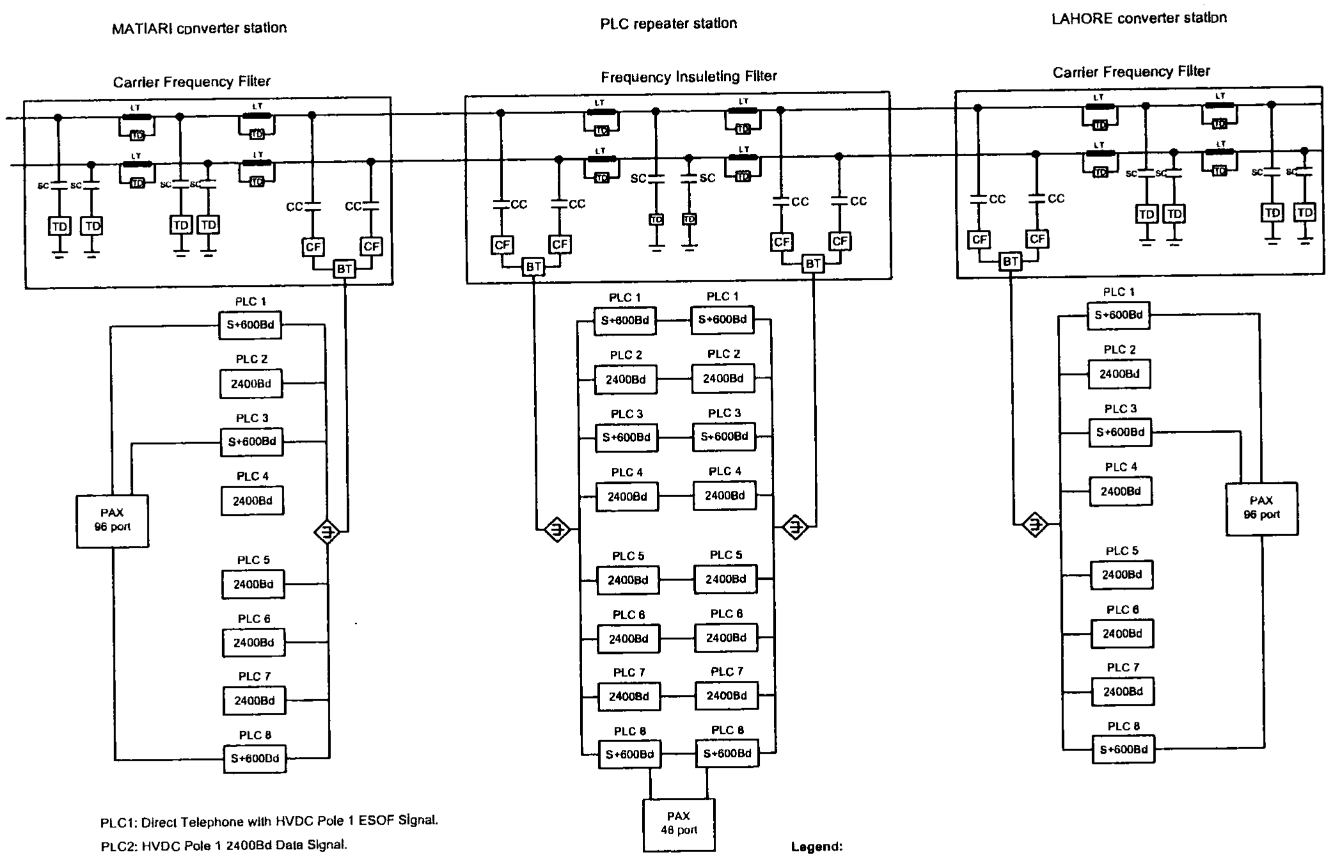


Note: 1) This drawing is typical and shows the minimum dimensions required
2) The Coupling capacitor, line trap & Filter capacitor shall pedestal mounting type.

TYPICAL PLC REPEATER STATION LAYOUT

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 4.6



PLC1: Direct Telephone with HVDC Pole 1 ESOF Signal.
PLC2: HVDC Pole 1 2400Bd Data Signal.
PLC3: Ralay Station Telephone with HVDC Pole 2 ESOF Signal.
PLC4: HVDC Pole 1 2400Bd Data Signal.
PLC5: HVDC Pole 2 2400Bd Data Signal.
PLC6: HVDC Pole 2 2400Bd Deta Signal.
PLC7: 2400Bd Data Signal.
PLC8: PAX Telephone with Metering Signal.

Legend:

LT	Line Trap	TD	Tuning Device
SC	Capacitor	S	Voice Signal
CF	Coupling Capacitor	ESOF	Emergency Switch-off Signal
BT	Blance Transfolmer		

CONCEPTUAL ARRANGEMENT OF HVDC POWER LINE CARRIER CHANNELS

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 4.7

Foundations Design

Pile foundation is adopted for valve hall, control building, comprehensive building, spare part warehouse, foundation of converter transformer, foundation of AC filter group and foundation of truss, which have high sedimentation requirement or large load; natural foundation or local sand replacement processing will be adopted for other equipment foundation.

Matiari station: Slurry-supported bored piles, friction pile, pile diameter 800mm, average pile length 22m, totality about 2100.

The elevation of Lahore station is 191.30m. However, the 100 years flood level is 193.8m. This means the foundation of Lahore shall be treated to increase 2.5m. The filling earth will be used for such propose.

Valve Cooling System

Main cooling circuit is closed single loop system which consists of deionizing water pump, converter valve group, air cooler, evaporative cooling tower, nitrogen cylinder, degassing tank, mechanical filter, expansion tank, pipe and necessary valve.

Air cooler and evaporative cooling tower are used for valve cooling system. Evaporative cooling tower works only when the external temperature is higher than 33°C.

The air+water cooling system needs water 300m3/d, 450m3/d less than pure water cooling. However, the valve cooling system still require further research. CET may employ the full water cooling system due to the high temperature in Pakistan.

4.3.3 Electrode Stations

Following standards were adopted during design period:

- The distance between converter station and grounding electrode should be 40~50km
- Low earth resistivity at grounding electrode, the earth resistivity should be lower than 100Ω·m.
- The soil should have abundant water and topsoil should have good thermal characteristics (high thermal conductivity and high thermal capacitivity)
- Within 10km, there should be no complex and important underground metallic facilities such as pipes, railway track and earth wire or transmission line with voltage about 132kV.

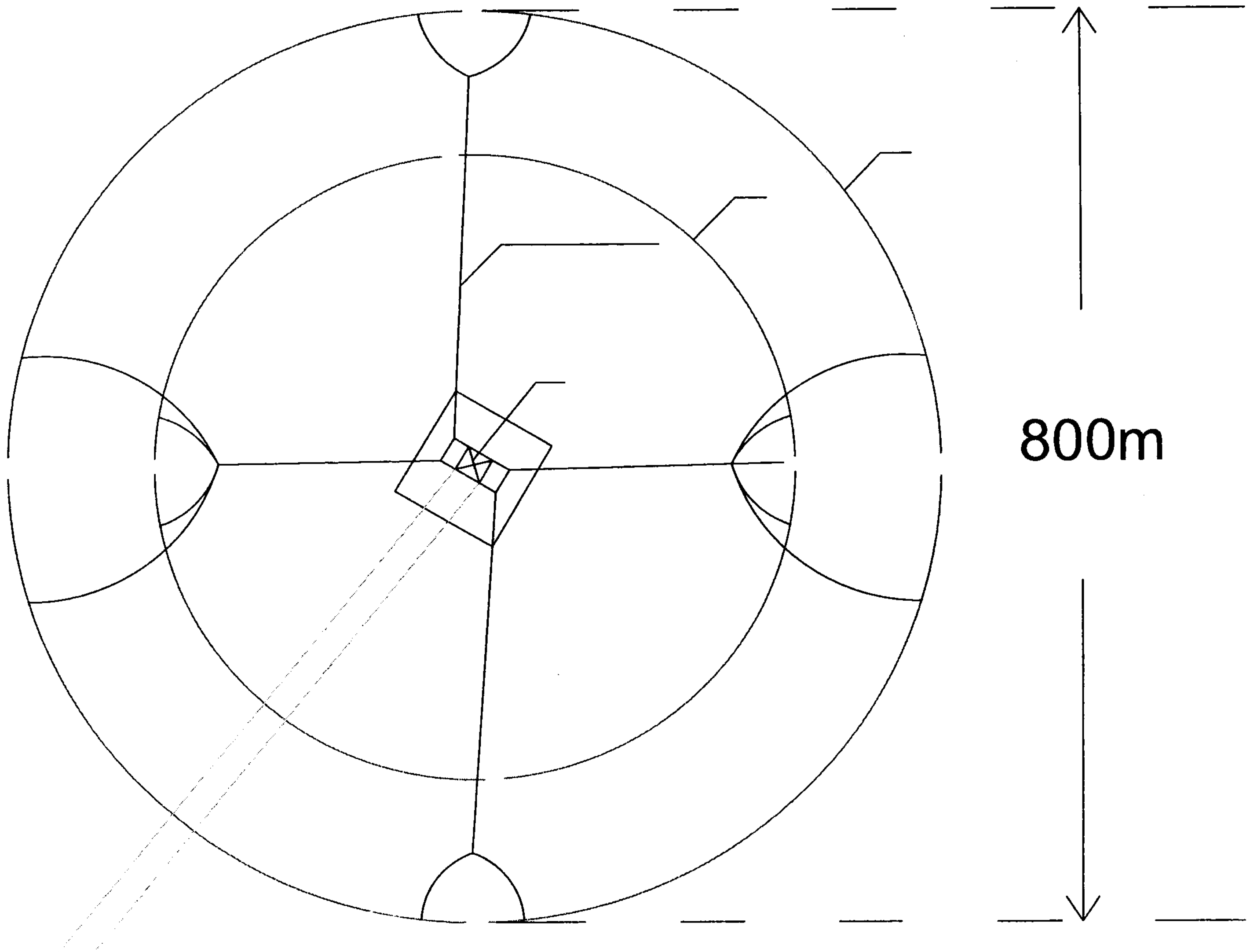
Planar graph of Grounding electrodes is attached as Figure 4.8.

4.4 Construction Aspects

4.4.1 Contractor's Arrangement

NTDC has planned to implement the Project through International Competitive Bidding (ICB) on Built Own Operate and Transfer (BOOT) basis. BOOT (build, own, operate, transfer) is a public-private partnership (PPP) project model in which a private organization conducts a large development project under contract to a public-sector partner, such as a government agency. A BOOT project is often seen as a way to develop a large public infrastructure project with private funding.

The public-sector partner contracts with a private developer - typically a large corporation or consortium of businesses with specific expertise - to design and implement a large project. The public-sector partner may provide limited funding or some other benefit (such as tax exempt status) but the private-sector partner assumes the risks associated with planning, constructing, operating and maintaining the project for a specified time period. During that time, the developer charges customers who use the infrastructure that's been built to realize a profit. At the end of the specified period, the private-sector partner transfers ownership to the funding organization, either freely or for



PLANAR GRAPH OF GROUNDING ELECTRODES

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 4.8

an amount stipulated in the original contract. Such contracts are typically long-term and may extend to 40 or more years.

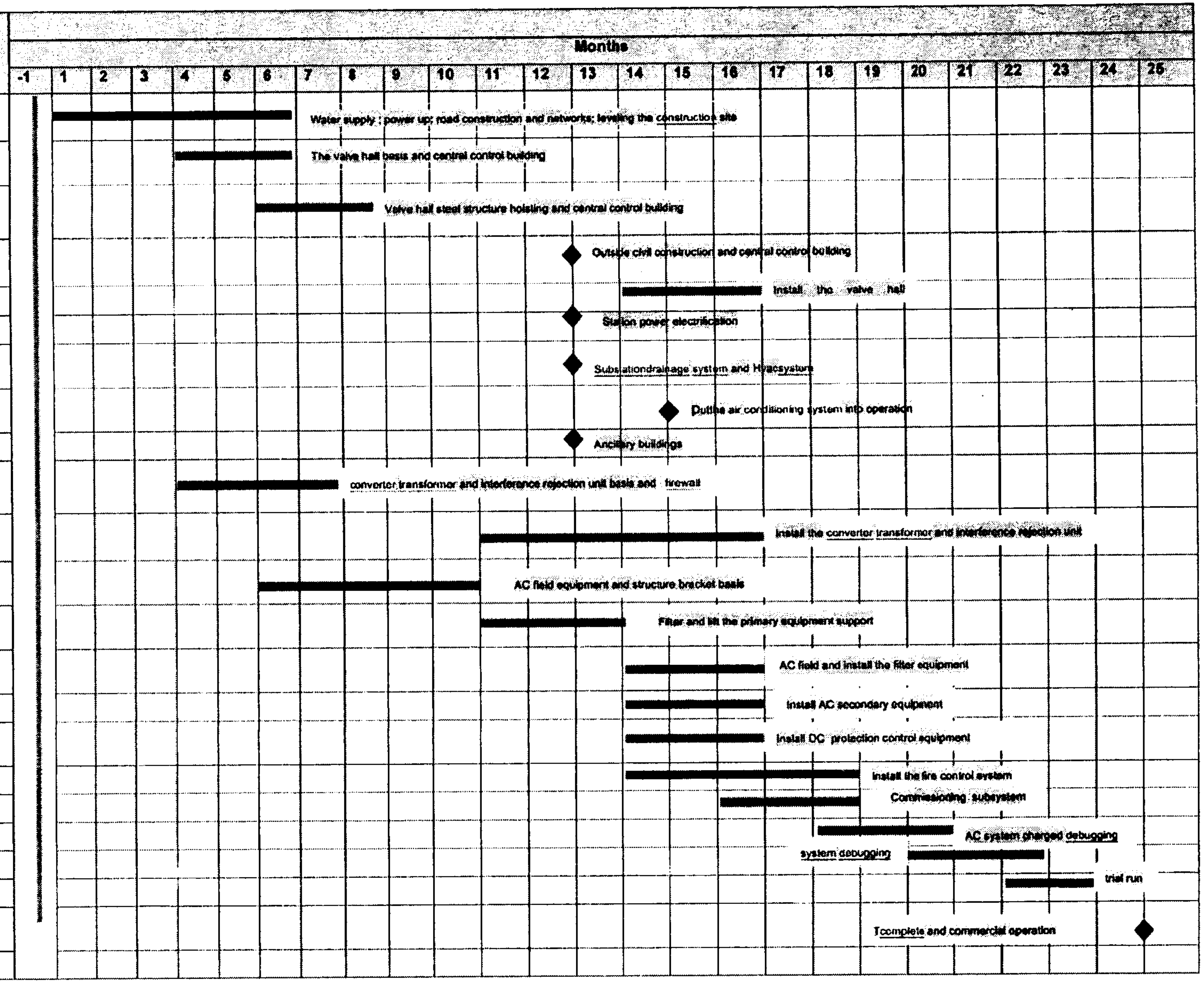
4.4.2 Construction Schedule

Proposed construction schedule of the T/L is attached as Figure 4-9. The total duration of the T/L construction will take around 2 years. It is anticipated that construction will start from Matiari and Lahore on urgent basis.

4.4.3 Construction Camps

Camp sites will be located keeping in view the availability of an adequate area for establishing camps including parking areas for machinery, stores and workshops, access to communication and local markets and an appropriate distance from the sensitive areas in the vicinity. Final locations will be selected by the Contractor with the approval of site Engineer in-charge. A construction camp will consist of about 5000m^2 (1.2 acre) of land.

NO	Item	Orig Dur
1	Water supply ; power up; road construction and networks; leveling the construction site	6
2	The valve hall basis and central control building	3
3	Valve hall steel structure hoisting and central control building	3
4	Outside civil construction and central control building	0
5	Install the valve hall device	3
6	Station power electrification	0
7	Substationdrainage system and Hvacsystem	0
8	Put the air conditioning system into operation	0
9	Ancillary buildings	0
10	converter transformer and interference rejection unit basis and firewall	4
11	Install the converter transformerand interference rejection unit	6
12	AC field equipment and structure bracket basis	5
13	Filter and lift the primary equipment support	3
14	AC field and install the filter equipment	3
15	Install AC secondary equipment	3
16	Install DC protection control equipment	3
17	Install the fire control system	5
18	Commissioning subsystem	3
19	AC system charged debugging	3
20	system debugging	3
21	trial run	2
22	complete and commercial operation	0



CONSTRUCTION SCHEDULE

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 4.9

It is estimated to establish a worker camp every 50 km in average along the line, depending upon the land conditions.

Since the average distance between Towers will be about 350 m and the average time to erect a Tower would be of one complete days.

4.4.4 Work Force

The Project involves many construction activities. For the purpose of ease, these are lumped into three main groups of activities, namely foundation laying, Tower erection and conductor, OHSW and OPGW stringing including fixing of hardware and accessories. Accordingly, three types of construction crews are deployed for the work. The estimated work force required for each group of activities for one (01) Construction Camp is shown in Table 4-7 below.

Table 4-7: Estimated Work Force Requirement for Proposed Bipole ± 600 KV HVDC T/L Project

Sr. No.	Staff	Foundation Crew	Tower Erection Crew	Conductor Stringing Crew
1	Site In-charge	1	1	1
2	Site Engineer	1	1	2
3	Supervisor	1	-	4
4	Foreman	1	1	2
5	Assistant Foreman	1	1	2
6	Surveyors	1	-	1
7	Skilled Workers	12	8	14
8	Semi-skilled Workers	-	8	14
9	Unskilled / Helpers	22	21	49
10	Drivers	2	3	4
	Total	**42**	**44**	**93**

The total number of crew, skilled and unskilled labour to be employed will depend on the Contractor's activity schedule at the time when the contract is awarded. The Contractor will be advised to hire unskilled labour from the local communities. A training programme will be conducted for unskilled workers (refer Section 9.12).

4.4.5 Construction Materials and Transport

The materials used for the construction of T/L include cement, coarse aggregates, fine aggregates (sand) and steel. Tentative quantities of various materials required for single Tower are provided in Table 4-8.

Table 4-8: Estimated Construction Materials for Single Tower

Sr. No.	Type of Material	Quantity/Tower	Source
Local Materials			
1.	Cement	300 bags	From nearby Cities
2.	Sand	20 cu.m	Locally
3.	Crush	30 cu.m	Locally
4.	Steel	2800 kg	Karachi and Lahore
Imported Material			
1.	Steel Towers	12-19 Tonnes	Imported and shifted from Karachi Port to Site Stores. In case of domestic goods,
2.	Conductor, OHSW and OPGW	10,500 kg	

Sr. No.	Type of Material	Quantity/Tower	Source
3.	Hardware	200 kg	shifted from the manufacturer's work sites.
4.	Insulator	3000 kg	

Transportation of the material will be provided by contractors and suppliers and the number of trucks moving on the roads should not exceed 5 to 8 days.

Construction Procedures: This section describe all the stages of the T/L construction that may cause a potential impact on the bio-physical and social environments, i.e. preparatory works that include access roads and the clearance of the ROW, construction of foundations, erection of Towers and laying of cable. Furthermore, the labour camps and an anticipated duration of the work are presented as an anticipated number of workers needed.

4.4.6 Access to the Construction Sties

The most of the length of the proposed T/L is approachable through National Highway (N-5), Thar Road, Nara Canal Road, DesrtRaod and tother local roads and Railway Tracks. There may be, however, certain areas where the Contractor has to develop a few new tracks. Neverless on the sandy areas of Cholistan (Bahawalpur, Sadiqabad and Rahim Yar Khan for Punjab) and Thar (Sanghar and Ghotki), the access could be more difficult and would require possibly tractors mounted blades having normal width of about four (04) to five (05) m.

According to usual terms and conditions, laid down by NTDC, the Contractor will be bound not to cause any damage to the existing roads and village tracks during construction works and due to movement of heavy vehicles. However, in case of any damage, the Contractor will be responsible for its repair. In this regard, NTDC bounds the Construction Contractor by withholding a 10% amount from the Contractors' interim bills submitted to the Engineer for payments to exert the Contractor to complete his pending works.

4.4.7 Clearing of ROW

To minimize the environmental impacts, NTDC normally imposes restrictions on the clearing of natural vegetation from ROW. This is allowed to the extent that is necessary for the safe construction and operation of the lines. For this, the area required for the placement of Tower footings will be completely cleared of vegetation, crops and trees. In the rest of the ROW, selective clearing will be carried out. Trees more than 2.5 m high, which may obstruct stringing or create hazard/danger to the T/L, will be removed. On the other hand, the clearing of desert vegetation is restricted to what is required for placement of footings and for the assembly and erection of Towers and wire pulling at site. While no such clearance is allowed in orchards or other areas having fruit bearing trees, except as specifically approved by the Engineer in the case of having no other alternative. NTDC allows that the cleared materials such as trees, crops etc., will be the property of landowners. While other materials such as fossils, coins and antiquities discovered on the site of the work will be deemed as the property of GOP. The clearance of ROW from the vegetation is normally done by mechanical means.

4.4.8 Tower Foundations and Erection

(a) Sitting of Towers

Since the Project is at the feasibility stage and detailed survey and design will be carried out by the turnkey Contractor, the spotting of Tower locations has not been indicated at this stage of the Project. If the subsoil conditions do not allow for any type of foundation specified by the Designer, the location of the Tower is changed along the centerline in consultation with the Engineer, without affecting the overall alignment of the T/L.

(b) Excavation, Concreting and Backfilling of Foundation

Depending upon the type of Tower and subsoil condition, the Tower footings have variable dimensions. However, on an average 400 m^2 working area is required for the excavation of normal foundation and 500 m^2 for pile foundation. The depth of excavation for the normal foundation varies from about 2.5 to 4 m. The excavation for Tower footing is carried out either manually or by mechanical excavator as per site requirements.

After fixing steel re-bars and concreting, the ditch is refilled with excavated material and the site is brought to the original ground level. As such, only four Tower pedestals protrude above the ground level by about 0.45 m for normal foundations and about 1.8 m for pile foundations.

(c) Tower Erection

Tower erection will be carried out on the concreted locations with the help of Derrick Poles or crane. The required working area for this activity will be about 900 m^2 for each Tower. The Tower will be erected in panels of 2 m to 3 m height. The panels will be assembled on the ground, lifted in parts with the help of Derrick Poles/crane and then joined together with nuts and bolts, which are tightened at the specified torque.

4.4.9 Stringing of Conductors and Overhead Ground Wire

After Tower erection is accomplished, stringing activity will be started. This involves preparing the Tower to access for tractor movement by clearing a strip of about 10 m wide from all the obstacles. Positioning of tensioner and puller will be temporarily anchored on both ends of the stringing stretch, which will be normally 3 to 6 km. At road, railway and telephone line crossings, rider poles will be provided during stringing to avoid any interruption to traffic or shutdown of the Power in the existing line. Shutdown will be arranged for Power lines crossing transmission route and temporary delinked and un-dipped from the Towers.

4.5 Operation and Maintenance (O&M)

The± 600KV HVDC T/L will become a vital link in the transmission grid system of Pakistan. Any outage on the line would seriously disrupt the Power supply to major load centers, possibly causing extensive damage and losses. Grid Station Operation (GSO) Division of NTDC (WAPDA) maintains regular patrolling/ inspection staff for patrolling and inspection of the lines.

NTDC's patrolling crews will be required to carry out a general inspection of the T/L every three (3) months, while a comprehensive inspection will be carried out every 3 years. Based on PEPCO maintenance manuals, following paragraph lists the items to be checked by the NTDC Inspection Crew during patrolling.

The O&M activities for different components are given below:

4.5.1 Foundations

- Check for any soil settlement around the foundation chimney, any unusual cracks between the stub angle and concrete and/or cracks in the concrete chimney;
- Check for erosion in and around the Tower foundations. Where erosion exists, locations and extent is noted on the inspection form, take measurement from the centerline. Note if a stream (Nullah) or dry wash is causing the erosion. Also, note any damage done by farming operations near or under the Tower. Towers located in the active hill-torrent zone will require inspection on a continual basis; and
- In areas where the line crosses hills/lowest slopes, very careful checking of the ground clearance and the amount of foundation chimney that is exposed must be done. It is anticipated that during different times of the year, either soil may be drifted up on the Tower legs or chimney may be exposed. These should be noted and immediate corrective measure taken to ensure uplift capability by replacing backfill or re-establishing minimum ground clearance.

4.5.2 Steel Works

Look for bent or missing steel members, missing or loose bolts. An excellent test in addition to visual inspection is to strike the Tower leg angle sharply with a stick of wood or rubber hammer. Any loose bolts or members will produce a rattling sound.

4.5.3 Conductor, Overhead Ground Wire, Hardware and Insulators

Conductor is the most important part of the line. A very thorough visual inspection will be made. The checklist for this component includes the followings:

- Check every bolt, nut, pin and cotter pin on the conductor shoe, shackles connecting links and other hardware fittings for looseness or missing;
- Check for chips, dirt and/or lightning "Tracks or marks" on the insulators. This lightning mark will especially show up on the first few insulators nearest the Tower attachment point;
- There will not be cracks of any size in the insulators because before porcelain cracks, a piece of the insulator will break off. Always look around the base of every Tower for pieces of insulators, pins, bolts, nuts etc.;
- Check every ball in the insulator strings for missing cotter pins. Note that ball can work itself half way out and still holds. First, the cotter pin falls out, next with the continual vibration the ball can very slowly work itself out to a point where the ball is only held by half of the socket. One can spot this condition by a slight tilting of the insulator below or beyond the loose ball. This also applies to shackle or hardware pins and is a very serious condition. Report it immediately;
- Check the stock-bridge dampers on the conductor and OPGW to make sure these are in the proper position;
- On dead end Towers, check the jumpers to see that all the bolts are tight in the jumper pads. Also there should be no missing or loose slots; and
- Along the line, check the conductors for frayed or broken strands.

Spot-check ground clearance and observe if any building or structure is being constructed under the line. Also, check for any tree growing near or under the line. Report these conditions immediately.

5 DESCRIPTION OF THE ENVIRONMENT

5.1 General

This Chapter describes the environmental baseline condition along the proposed T/L route within a COI of 1,000m i.e. 500m from centerline on either side for the proposed T/L Project. The data is based on the baseline surveys and secondary data such as DCRs, Google satellite imagery (refer Index Map Figure 5-1).Landuse map of the proposed T/L and Converter Station sites was prepared based on the collected and available information utilizing Arc GIS and AUTOCAD. Landuse maps of proposed T/L and Converter Stations are attached as Figure 5-2 (Sheet 1 to 47) & 5-3 (Sheet 1 & 2) in Volume 2.

Information on Soils, Topography, Climate, Hydrology, Land-use, Physical infrastructure, Drainage, Water resources, Ambient air quality, Noise level, Flora, Fauna, Aquatic life, Socio-economic indicators i.e. Demographic aspects, Occupations, Housing conditions, Livelihoods, Indigenous people, Social settings, Women issues, Cultural assets, Historical and Archaeological monuments and other relevant Environmental and Social parameters was collected in the field through primary sources. Based on the collected information an environmental profile containing physical, ecological and socio-economic parameters in the form of a table was generated. Brief description of the baseline is given below. AM wise environmental details are provided in the baseline environmental profile (Annex-IV) presented in Volume II.

Principally the whole T/L has been divided into two (02) sections namely Section I&II. Section-I lies in the Sindh Province i.e. from AM #1 to AM # 49 while Section-II lies in Punjab Province i.e. from AM # 50 to AM #169.

5.2 Physical Environment

The following section provides an overview of the information on physical environment of the COI collected from primary as well as secondary sources. The major parameters covered include Physiography and Topography, Climate, Soil, Seismicity, Geology, Water Resources, Ambient air, Noise, Landuse etc.

5.2.1 Physiography and Topography

Following is the description of Physiographic and Topographic conditions of the districts through which the proposed T/L route is passing:

5.2.1.1 Section-I

T/L starts at the Samoo village in Matiarir district. Coverter station is also located in Matiari distrirct. From AM # 1 to 7 the T/L crosses over higly fertile lands of Matiria districts. Topography is flat. Orchards of Guava, Mangos etc. can be seen. This is a higly fertile land.

At AM# 8 to 27 the proposed T/L enters the Sanghar district. The district does not have any mountain or hill. The T/L passes through eastern desert area and cultivated areas a portion of Sanghar Taluka. Some of the area consists of barren tracks of sand dunes covered by thorny bushes while most of the area is the cultivated lands.

At AM# 28 to 35 district Khairpur starts. The portion where T/L enters the district consists of hills of windblown sand running in parallel rows from north-east to south-east. This is known as Rajistan and is part of the Thar Desert.

From Khairpur T/L enter the Sukkur district near AM# 36. The T/L passes through desert portion of the Salehput sub-division.

T/L passes through the Ghotki district from AM# 41 to AM# 49. T/L passes through the desert area of the district i.e. Mirpur Mathelo and sub-division Khan Garh which consists of hills of windblown sand and known as Rajistan and is part of Thar desert.

5.2.1.2 Section-II

T/L enters the Sadiqabad at AM # 49 district Rahim Yar Khan. T/L passes through the desert area known as Cholistan. The surface of the desert consists of a succession of sand dunes and covered with the vegetation peculiar to sandy tracts.

Bahawalpur district starts at AM# 63. T/L continues on the desert area known as Cholistan. It extends along the entire eastern boundary of Bahawalnagar district in the north and Rahim Yar Khan district in the south. The surface of the desert consists of a succession of sand dunes. It is covered with the vegetation peculiar to the sandy tracks.

T/L enters Bahawalnager district at AM # 75. The line passes through the irrigated agriculture area. This area is known as Uttar (Nehri) and lies between the railway line and the Cholistan. The main source of irrigation in this area is semi-perennial and perennial canals which debouche from Sulemanki Head Works. T/L crosses the Sutlej.

T/L enters Pakpattan district at AM# 95. The area is a flat plain, covered on the north by the old bed of the Bias River. The major means of irrigation in the COI are canal and tubewells. Pakpattan canal takes off from Sulemanki Headwork's also cross by the T/L. This canal and its branch namely Khadir branch irrigate a vast area of the district.

T/L enters Okara after AM # 125. T/L is crossed by Depalur canal. T/L crosses the semi-urban area which is rich in agriculture.

T/L enters Kasur district at AM # 151 near village Kitan Kalan and passes through the upland area where T/L also crosses the old bed of Bias River. The soil is sandy. The upland is flat plain sloping from north-east to south-west. T/L enters the district Nankana Sahib and ends near Lahore

5.2.2 Climate

This section presents the climate details of the meteorological gauging stations situated near the T/L starting from Matiari to Converter Station near Lahore. Figure 5-4 shows the location of Meteorological Gauging Stations existing near the proposed T/L route. Detailed report related to the Climate is attached as Annex-V.

5.2.2.1 Section-I

Temperature

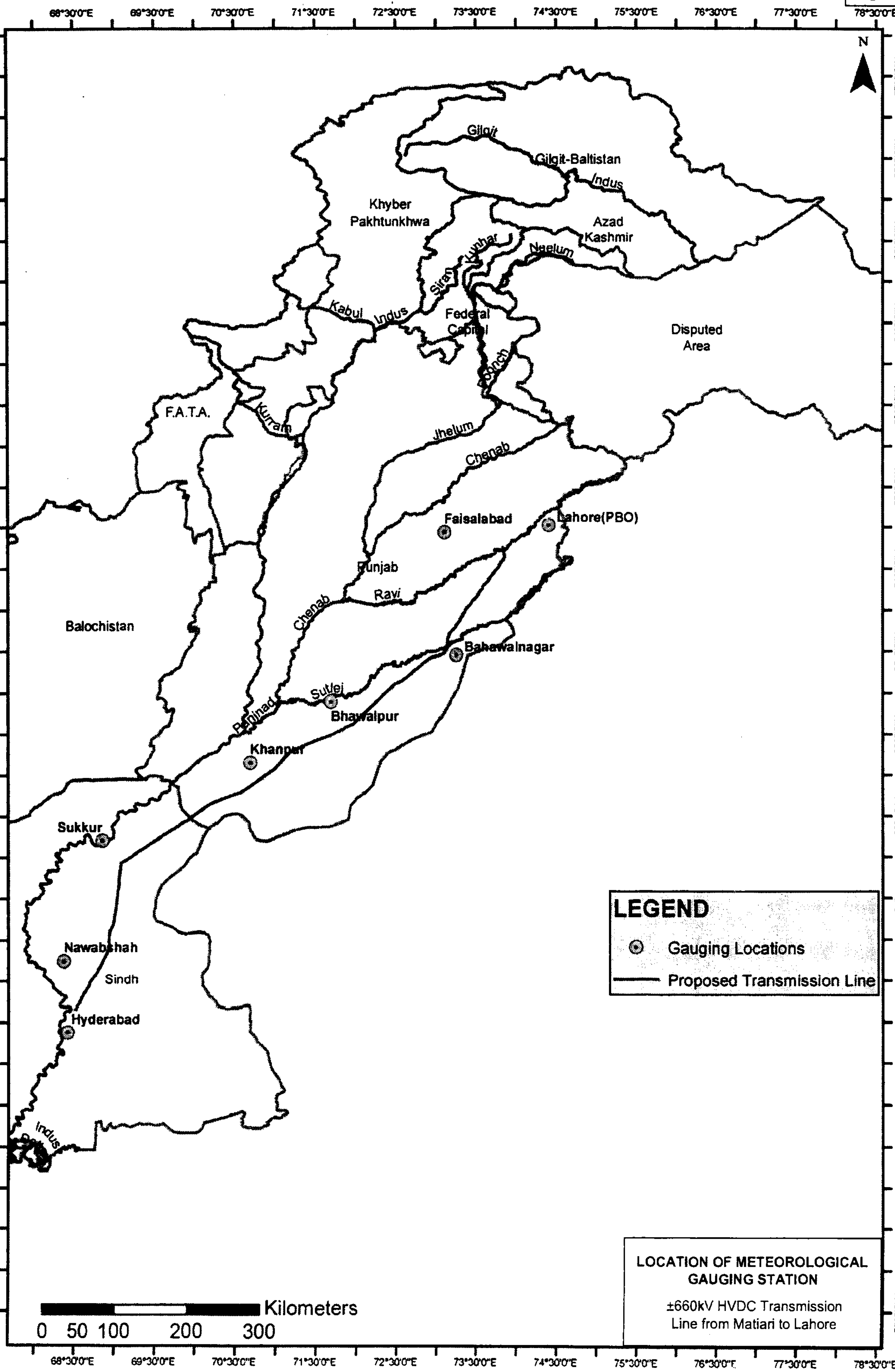
Table 5-1 describes the mean daily maximum and minimum temperatures in Summer and Winter seasons of the Meteorological Gauging Stations which represents the climate of Section-I:

Table 5–1 (a): Mean Daily Temperatures at Meteorological Gauging Stations (1981-2010)

Sr. No.	Meteorological Gauging Station	District	Mean Daily Temperature (Summer) °C		Mean Daily Temperature (Winter) °C	
			Minimum	Maximum	Minimum	Maximum
1	Sukkur	Sukkur	34.6	35.6	14.8	16.5
2	Nawabshah	Benazirabad	33.8	35.7	15.4	16.9
3	Hyderabad	Hyderabad	32.4	34.0	18.0	19.6

Source: 1. Pakistan Meteorological Services; and
2. Surface Water Hydrology Project, WAPDA.

Figure 5.4

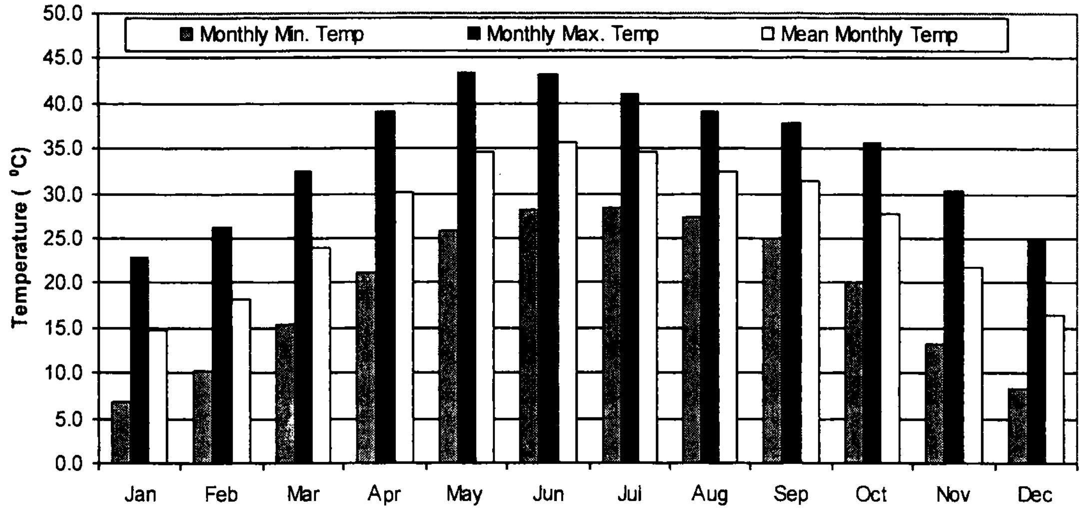


LOCATION OF METEOROLOGICAL GAUGING STATION

±660kV HVDC Transmission Line from Matiari to Lahore

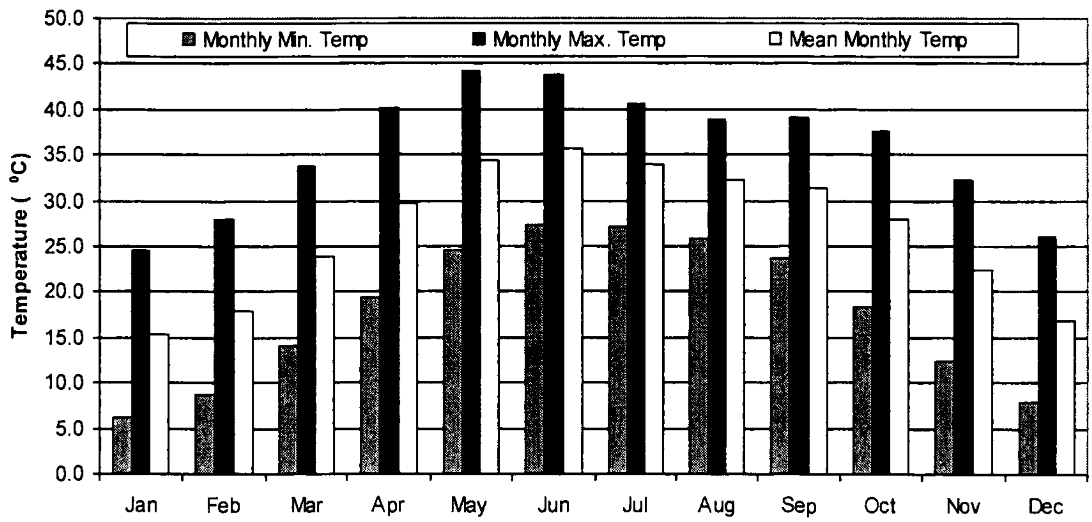
Graphical representations of monthwise temperature data of above mentioned Meteorological Gauging Station are given below in Figure 5-5 to 5-7.

Figure 5–5: Mean Monthly Temperature of Sukkur Meteorological Gauging Station (1981-2010)



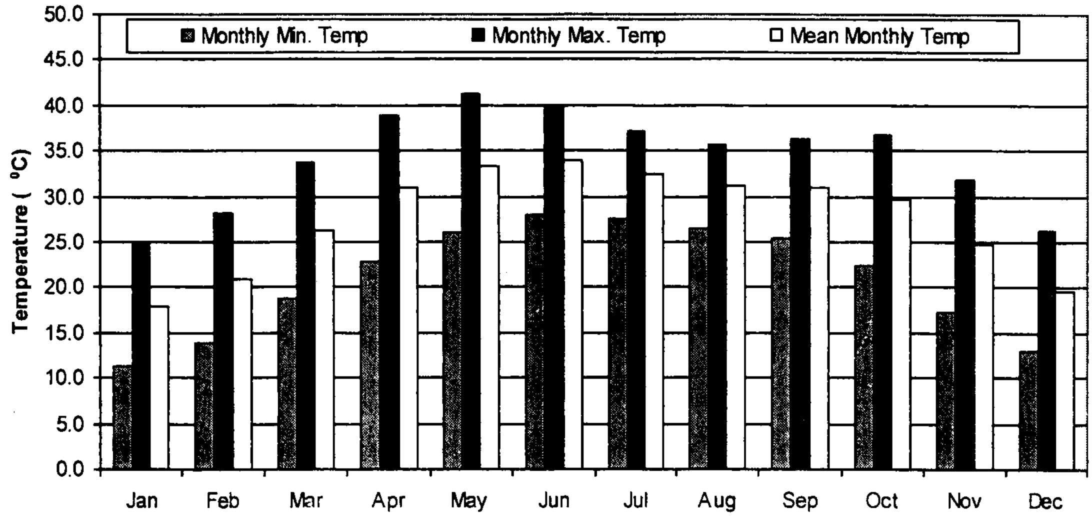
The climate of Sukkur can be classified as hot and arid. The mean daily temperature ranges from 34.6 °C to 35.6 °C in the summer season (May to July) and 14.8 °C to 16.5 °C in winter season (December to January).

Figure 5–6: Mean Monthly Temperature of Nawabshah Meteorological Gauging Station (1981-2010)



The climate of Nawabshah can be classified as hot and arid. The mean daily temperature ranges from 33.8 °C to 35.7 °C in the summer season (May to July) and 15.4° to 16.9 °C in winter season (December to January).

Figure 5–7: Mean Monthly Temperature of Hyderabad Meteorological Gauging Station (1981-2010)



The climate of Hyderabad can be classified as hot and arid. The mean daily temperature ranges from 32.4 °C to 34.0 °C in the summer season (May to July) and 18.0° to 19.6 °C in winter season (December to January).

Relative Humidity

Variation in mean monthly relative humidity over a year for the above Meteorological Gauging Stations which represents the climate of Section-I is given in Table 5-1(b).

Table 5–1(b): Relative Humidity (1981-2010)

Month	Relative Humidity (%)								
	Sukkur			Newabshah			Hyderabad		
	00:00 hr	03:00 hr	12:00 hr	00:00 hr	03:00 hr	12:00 hr	00:00 hr	03:00 hr	12:00 hr
January	85.1	84.9	42.1	84.8	83.5	43.1	24.7	11.4	18.0
February	79.9	79.1	37.4	80.7	79.4	37.4	28.1	13.9	21.0
March	75.4	70.4	31.8	76.7	73.3	33.5	33.7	18.8	26.2
April	61.9	54.4	23.5	70.8	64.1	28.4	38.8	22.8	30.9
May	61.6	53.5	22.6	69.5	61.7	26.4	41.3	26.1	33.3
June	68.9	63.4	31.1	74.3	66.9	34.2	40	27.9	34.0
July	76.1	71.9	44.6	79.4	74.5	48.8	37.2	27.6	32.4
August	80.1	75.6	48.5	82.5	78.5	52.8	35.6	26.5	31.1
September	83.6	78.0	45.9	83.8	79.8	44.5	36.3	25.4	31.0
October	84.3	79.3	42.4	83.0	78.8	36.8	36.7	22.5	29.6
November	83.9	81.1	43.1	83.9	80.8	39.1	31.9	17.4	24.8
December	86.6	85.8	47.0	85.1	83.2	43.9	26.2	13.0	19.6

Time is according to Greenwich Mean Time (GMT): Pakistan Standard
Time is GMT + 05:00 hrs
Source (Pakistan Meteorological Department)

Precipitation

The mean monthly rainfall over the year for Meteorological Gauging Stations which represents the climate of Section-I is given in Table 5-1(c).

Table 5–1(c): Mean Monthly Rainfall (1981-2010)

Month	Mean Monthly Rainfall (mm)		
	Sukkur	Nawabshah	Hyderabad
January	3.5	2.5	1.4
February	7.0	3.3	6.8
March	6.8	3.5	4.2
April	5.7	2.8	7.0
May	5.0	1.5	2.8
June	4.5	5.0	4.4
July	20.8	58.3	47.9
August	20.4	48.8	71.8
September	0.9	16.1	13.0
October	3.0	3.4	5.4
November	0.6	0.4	2.2
December	9.4	3.2	2.1
Annual	**87.6**	**148.8**	**169.0**

Source (Pakistan Meteorological Department)

Wind Speed

Wind speed data at 3 hours interval for Meteorological Gauging Stations of Section-I is given in Table 5-1(d).

Table 5–1(d): Mean Wind Speed at Synoptic Hours (1981-2010)

Month	Wind Speed (knots)								
	Sukkur			Nawabshah			Hyderabad		
	00:00 hr	03:00 hr	12:00 hr	00:00 hr	03:00 hr	12:00 hr	00:00 hr	03:00 hr	12:00 hr
January	1.5	2.0	2.7	1.4	1.6	4.0	4.8	4.7	7.1
February	1.9	2.9	3.3	1.5	1.7	4.3	4.7	4.8	7.3
March	2.4	3.0	3.6	1.7	2.1	4.9	5.2	5.1	8.1
April	3.0	3.6	4.4	2.3	2.9	5.5	7.4	7.4	11.0
May	3.9	5.2	5.4	4.2	5.1	6.8	10.7	11.7	15.3
June	4.8	6.1	5.9	6.6	7.9	8.9	12.1	13.7	15.2
July	3.9	4.8	5.2	6.5	7.0	9.1	12.7	13.9	16.3
August	3.1	4.0	4.0	5.7	6.1	8.2	12.0	12.3	14.6
September	2.8	3.8	3.6	4.6	4.9	6.9	9.3	9.9	12.9
October	1.3	1.8	2.1	1.8	2.1	4.0	5.0	5.0	8.0
November	1.2	1.9	1.3	0.9	1.3	2.4	4.2	4.1	5.9
December	0.7	1.4	1.4	1.2	1.6	3.2	4.4	4.5	6.4

Time is according to Greenwich Mean Time (GMT): Pakistan Standard Time is GMT + 05:00 hrs
Source (Pakistan Meteorological Department)

5.2.2.2 Section-II

Table 5-2 (a) shows the mean daily maximum and minimum temperatures in Summer and Winter seasons of the Meteorological Gauging Stations which represents the T/L Section-II from AM # 50 to 74.

Temperature

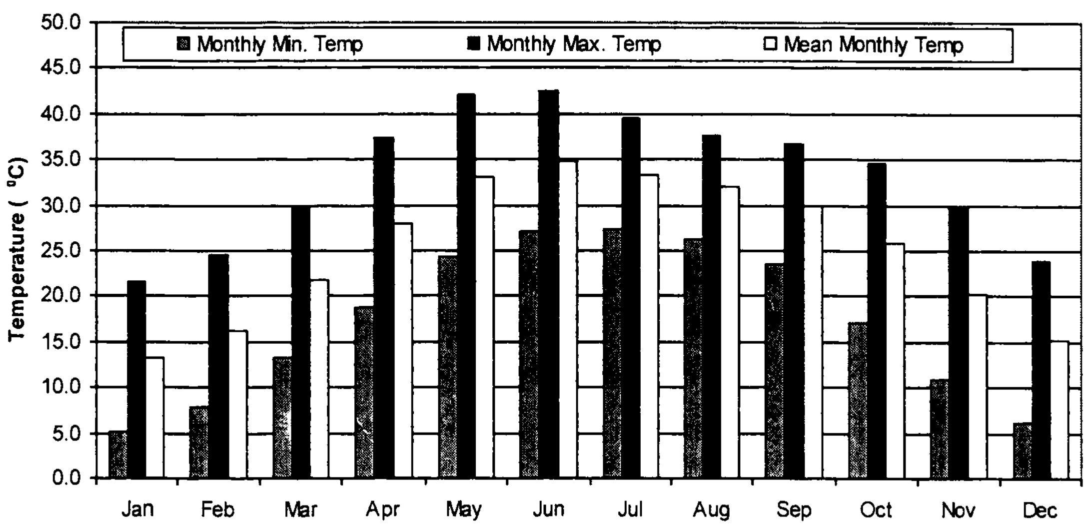
Table 5–2(a): Mean Daily Temperatures at Meteorological Gauging Stations (1981-2010)

Sr. No.	Meteorological Gauging Station	District	Mean Daily Temperature (Summer) ^{0}C		Mean Daily Temperature (Winter) ^{0}C	
			Minimum	Maximum	Minimum	Maximum
1	Khanpur	Rahim Yar Khan	33.1	34.8	13.3	15.1
2	Bahawalpur	Bahawalpur	32.2	35.0	13.5	15.5

Source: 1. Pakistan Meteorological Services; and
2. Surface Water Hydrology Project, WAPDA.

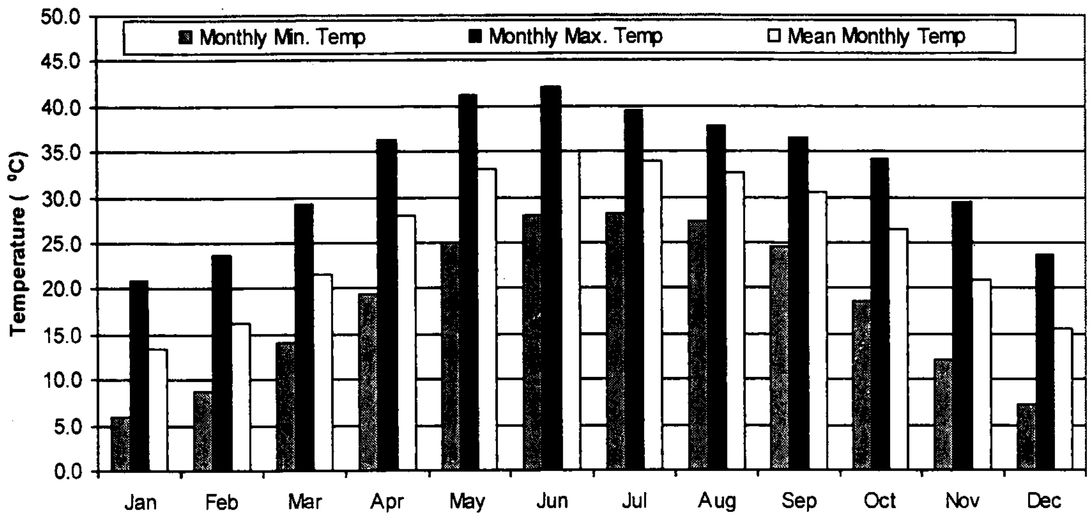
Graphical representations of temperature data of above mentioned Meteorological Gauging Station are given below in Figure 5-8 to 5-9.

Figure 5–8: Mean Monthly Temperature of Khanpur Meteorological Gauging Station (1981-2010)



The climate of Khanpur can be classified as hot and arid. The mean daily temperature ranges from 33.1 ^{0}C to 34.8 ^{0}C in the summer season (May to July) and 13.3 ^{0}C to 15.1 ^{0}C in winter season (December to January).

Figure 5–9: Mean Monthly Temperature of Bahawalpur Meteorological Gauging Station (1981-2010)



The climate of Bahawalpur can be classified as hot and arid. The mean daily temperature ranges from 33.2 ^{0}C to 35.0 ^{0}C in the summer season (May to July) and 13.5 ^{0}C to 15.5 ^{0}C in winter season (December to January).

Relative Humidity

Variation in mean monthly relative humidity over a year Seasons of the Meteorological Gauging Stations which represents the climate of Section-II is given in Table 5-2(b).

Table 5–2(b): Relative Humidity (1981-2010)

Month	Relative Humidity (%)					
	Khanpur			Bahawalpur		
	00:00 hr	03:00 hr	12:00 hr	00:00 hr	03:00 hr	12:00 hr
January	87.8	86.1	42.0	85.6	85.0	48.4
February	83.1	80.8	38.8	82.0	80.2	45.3
March	80.3	73.7	35.4	79.1	73.0	39.9
April	66.3	53.8	23.2	63.3	54.9	26.0
May	59.4	50.2	23.1	55.6	47.1	23.1
June	67.0	61.4	29.5	61.6	56.2	30.6
July	77.0	71.5	45.5	73.9	68.8	45.6
August	82.6	76.4	52.5	79.1	72.6	51.0
September	85.0	78.1	49.3	79.4	73.5	47.9
October	84.9	75.1	40.7	78.7	71.0	41.8
November	86.9	80.2	41.1	81.1	75.0	43.4
December	88.6	85.5	42.8	85.9	83.2	48.2

Time is according to Greenwich Mean Time (GMT): Pakistan Standard Time is GMT + 05:00 hrs
Source (Pakistan Meteorological Department)

Precipitation

The mean monthly rainfall over the year for Meteorological Gauging Stations which represents the climate of Section-II is given in Table 5-2(c).

Table 5–2(c): Mean Monthly Rainfall (1981-2010)

Month	Mean Monthly Rainfall (mm)	
	Khanpur	Bahawalpur
January	5.0	7.4
February	7.9	10.0
March	5.4	10.0
April	4.3	10.5
May	4.5	7.1
June	6.5	16.2
July	33.3	40.4
August	33.2	39.1
September	12.0	16.5
October	2.7	4.7
November	0.4	1.4
December	4.8	4.7
Annual	**120.0**	**168.0**

Source (Pakistan Meteorological Department)

Wind Speed

Wind speed data at 3 hours interval for Meteorological Gauging Stations of Section-II is given in Table 5-2(d).

Table 5–2(d): Mean Wind Speed at Synoptic Hours (1981-2010)

Month	Wind Speed (knots)					
	Khanpur			Bahawalpur		
	00:00 hr	03:00 hr	12:00 hr	00:00 hr	03:00 hr	12:00 hr
January	0.6	0.5	1.8	0.8	1.0	1.8
February	1.1	0.9	2.6	1.3	1.6	2.6
March	1.2	1.4	2.5	1.5	1.7	2.7
April	1.2	2.2	3.2	0.9	2.2	3.1
May	2.1	3.7	3.3	2.7	3.2	3.4
June	2.8	4.7	3.5	3.5	5.1	4.0
July	2.8	4.3	3.7	3.4	4.7	3.9
August	1.9	3.7	2.7	3.1	3.9	3.4
September	1.0	2.5	2.1	2.2	2.8	2.9
October	0.9	0.7	1.0	1.2	1.4	1.6
November	0.4	0.5	0.8	0.7	0.9	1.0
December	0.5	0.5	1.3	0.7	0.8	1.2

Time is according to Greenwich Mean Time (GMT): Pakistan Standard Time is GMT + 05:00 hrs

Source (Pakistan Meteorological Department)

Table 5-3 (a) shows the mean daily maximum and minimum temperatures in Summer and Winter Seasons of the Meteorological Gauging Stations which represents the T/L Section-II from AM #75 to 169.

Temperature

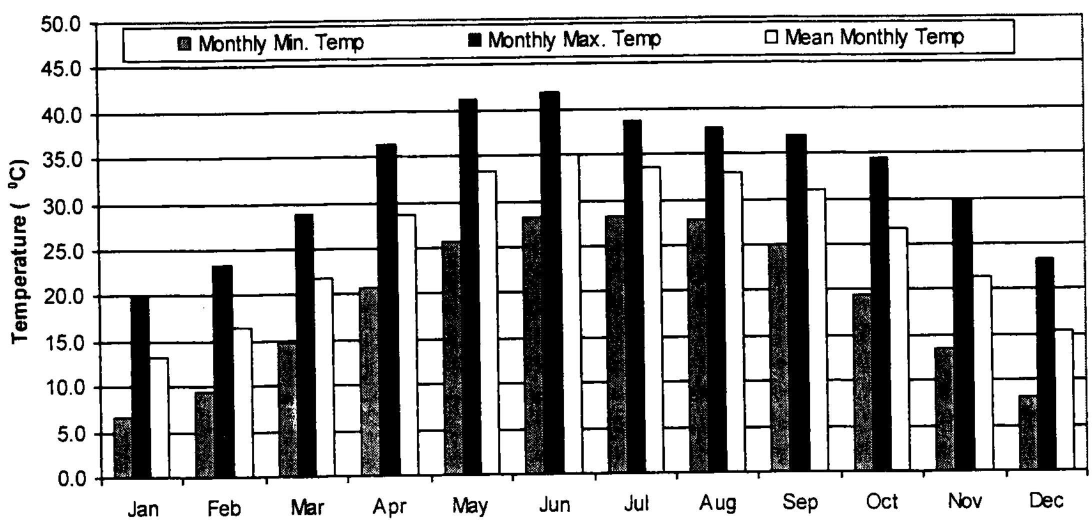
Table 5–3(a): Mean Daily Temperatures at Meteorological Gauging Stations (1981-2010)

Sr. No.	Meteorological Gauging Station	District	Mean Daily Temperature (Summer) °C		Mean Daily Temperature (Winter) °C	
			Minimum	Maximum	Minimum	Maximum
1	Bahawalnagar	Bahawalnagar	33.4	35.0	13.3	15.4
3	Faisalabad	Faisalabad	31.4	33.5	11.8	13.7
4	Lahore (PBO)	Lahore	31.3	33.6	13.3	14.8

Source: 1. Pakistan Meteorological Services; and
2. Surface Water Hydrology Project, WAPDA.

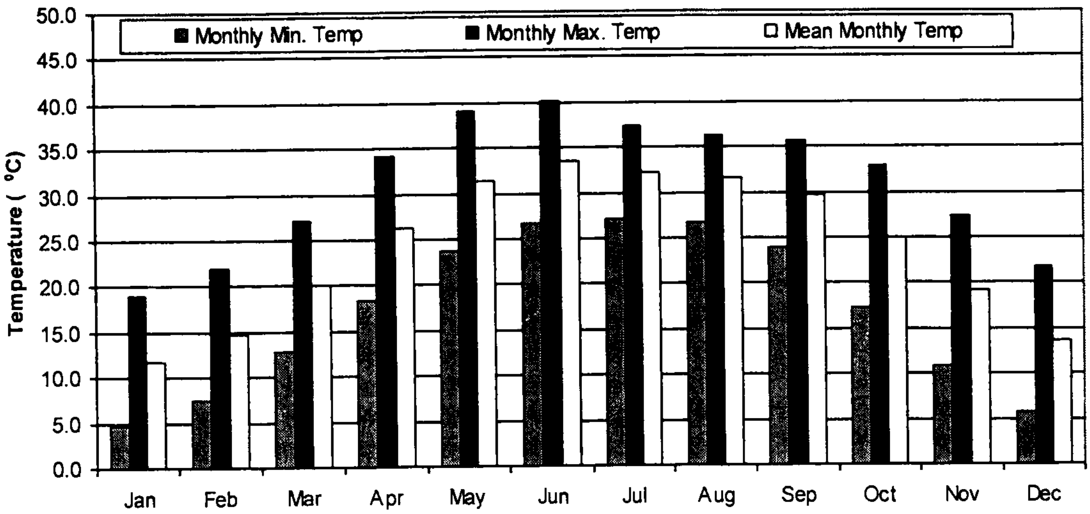
Graphical representations of monthwise temperature data of Meteorological Gauging Station mentioned in Table 5-3 (b) are given below in Figure 5-10 to 5-12:

Figure 5–10: Mean Monthly Temperature of Bahawalnagar Meteorological Gauging Station (1981-2010)



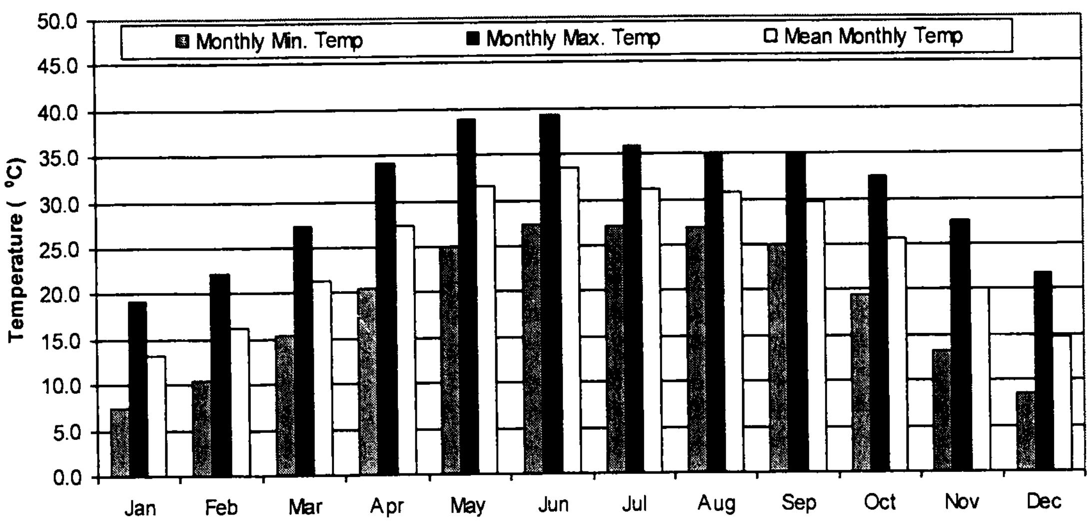
The climate of Bahawalnagar can be classified as hot and arid. The mean daily temperature ranges from 33.4 °C to 35.0 °C in the summer season (May to July) and 13.3 °C to 15.4 °C in winter season (December to January).

Figure 5–11: Mean Monthly Temperature of Faisalabad Meteorological Gauging Station (1981-2010)



The climate of Faisalabad can be classified as hot and semi arid. The mean daily temperature ranges from 31.4 °C to 33.5 °C in the summer season (May to July) and 11.8°C to 13.7 °C in winter season (December to January).

Figure 5–12: Mean Monthly Temperature of Lahore Meteorological Gauging Station (1981-2010)



The climate of Lahore can be classified as hot and semi-arid. The mean daily temperature ranges from 31.3 °C to 33.6 °C in the summer season (May to July) and 13.2 °C to 14.8 °C in winter season (December to January).

Relative Humidity

Variation in mean monthly relative humidity over a year Seasons of the Meteorological Gauging Stations which represents the climate of Section-II is given in Table 5-3(b).

Table 5–3(b): Relative Humidity (1981-2010)

Month	Relative Humidity (%)								
	Bahawalnagar			Faisalabad			Lahore		
	00:00 hr	03:00 hr	12:00 hr	00:00 hr	03:00 hr	12:00 hr	00:00 hr	03:00 hr	12:00 hr
January	88.6	85.8	49.5	89.9	87.8	51.9	86.0	84.2	51.5
February	84.7	79.4	43.0	87.3	81.8	44.4	79.9	76.4	44.8
March	79.2	70.6	36.7	82.7	74.1	40.1	74.7	68.0	40.2
April	62.2	49.8	23.8	68.8	54.3	29.3	60.1	48.6	27.2
May	54.4	43.5	21.6	57.6	43.3	25.5	52.7	42.9	24.5
June	61.0	52.6	28.9	64.2	51.5	31.8	61.2	52.4	33.2
July	74.6	68.6	46.1	79.0	70.7	50.0	80.5	73.9	57.0
August	78.7	71.0	50.2	83.0	75.2	54.7	84.6	78.2	62.3
September	79.1	70.5	44.5	84.1	73.8	47.2	81.4	73.6	52.5
October	77.3	66.5	35.0	81.5	71.3	39.2	79.1	71.5	42.6
November	81.2	72.6	39.3	86.6	81.8	45.1	82.5	78.9	47.8
December	86.8	83.4	48.1	87.8	86.3	50.1	85.3	83.7	52.7

Time is according to Greenwich Mean Time (GMT): Pakistan Standard
Time is GMT + 05:00 hrs
Source (Pakistan Meteorological Department)

Precipitation

The mean monthly rainfall over the year for Meteorological Gauging Stations which represents the climate of Section-II is given in Table 5-3(c).

Table 5–3(c): Mean Monthly Rainfall (1981-2010)

Month	Mean Monthly Rainfall (mm)		
	Bahawalnagar	Faisalabad	Lahore
January	11.4	11.1	23.2
February	17.3	19.1	35.3
March	15.7	23.8	36.0
April	10.8	23.7	21.6
May	13.2	14.9	22.4
June	39.2	43.8	55.1
July	70.8	100.8	190.9
August	34.2	87.0	179.4
September	14.9	42.5	60.4
October	7.9	4.7	15.3
November	2.5	2.0	6.8
December	3.6	7.1	9.8
Annual	**241.5**	**380.5**	**656.7**

Source (Pakistan Meteorological Department)

Wind Speed

Wind speed data at 3 hours interval for Meteorological Gauging Stations of Section-II is given in Table 5-3(d).

Table 5–3(d): Mean Wind Speed at Synoptic Hours (1981-2010)

Month	Wind Speed (Knots)								
	Bahawalnagar			Faisalabad			Lahore		
	00:00 hr	03:00 hr	12:00 hr	00:00 hr	03:00 hr	12:00 hr	00:00 hr	03:00 hr	12:00 hr
January	1.0	1.0	2.3	0.5	0.5	1.4	0.5	0.4	1.5
February	1.3	1.3	3.2	0.9	0.9	2.8	1.0	0.8	2.8
March	2.1	2.1	3.8	1.1	1.4	3.0	1.3	1.4	3.5
April	2.0	2.4	4.1	1.7	2.5	3.5	1.6	1.9	3.6
May	3.1	3.9	4.6	1.8	3.4	3.8	1.7	2.3	3.0
June	3.3	5.1	4.9	2.1	4.1	4.4	1.8	2.7	3.0
July	2.9	4.3	4.4	2.1	4.1	4.6	1.6	2.4	2.8
August	2.8	3.6	4.4	1.6	3.5	4.4	0.9	1.6	2.3
September	1.9	2.7	3.7	1.0	2.3	3.4	0.7	1.2	2.1
October	1.1	1.3	2.3	0.6	1.0	1.6	0.4	0.6	1.2
November	0.8	0.8	1.6	0.3	0.5	0.8	0.4	0.3	0.6
December	0.7	0.7	1.5	0.4	0.4	0.8	0.4	0.3	0.7

Time is according to Greenwich Mean Time (GMT): Pakistan Standard
Time is GMT + 05:00 hrs
Source (Pakistan Meteorological Department)

5.2.3 Soil

The soil is dependent on the geology of the area as the route of the proposed project passes from various topographical locations dessert and plain green fields. Soil of the desert area is composed of sand with no moisture and organic content having light brown appearance. The soils of the Arid Zone are generally sandy to sandy-loam in texture. The consistency and depth vary according to the topographical features. The low-lying loams are heavier and may have a hard pan. Some of these soils contain a high percentage of soluble salts in the lower horizons, turning water in the wells brackish.

5.2.3.1 Section-I

The Coverter Station and T/L starts in Matiari district, the soils formed here are sandy, silt loam/fine sand and calcareous / fine textured respectively. The soils are calcareous alluvial loam fine to medium textured homogenized and well drained. These are highly fertile and productive. Moisture content in the soils is very high. The soil falls in erinaceous zone. Suitability Criteria of Soils for the construction of Grid Station and T/L are given in the following:

These include composition, structure, texture and susceptibility to frost, shrinkage, swell potential, permeability drainage, depth of water table, moisture and bearing capacity.

Corrosiveness, sulphate content, electrical conductivity and salinity/alkalinity are the common parameters considered for determination of soil suitability for the construction of towers and transmission lines.

The soils of the District Sanghar is fertile and mixture of sand and clay having light brown appearance. It is rich in organic content and making conditions suitable for farming and irrigation.

There are seven (07) main groups of soils which are found in the desert portion of the Sagnhar, Gotki and Sulkkur distriects. These are:

- Desert soils;
- Red desertic soils;
- Sierozems (brownish grey soils);
- Red and yellow spoils of the foothills;

- The saline soild of the depressions;
- The lithosols (shallow, weathered soils); and
- Rigosols (soft loose soils) found in the hills.

All of these soils are generally coarse-textured, well drained and calcareous in nature. At varying depths, a thick accumulation of lime may also be encountered. The soils of Thar Desert are usually overblown with sand due to severe wind erosion. In general, these are infertile soils except for the rainy period.

The fertile portion of the soil of District Sukkur and Ghotki which are found along the proposed COI consists of loose sand forming domes due to wind action. Local nullahs and tributaries form deltas, consist of sandy silt/silty sand at the surface and silty sandy gravel at depth.

5.2.3.2 Section-II

The soil conditions of district Rahim Yar Khan is similar with district Sukkur and Ghotki which is discussed in Section-I. The soil along the COI of T/L in district Bahawalpur consists of sandy silt/silty sand that are all eolian land deposits, lower horizons of Bahawalpur area have soluble salts, converting subsurface water brackish/saltish.

The Bahawalnagar, Pakpattan, Okara and Kasur district exist in the central Indus Basin, forming wide spread terracos having the soil consisting dominantly silt with trace to little amount of sand and clay. Soil is light brown in colour and it is very fertile.

Sutlej River is passing through this area establishing streamed and meandering bed deposits. This soil also consists of silt with traced to little amount of sand and clay at the surface and silty sandy gravel at depth.

5.2.4 Seismology

On the basis of Peak Ground Acceleration (PGA) values obtained through Probabilistic Seismic Hazard Assessment (PSHA), Pakistan is divided into five (05) seismic zones in line with the UBC (1997). The boundaries of these zones are defined on the basis as shown in Table 5-4.

Table 5-4: Values of Seismic Zones of Pakistan

Sr. No.	Zone	PGA (g)
1	1	0.05 to 0.08
2	2A	0.08 to 0.16
3	2B	0.16 to 0.24
4	3	0.24 to 0.32
5	4	> 0.32 g

The proposed T/L route i.e. Section-I & II as per Building Code of Pakistan (BCP), 2007 (Seismic Provisions) falls entirely in the zone 2A which is the regions of moderate seismic risk (refer to Figure 5-13). Hence all the applicable provisions of BCP, stated in Chapter 11 related to, Mechanical and Electrical System should be met during the design and construction[12] for safety against seismic hazards.

5.2.5 Geology

The proposed T/L route passes the Indus plain and lower Indus Basin in the Southern area of Pakistan. It is bounded in the north by the central Indus Basin, North West by the

[12] Building Code of Pakistan (Seismic Provisions – 2007), Ministry of Housing and Works

Sulaiman Fold Belt and Kirthar Fold Belt in the West (refer Figure 5-14). Following is the description of geology of the area.

Tectonics

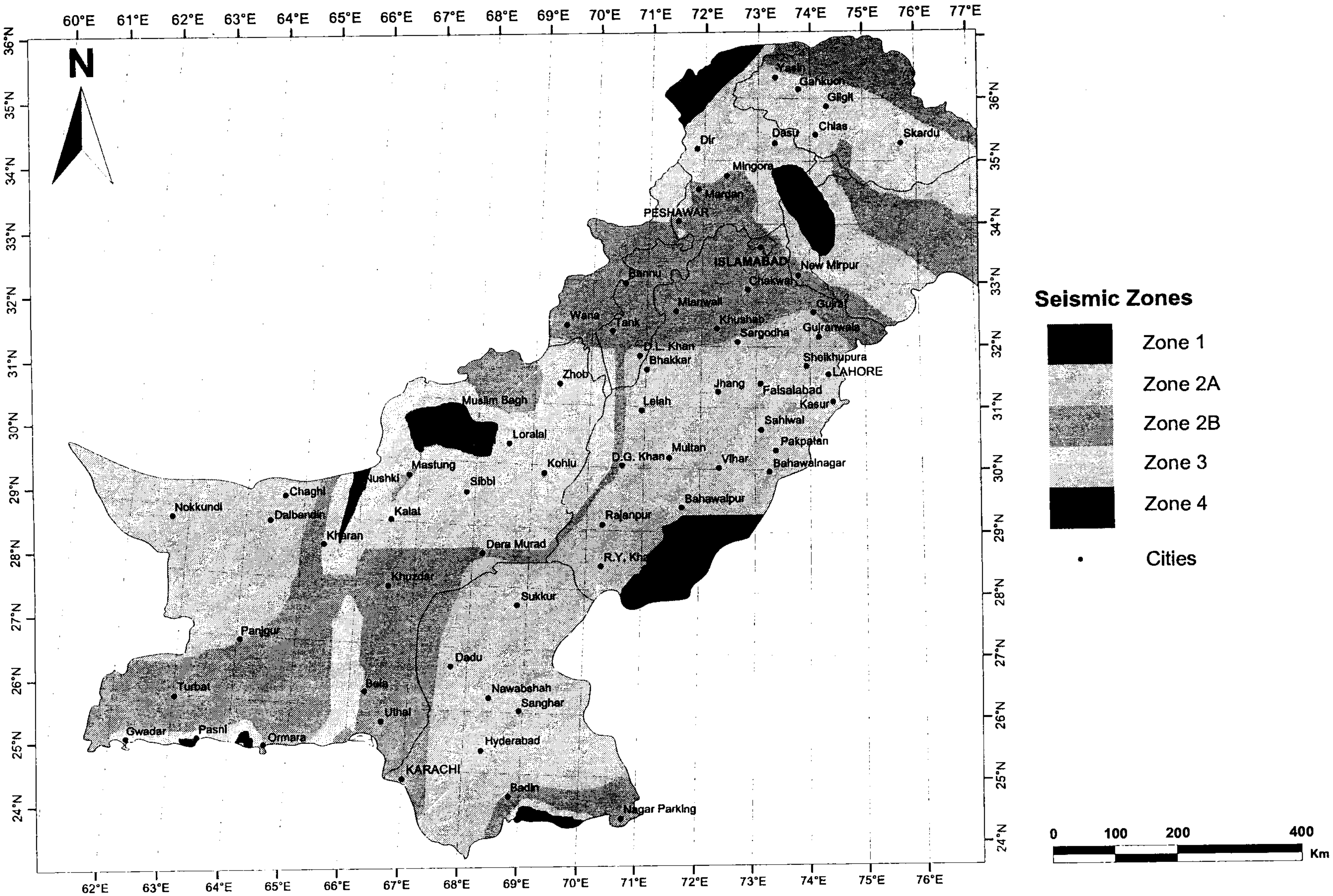
Pakistan geologically overlaps both with the Indian and the Eurasian tectonic plates where its Sindh and Punjab provinces lie on the north-western corner of the Indian plate while Balochistan and most of the Khyber-Pakhtunkhwa lie within the Eurasian plate which mainly comprises the Iranian plateau, some parts of the Middle East and Central Asia.

Geomorphology

The alluvial deposits along the proposed T/L are mainly from the river Indus. These alluvial landforms are distributed in an orderly pattern in relation to that amount of the deposits of the river. The Indus has flown through a broad track of active flood plain. Flanking this landform and lying parallel to it are broad almost unbroken belts of meander flood plains. These have a general level somewhat higher than that of the river.

Route Lithology

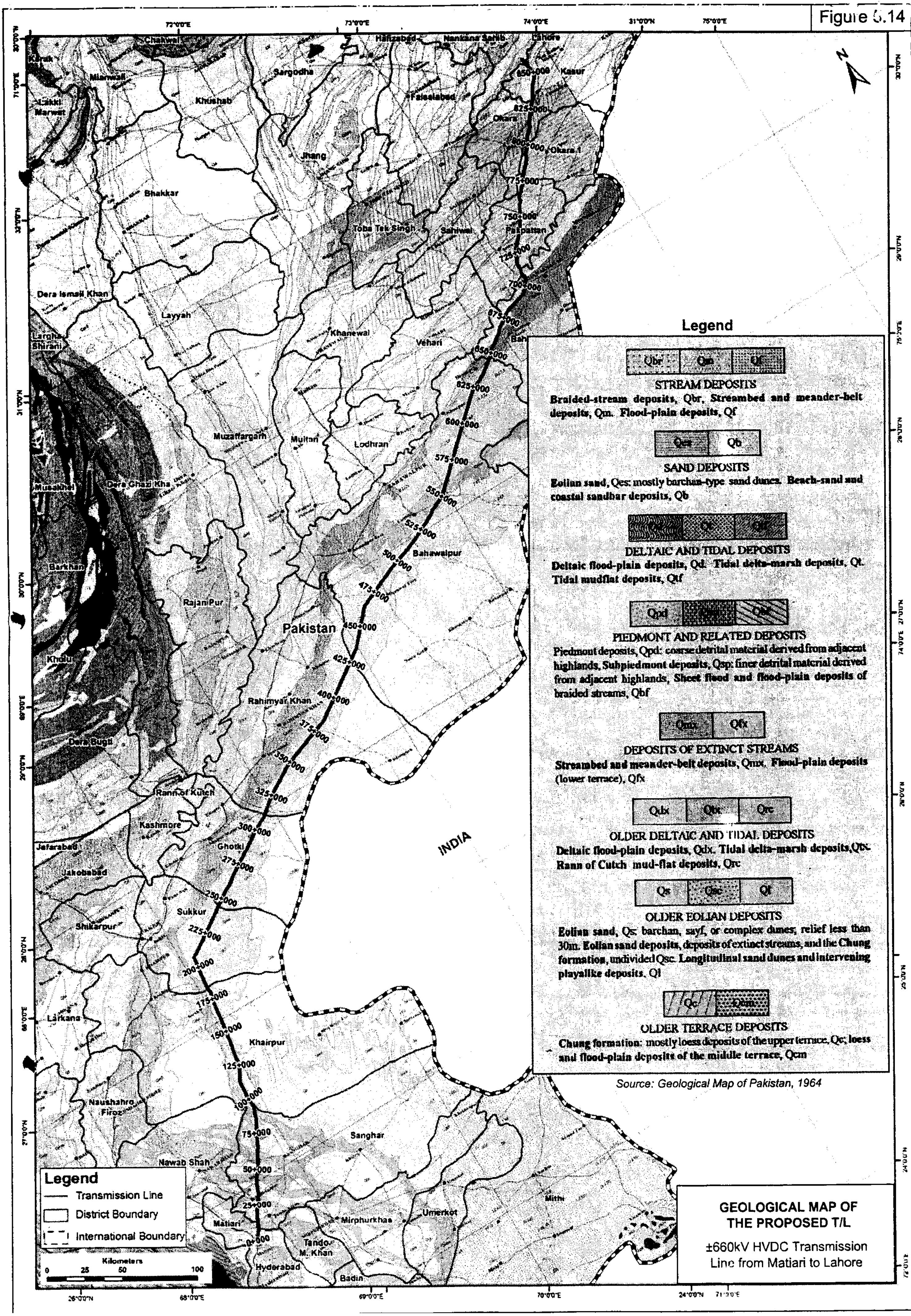
As mentioned earlier that the proposed T/L will start from Matiari and end at Nankana Sahib (near Lahore). There are different types of Quaternary deposits which exist along the proposed T/L route (refer Figure 5-14). These Quaternary deposits are described section wise below:



Source: *Building Code of Pakistan, Seismic Provisions, 2007*

SEISMIC ZONING MAP OF PAKISTAN
±660kV HVDC Transmission Line from Matiari to Lahore

Figure 5.13



Legend
STREAM DEPOSITS
Braided-stream deposits, Qbr, Streambed and meander-belt deposits, Qm. Flood-plain deposits, Qf
SAND DEPOSITS
Eolian sand, Qes: mostly barchan-type sand dunes. Beach-sand and coastal sandbar deposits, Qb
DELTAIC AND TIDAL DEPOSITS
Deltaic flood-plain deposits, Qd. Tidal delta-marsh deposits, Qt. Tidal mudflat deposits, Qtf
PIEDMONT AND RELATED DEPOSITS
Piedmont deposits, Qpd: coarse detrital material derived from adjacent highlands, Subpiedmont deposits, Qsp: finer detrital material derived from adjacent highlands, Sheet flood and flood-plain deposits of braided streams, Qbf
DEPOSITS OF EXTINCT STREAMS
Streambed and meander-belt deposits, Qmx. Flood-plain deposits (lower terrace), Qfx
OLDER DELTAIC AND TIDAL DEPOSITS
Deltaic flood-plain deposits, Qdx. Tidal delta-marsh deposits,Qtx. Rann of Cutch mud-flat deposits, Qrc
OLDER EOLIAN DEPOSITS
Eolian sand, Qs: barchan, sayf, or complex dunes; relief less than 30m. Eolian sand deposits, deposits of extinct streams, and the Chung formation, undivided Qsc. Longitudinal sand dunes and intervening playalike deposits, Ql
OLDER TERRACE DEPOSITS
Chung formation: mostly loess deposits of the upper terrace, Qc; loess and flood-plain deposits of the middle terrace, Qcm
Source: Geological Map of Pakistan, 1964
Legend
Transmission Line
District Boundary
International Boundary
Kilometers
0 25 50 100
GEOLOGICAL MAP OF
THE PROPOSED T/L
±660kV HVDC Transmission
Line from Matiari to Lahore
Pakistan
INDIA
Lahore
Kasur
Okara
Sargodha
Faisalabad
Khushab
Mianwali
Jhang
Bhakkar
Toba Tek Singh
Sahiwal
Pakpattan
Dera Ismail Khan
Layyah
Khanewal
Vehari
Muzaffargarh
Multan
Lodhran
Dera Ghazi Khan
Bahawalpur
RajanPur
Rahimyar Khan
Dera Bugti
Kashmore
Ghotki
Jacobabad
Sukkur
Shikarpur
Larkana
Khairpur
Naushahro Firoz
Nawab Shah
Sanghar
Matiari
Hyderabad
Mirpurkhas
Umerkot
Tando M. Khan
Badin
Mithi

Figure 5.14

5.2.5.1 Section-I

Alluvial Deposits

The proposed T/L will starts from Matiari District. The area comprises of stream and meander bed deposits consisting of unconsolidated silty sand/sandy silt intervened by levelled flood plains formed by the River Indus. The depth of such deposits may vary up to several hundreds of meter and belongs to Pleistocene to Recent age.

Alluvial and Eolian Sand Deposits

The area near Sanghar consists of Alluvial and Eolian deposits. The alluvial deposits consists of stream bed and meander belts deposits of Indus River which on later stage transported by the wind action forming low relief sand dunes.

Eolian Sand and Longitudinal Sand Dune Deposits

These are the loose sand deposited by the extinct streams with sandy silt/ silty sand as the surface layer at places. The districts containing these deposits are Khairpur, Sukkur, Ghotki, and a part of Rahimyar Khan.

5.2.5.2 Section-II

Eolian Sand Deposits

The districts containing these deposits are Rahim Yar Khan and Bahawalpur. These are the loose sand deposited by the extinct streams with sandy silt as the surface layer at places.

Stream Bed and Meander Belt Deposits

These deposits are found in the district Bahawalpur along the proposed T/L route. These deposits are stream bed and the meander bed deposits, consists mainly of silty sand /sandy silt at the surface and silty sandy gravel at depth with lower relief deltas and uneven surfaces ranging from 10 to 25 m.

Eolian Sand Deposits

These deposits are found in the Bahawalnagar districts along the proposed T/L route. These are the loess and flood plain deposits of extinct streams with sandy silt as the surface layer at places with uneven surfaces at places.

Loess and Flood Plain Deposits

It consists of flood plains deposits also forming the wide spread terraces. These deposits consist of silt with trace to little amount of sand and clay. These deposits are found in the district Pakpattan along the proposed T/L route.

Stream Bed and Meander Belt Deposits

These deposits are found in the district Okara along the proposed T/L route. These are the streamed and meander bed deposits consist of silty sand with trace to little amount of clay at the surface and silty sandy gravel at depth. It forms the alluvial fans of the river with the relief ranging from 15-25 m.

Loess Deposits

It consists of alluvial deposits of the river Ravi forming terraces. It is mainly silt with sand and small fraction of clay. These deposits are found in the district Kasur and Lahore along the proposed T/L route.

5.2.6 Water Resources

In the COI water resources i.e. groundwater and surface water exist at various locations. Surface water canals, streams, drains, rivers are of perennial and non-perennial nature. Most of the proposed COI is located in fresh groundwater area however, at places brackish groundwater also encoutered. Irrigation requirements are fulfilled through these resources by installing tubewells, canals and rain (barani).

5.2.6.1 Surface Water

Section-I

Proposed T/L does not cross any river. However, some canals/distributroies/minors are being crossed over in the Section-I. Table below shows the details of these crossings.

Table 5–5: Surface Water Resources falling in the COI of the proposed T/L (Section-I)

Sr. No.	Sub-Section	District	Canal Name
1	AM #5 to 6	Matiari	Sukkur Branch
2	AM #6 to 7	Matiari	Dhandu Minor
3	AM #6 to 7	Matiari	Water Ponds
4	AM #7 to 8	Sanghar	Sui Kandhar
5	AM #8 to 9	Sanghar	Tando Adam Branch and Water Course
6	AM #9 to 10	Sanghar	water logged
7	AM #10 to 11	Sanghar	Jam Branch
8	AM #11 to 12	Sanghar	Sanghar Distributary
9	AM #12 to 13	Sanghar	Shahu Wah and channel from shahpur Distributary
10	AM #14 to 15	Sanghar	Jamrao Canal, Sinjhoro Minor and Channel from Rind Minor
11	AM #15 to 16	Sanghar	Rind Minor and channel from Rind Minor
12	AM #16 to 17	Sanghar	Water Course from Rind Minor
13	AM #17 to 18	Sanghar	Dim Branch Canal
14	AM #20 to 21	Sanghar	Habeebullah Minor Canal
15	AM #21 to 22	Sanghar	Sardar-2 Minor from Jamrao and water ponds
16	AM #23 to 24	Sanghar	Jamrao Canal and Nara Canal
17	AM #25 to 26	Sanghar	Water Ponds
18	AM #26 to 27	Sanghar	Water Ponds
19	AM #27 to 28	Khairpur	Water Ponds
20	AM #28 to 29	Khairpur	Water Ponds
21	AM #28 to 29	Khairpur	Minor from Nara Canal
22	AM #31 to 32	Khairpur	Gindahu Minor
23	AM #33 to 34	Khairpur	Minor from Nara Canal
24	AM #35 to 36	Khairpur	Minor from Nara Canal
25	AM #36 to 37	Sukhar	Nara Canal
26	AM #37 to 38	Sukhar	Nara Canal
27	AM #38 to 39	Sukkur	Water Ponds, Minor from Nara Canal, Water Course
28	AM #40 to 41	Sukkur	Dahar Wah and Water Course
29	AM #42 to 43	Sukkur	Water Course
30	AM #43 to 44	Ghotki	Water Ponds
31	AM #44 to 45	Ghotki	Narli Minor
32	AM #45 to 46	Ghotki	Water Course
33	AM #48 to 49	Ghotki	Rani Canal

Section-II

Rivers

The Proposed T/L crosses the Sutlej River and River Ravi near AM # 92 and 93and AM # 166 and 167 respectively. The hydrology of the Sutlej and Ravi River is given below:

Hydrology

Sutlej River in Bahawalnagar district crosses the proposed T/L near AM # 92 and 93. Proposed T/L also crosses the River Ravi near AM # 166 and 167. Last AMs of the proposed T/L are located in the flood plains of Ravi River near Lahore. A brief description about these rivers is given below:

Sutlej River

Sutlej River originates in western Tibet, south of the Kailas Mountain Range. In this area Indus, Brahmaputra and Ganges also begin their long journey. The total length of the river till the confluence with Chenab River is about 1,550 km. The river flows first in north-westerly direction, crossing the Mansrowar and RakesLakes north of the Tibet-India-Nepal triple point and drains the northern slopes of the GreatHimalayaRange with peaks upto 7,800 m. The river reaches Pakistan about 10 km downstream of Ferozepur barrage, where the borderline mingles with the river alignment. Below the Rohi nallah confluence till Ferozepur barrage, the river again flows through Indian Punjab. Thereafter, it becomes border line for some kilometres and only from Bakerke onward, some 15km downstream of Ferozepur, Sutlej runs entirely in Pakistani territory.

Occurrence of Floods

In the view of the high elevation in the upper reaches of the river basin, snowmelt is an important water resource. Although in March and April snowmelt contributes to the river flow, this phenomenon does not create large floods. Floods in the Sutlej occur particularly around August due to heavy rainfall during the monsoon as a result of storm depressions originating from the Bay of Bengal.

However, since the completion of the dams in India the occurrence and severity of floods have changed drastically. The area upstream of Bhakra and Pong dams adds upto about 57,000km^2, i.e. about half of the total catchment area.

The dams particularly affect the floods occurring in July and August, at times when the above reservoirs are not yet fully replenished. These facts, however, do not mean that extreme floods on the Sutlej are history. Extreme floods may also occur late in the monsoon season, when low monsoon depression tends to move in a more northerly direction. This happened, for example, in late September 1988. Also rainfall in the 25,000 km^2 large catchment area upstream of Sulemanki, which is not controlled by the dams in India, can contribute to the flood in Sutlej in Pakistan.

Ravi River

The river drains a catchment area of over 40,000 km2. The river originates in the Lesser Himalayan mountains in the centre of the Indian state of Himachal Pradesh. From its source to the confluence with Chenab River downstream of Trimmu barrage it travels about 900 km. The river enters Pakistan at Kot Naina, about 33 km upstream of the rim station Jassar Bridge. Then for more than 100 km all the way down to Ravi syphon, the Ravi forms the border between Pakistan and India. From Jassar Bridge, it traverses through 385 km before joining Chenab River, about 75 km below Trimmu barrage. Sidhnai barrage is the last structure on Ravi River, which is located 27 km upstream of its confluence with Chenab River.

The upper area of Ravi basin is mountainous with elevations up to 5,000 to 6,000 m. Its major part is covered with forest. Only the plains, about 25% of the upper area, are cultivated. In India the river is steep up to Madhopur with an average slope of 30 m/km, whereas downstream of Madhopur till Jassar (Pakistan) its slope reduces to 2 m/km. Further downstream the slope gradually reduces to 0.30 m/km between Jassar and Balloki and 0.15 m/km in the reach at its tail end. The width of river below Jassar, on average, is about 600 to 650 m. The river has wide flood plains, varying in width from 8 to 12 kms. This implies extreme low flood wave celerities.

About 25% of the basin drains upstream of Jassar bridge, including Ujh River and Bein nallah with catchment areas of 1,769 km2 and 826 km2 respectively. Between Jassar and Ravi syphon two more nallahs, Basanter and Sakki with catchment areas of 726 and 1034 km2 respectively, enter the river. Finally between Shahdara Bridge and Balloki barrage, Hudiara nallah and Deg nallah join Ravi River, draining areas of 1,502 km2 and 4,495 km2 respectively. Deg nallah is intercepted at its downstream end by Upper Chenab canal (UCC). No tributary enters the Ravi River downstream of Balloki barrage.

Occurrence of Floods

Floods in Ravi River are generated by monsoon rains from July through September and most frequently in August. Snowmelt contributes to the river flows but not significantly to the river floods. The magnitude of flood is considerable in the upper reaches, which reduces due to the wide flood plains in the lower reaches. Thein dam may reduce the extremity of floods during the early flood season, when it is not filled-up; but its flood mitigating capacity at the end of the monsoon season will be limited. In view of their small storage capacities the Madhopur Headworks and barrages at Balloki and Sidhnai have negligible flood mitigating potential.

According to the Indus Waters Treaty, India has right to all the flows of Ravi. At present, India is diverting all the flows of Ravi River except those occurring during floods.

Proposed T/L does crosses canals, distributories and minors in the Section-II. Distributaries and minors are being crossed by the proposed T/L which are given below in the Table 5-4.

Table 5–6: Surface Water Resources falling in the COI of the proposed T/L

Sr. No.	Sub-Section	District	Canal Name
1	AM #50 to 51	Raheem Yar Khan	Lakhi Canal and Water Ponds
2	AM #50 to 51	Raheem Yar Khan	Maleer Canal
3	AM #53 to 54	Raheem Yar Khan	Kander Minor
4	AM #54 to 55	Raheem Yar Khan	Chaman Distributary
5	AM #57 to 58	Raheem Yar Khan	Abe Hayat Distributary
6	AM #73 to 74	Bahawalpur	Fateh Distributary
7	AM #74 to 75	Bahawalpur	Fateh Distributary
8	AM #75 to 76	Bahawalnagar	Faten Minor From Ford Canal and Same Nullah
9	AM #78 to 79	Bahawalnagar	Sher Freed Minor Canal From Ford Canal
10	AM #79 to 80	Bahawalnagar	Soda Minor from Ford Canal
11	AM #81 to 82	Bahawalnagar	Soda Minor from Ford Canal (Passing near to COI) and Water Ponds
12	AM #83 to 84	Bahawalnagar	Sher Freed Minor Canal From Ford Canal
13	AM #89 to 90	Bahawalnagar	Sikandar Minor
14	AM #92 to 93	Bahawalnagar	River Sutlej
15	AM #98 to 99	Pakpattan	Buddan Shah Minor
16	AM #99 to 100	Pakpattan	Buddan Shah Minor
17	AM # 100 to 101	Pakpattan	Buddan Shah Minor
18	AM #102 to 103	Pakpattan	Khadir Branch (Pakpatan Canal)
19	AM #102 to 103	Pakpattan	Hazara Distributary
20	AM # 106 to 107	Pakpattan	Pakpattan Distributary from Khadar Canal
21	AM # 107 to 108	Pakpattan	Pakpattan Distributary from Khadar Canal (passing near to COI)
22	AM # 109 to 110	Pakpattan	Khama Dogar Minor from Khadar Canal
23	AM # 110 to 111	Pakpattan	Moga Minor from Khadar Canal

Sr. No.	Sub-Section	District	Canal Name
24	AM # 111 to 112	Pakpattan	Taber Minor from Khadar Canal
25	AM #117 to 118	Pakpattan	Malka Hans Distributry
26	AM #118 to 119	Pakpattan	Nur pur Distributry
27	AM # 124 to 125	Pakpattan	Nahran Wala Distributry
28	AM # 125 to 126	Okara	Same Nullah
29	AM # 127 to 128	Okara	50-B Minor from Okara Canal
30	AM # 128 to 129	Okara	Dastagir Canal
31	AM # 129 to 130	Okara	Minor from Dastagir Canal
32	AM # 134 to 135	Okara	Qila Javed Singh Canal
33	AM # 139 to 140	Okara	Fauji 1L Minor from Khokhar Canal

5.2.6.2 Groundwater

Section-I

Groundwater is generally sweet and at some locations it is brackish in this section of the proposed T/L COI. Almost all the settlements in the COI utilize ground water for drinking purpose through hand pumps and for irrigation purpose through tubewells.

Section-II

Groundwater conditions in the COI of Section-II are somewhat similar to Section-I due to the presence of distributaries and minors in the surroundings areas. Groundwater in the COI is generally fresh and potable near canals and distributaries but at somelocationsit is reported as brackish. Settlements of the COI use the groundwater for drinking and irrigation purpose through tubewells and hand pumps. In general the depth of the ground water varies between 10 to 15 m.

Groundwater in the COI is generally fresh and potable. The water table depth decreases as we move away from the main canals. The settlements near the COI utilize the groundwater for drinking purpose through hand pumps and motor pumps. The groundwater is also utilized for irrigation purposes through the tubewells especially in the tail areas of the canals (minor), where the water supply through the canal stream is reduced.

5.2.7 Environmental Monitoring, Sampling and Testing for Proposed T/L

In order to determine the existing ambient air, noise, water and wastewater quality of the area following locations were selected in the COI. The sampling locations for the Environmental Monitoring of ambient air, noise and water for Proposed T/L Section-I and II are shown in Table 5-7 a&b below.

5.2.7.1 Section-I

Table 5–7 (a): Sampling Points for Environmental Monitoring (Section-I)

Sr. No	Stretch (AM.)	District	Surface Water	Waste Water	Ground Water	Ambient Air Monitoring	Noise Level
				Converter Station Sindh			
1	Sekhat, Matiari		SW-01 Mitiari Distributary	--	GW -01 Hand pump Goth Hashim Dhakhna	AA-01 Goth Wali Muhammad	NL-01 Sekhat Road
				Along the Transmission Line Route (Sindh Section)			
2	AM 1-7	Matiari	SW-02 Rohri Canal/Udero	--	GW -02 Hand Pump Sher	AA-02 Goth Machi	NL-02 Udero Lal Road

Sr. No	Stretch (AM.)	District	Surface Water	Waste Water	Ground Water	Ambient Air Monitoring	Noise Level
			lal Canal		Muhammad Thora Village		
3	AM 8-15	Sanghar	–	**WW- 01** Wastewater Pond Gidra Machni	**GW -03** Hand Pump Kario Bachal Khan Budani	**AA-03** Goth Maula Makhan	**NL-03** Shadadpur Tando Adam Road
4	AM 16-25	Sanghar	**SW-03** Rind Minor	–	**GW -04** Hand pump Goth Haji Ghulam Laghari	**AA-04** Goth Haji Ghulam Laghari on Sanghar Road	**NL-04** Nawab Shah Road
5	AM 26-33	Khairpur	--	**WW- 02** Goth Wahid Baksh Brackish Water pond	**GW -05** Tube well Gujro Bhit	**AA-05** Goth Piran Bhambro	**NL-05** Thal Road
6	AM 34-38	Sukkur	**SW-04** Nara Canal (Minor)	–	**GW -06** Hand Pump Goth Khanan	**AA-06** Engro Dairy farm Nara	**NL-06** Kara Nara Road
7	AM 39-49	Ghotki	**SW-05** Dahar Minor	–	**GW -07** Hand Pump Allah Obhayo Mahar Near Rja farm Gabbar Link Road	**AA-07** Mast Wari Bhit	**NL-07** Bagsar Road
Grand Total			5	2	7	7	7

Environmental Monitoring Report results are in process.

5.2.7.2 Section-II

Table 5–7b: Sampling Points for Environmental Monitoring (Section-II)

Sr. No.	Stretch (AM.)	District	Surface Water	Waste Water	Ground Water	Ambient Air Monitoring	Noise Level
Converter Station Punjab							
1	Nankana Saheb		**SW-01** Upper Chanab Canal	--	**GW -01** Tube well Qila Mohkam Singh	**AA-01** Shaukatabad	**NL-01** Bhai Pehru Mor Khunda Road
Along the Transmission Line Route (Punjab Section)							
2	AM 50 - 55	Rahim Yar Khan	**SW-02** Kandera Minor Near Chak 237 P	--	**GW -02** Tube well Chak 144 P	**AA-02** Chak 262 P Sharif wala	**NL-02** Access Road Near Chak 186 P
3	AM 55 - 60	Rahim Yar Khan	**SW-03** Chaman Distributar y	–	**GW -03** Hand Pump Chak 94 P	**AA-03** Chak 241 P	**NL-03** Rahim Yar Khan Desert Road
4	AM 61-74	Bahawalpur	**SW-04** Fateh Distributar y	–	**GW -04** Hand Pump Chak 73 DB	**AA-04** Chak 85	**NL-04** Yazman Fort Abbas Road
5	AM 75-84	Bahawalnag ar	**SW-05** Sher Freed Minor From Ford Canal	–	**GW -05** Hand Pump Basti Khuda Baksh	**AA-05** Chak Chopa	**NL-05** Bahawalpur Bahawalnaga r Road

Sr. No.	Stretch (AM.)	District	Surface Water	Waste Water	Ground Water	Ambient Air Monitoring	Noise Level
6	AM 85-93	Bahawalnagar	–	**WW-01** Open Sewage System Khemgarh	**GW -06** Tube Well Basti Bulla Shah Pir Sikandar	**AA-06** Sanateka Village	**NL-06** Mominabad Road
7	AM 94-110	Pakpatan	**SW-06** Khadir Branch Pakpatan Canal	–	**GW -07** Hand Pump Lukman Mehruka	**AA-07** Chak 33 SP	**NL-07** Arifwala Sahiwal Road
8	AM 111-123	Pakpatan	**SW-07** Malika Hans Distributary	–	**GW -08** Tube Well Chak 60 D Khokharawala	**AA-08** Chak 68 D	**NL-08** Pakpatan Arifwala Road
9	AM 124-136	Okara	**SW-08** Alward Minor	–	**GW -09** Hand Pump Chak 43 D	**AA-09** Chak 50 D	**NL-09** Piplipahar Depalpur Road
10	AM 136-149	Okara	–	**WW-02** Chak 6 Wastewater Pond	**GW -10** Tube Well Chak 16 1/AL	**AA-10** Chak No 7/1L	**NL-10** Depalpur Renala Khurd Road
11	AM 150-157	Kasur	–	**WW-03** Gopi Rai Open Sewage System	**GW -11** Hand Pump Shaikhum Khurd	**AA-11** Chak 41	**NL-11** Shahrah-e-Quaid e Azam Road
12	AM 158-165	Kasur	**SW-09** Niaz Baig Distributary	–	**GW -12** Tube well Near Qasaiwala	**AA-12** Chah Bharianwala	**NL-12** Balloki Hala Road
13	AM 166-169	Nankana Sahib	**SW-10** River Ravi	–	**GW -13** Tube well Goth Hakim Ali	**AA-13** Thatta Bhumbi Da	**NL-13** Lower Bari Doab Road
Grand Total			**10**	**3**	**13**	**13**	**13**

Environmental Monitoring Report results are in process.

All the details will be attached in Environmental Monitoring Report as Annex-VI on receipt.

5.2.8 Landuse

There are different classes of landuse i.e. utilizing the canal water, tubewells and lift pumps, irrigated agricultural land rain fed (barani) agricultural land and uncultivable land. Landuse maps of the proposed T/L Project are presented as Figure 5-2 & 5-3 in Volume-II of EIA Report. A brief of landuse is given below.

5.2.8.1 Section-I

The COI in Section-I is rich in source of irrigation (i.e. canals/minors). In some portion of the Sanghar district although irrigation water is available at few places water comes from natural precipitation or the runoff water coming down from the surrounding area during floods so rain fed (barani) agriculture is practiced in these parts of COI. Landuse of the Section-I based on the GIS landuse map in the COI and ROW is given in Table 5-8 a and b below.

Table 5–8 (a & b): Summary of Landuse in the COI of Section-I

Sr. No.	Sub-Section	Landuse in the COI (In Acre)								
		District	Agriculture	Tree Cover	Barren Land	Residential	Roads	Water Course	Water Pond	Total
		Section-I								
1	AM # 1 to 6	**Matiari**	830.54	85.11	546.10	39.27	42.13	15.19	3.12	1561.46
2	AM# 7 to 26	**Sanghar**	6747.10	91.52	3214.24	195.64	277.98	110.06	442.98	11,079.52
3	AM# 27 to 34	**Khairpur**	1276.21	9.60	8967.11	103.95	23.56	6.73	197.20	10,584.35
4	AM # 35 to 39	**Sukkur**	2517.77	90.60	4727.55	123.16	42.00	48.39	76.72	7,626.20
5	AM # 40 to 49	**Ghotki**	3799.68	13.78	3915.26	150.96	88.07	96.82	205.89	8,270.46
	Total		15171.31	290.60	21370.26	612.98	473.75	277.20	925.90	39121.99
	Percentage		**39%**	**1%**	**55%**	**2%**	**1%**	**1%**	**2%**	

Sr. No.	Sub-Section	Land-use in the ROW (In Acre)								
		District	Agriculture	Tree Cover	Barren Land	Residential	Roads	Water Course	Water Pond	Total
Section-I										
1	AM # 1 to 6	**Matiari**	150.16	18.12	119.82	2.51	6.51	2.99	0.00	300.11
2	AM# 7 to 26	**Sanghar**	1357.99	15.59	672.76	9.12	55.60	21.74	73.35	2,206.16
3	AM# 27 to 34	**Khairpur**	214.98	0.96	1854.58	12.61	4.89	1.34	24.81	2,114.17
4	AM # 35 to 39	**Sukkur**	512.48	21.12	940.81	18.99	8.55	9.63	14.37	1,525.95
5	AM # 40 to 49	**Ghotki**	766.65	0.61	788.63	18.41	15.52	19.09	45.20	1,654.10
		Total	3002.26	56.39	4376.60	61.63	91.08	54.79	157.74	7800.49
		Percentage	**38%**	**1%**	**56%**	**1%**	**1%**	**1%**	**2%**	

5.2.8.2 Section-II

Project Area of Section-II is mostly irrigated agricultural land where the main source of irrigation is distributaries and minors even in the deset areas only a few places irrigation water is not available. The source of surface water in the COI of Section-II is Kandera Minor, Khamman-IL Minor, Chaman Distributary, Ab-i-Hayat Distributary, Nathal Minor, Hasilpur Distributary and Fateh Distributary.

The cropping pattern followed in the Project Area in general is the Rabi Crop, which is sown during the month of November to December and is harvested during May to June and the Kharif crop sown during June, July and harvested in the month of October to November. The main Kharif crops are rice, maize, cotton and sugarcane, and the major Rabi crops are wheat Vegetables, pulses. Fodder is also grown in the area by the farmers to supplement their income in both Kharif and Rabi seasons.

Table 5-9 a and b provides the information collected through GIS Satellite imagery regarding the landuse in COI and ROW of Section-II.

Table 5–9 (a & b): Summary of Landuse in the COI of Section-II

Sr. No.	Sub-Section	Landuse in the COI (In Acre)								
		District	Agriculture	Tree Cover	Barren Land	Residential	Roads / Track	Water Course	Water Pond	Total
Section-II										
1	AM # 50 to 62	Rahimyar Khan	3049.15	49.69	11177.34	113.34	52.82	47.97	10.16	14,500.47
2	Am # 63 to 74	Bahawalpur	8364.37	53.81	48.12	2146.93	60.01	9.11	4.34	10,686.70
3	AM # 75 to 94	Bahawalnagar	13764.84	22.78	344.19	9398.55	127.91	91.52	33.14	23,782.94
4	AM # 95 to 124	Pakpattan	71.18	3.48	236.67	6906.54	127.92	41.17	5.16	7,392.13
5	AM # 125 to 150	Okara	305.33	343.22	172.98	4830.22	119.88	21.60	20.04	5,813.27
6	AM # 151 to 166	Kasur	18.20	156.21	78.18	2581.94	56.98	16.72	0.84	2,909.07
7	AM # 167 to 169	Nankana Sahib	16.33	27.59	11.25	489.47	3.94	91.45	4.54	644.56
			25589.39	656.79	12068.72	26467.01	549.47	319.55	78.22	65729.14
			39%	**1%**	**18%**	**40%**	**1%**	**0%**	**0%**	

Sr. No.	Sub-Section	Landuse in the ROW (In Acre)								
		District	Agriculture	Tree Cover	Barren Land	Residential	Roads	Water Course	Water Pond	Total
Section-II										
1	AM # 50 to 62	Rahimyar Khan	634.71	12.61	2179.55	8.61	9.77	11.67	2.06	2,858.98
2	Am # 63 to 74	Bahawalpur	1072.32	15.32	4159.84	11.30	18.05	8.87	0.94	5,286.64
3	AM # 75 to 94	Bahawalnagar	1249.64	7.51	149.59	28.05	18.37	11.28	3.94	1,468.38
4	AM # 95 to 124	Pakpattan	1417.56	0.15	14.23	8.00	24.31	7.19	0.71	1,472.14
5	AM # 125 to 150	Okara	984.13	77.08	67.30	8.48	24.53	4.23	4.42	1,170.17
6	AM # 151 to 166	Kasur	564.31	35.39	3.37	3.04	10.99	3.02	-	620.11
7	AM # 167 to 169	Nankana Sahib	99.09	6.29	3.36	0.85	0.60	14.83	0.75	125.78
			6021.76	154.35	6577.25	68.33	106.61	61.08	12.83	13002.21
Total			**46%**	**1%**	**51%**	**1%**	**1%**	**0%**	**0%**	**28,603.19**

5.3 Ecological Environment

5.3.1 Major Habitats Bio Diversity Features

The proposed Transmission Line (TL) from Matiari to Lahore passes through two main eco-regions i.e. Desert-Xeric Shrublands and Sub-Tropical Thorn area. The Desert-Xeric shrubland category includes districts of Sanghar, Khairpur, Sukkur, Ghotki, Rahim Yar Khan, Bahawalpur and Bahawalnagar, and consists of Angle Marks No. 8 to 94. The eco-region of Sub-Tropical Thorn area includes rest of the districts i.e. Matiari, Pakpattan, Okara, Kasur, and Nankana Sahib and stretches over AM-1 to AM-7 and AM-95 to AM-169. However, for the purpose of collection of field data, the proposed T/L route has been split up into two Sections i.e. Section-I (districts falling in Sindh) and Section II (districts falling in the Punjab).

5.3.1.1 Dersert-Xeric Shrublands

The habitat is typically influenced by extreme climate, mainly stretching over desert conditions. Because of low biomass productivity, the litter layer is almost non-existent with very low organic content of soil surface. The land is highly sensitive to grazing, burning, soil disturbance and other cover alteration. Soil restoration potential is very low with very slow regeneration capabilities. Temperatures range from freezing in winter to extremely hot (more than 46^{0}C) in summer. The desert vegetation is quite varied due to range of temperature with Prosopis shrubs being the characteristic species alongwith cacti species with specialized photosynthesis mechanism to store more water. The animals found in desert ecosystem (called xerocoles) evolved to survive in this unique environment because they do not sweat and can retain water in their bodies. Most animals found in hot desert are much smaller in size such as rodents, rabbits and lizards.

5.3.1.2 Sub-Tropical Thorn Area

This type of habitat includes low, open and pronouncedly xerophytic species in which thorny leguminous species predominate. It occupies almost whole of the Indus plain except the driest parts. The climax tree species are Capparis, Salvadora, Tamarix, Prosopis and Zizyphus. The soils range from flat alluvial to heavy clays, loams and sandy loams. The climate varies from semi-arid (250 to 750 mm rainfall) to arid (less than 250 mm rainfall). The summer temperature in the tract is as high as 48^0 C. This tract provides an ideal habitat to the wildlife of the area which seasonally migrate according to their needs. Avifauna migration is from the lower hills towards the plains during cold winter in search of food and shelter, and from the flood plains towards the dry areas during floods and towards the rivers during the summer drought.

5.3.2 General Flora and Fauna of the T/L Route

The Project Area being part of the Indus basin the climate of the tract is arid, sub tropical, the original flora of the area consists of tropical thorn forest type vegetation, in which thorny usually hard wooded species predominate, acacia species being particularly characteristic. The trees have usually short boles and low branching crowns, which rarely meet except on exceptionally favourable spots. The usual height of tree is 6-10 m.

Following is the baseline of flora and fauna found in the COI. AM wise details are provided in the Annex-IV.

5.3.2.1 Flora

In order to collect baseline data, field survey was conducted in the COI. On-site observation as well as local information was recorded for the floral species in the area, which is given in Table 5-10 and 5-11 below.

a) Section-I

Table 5-10: Major Floral Species Found along the Project Route Alignment in Sindh

Sr. No.	Sub-Section	District	Tree		Herb		Shrub	
			English/ Local Name	Scientific Name	English/ Local Name	Scientific Name	English/ Local Name	Scientific Name
1	AM-1 to AM-7	Matiari	Kandi	*Prosopis cineraria*	Kander	*Alhaji camelorum*	Akk	*Calatropis procera*
			Kikar	*Acacia nitolica*	Khip	*Leptadenia spartum*	Lai	*Tamarix dioica*
			San	*Salvadora oleoides*	Booi	*Aerva javanica*	Mallah	*Zizyphus nummularia*
			Khabar	*Salvadora oleoides*	-	-	Sehwar	*Rhazia stricta*
2	AM-8 to AM-27	Sanghar	Kikar	*Acacia nitolica*	Kander	*Alhaji camelorum*	Akk	*Calatropis procera*
			Kandi	*Prosopis cineraria*	Kandi/ Sangri	*Prosopis cineraria*	Mallah	*Zizyphus nummularia*
			Shisham	*Dalbergia sissoo*	-	-		
			Neem	*Azadirachta indica*	-	-	-	-
			Khabar	*Salvadora oleoides*	-	-	-	-
			Sufaida	*Eucalyptus camal dulensis*	-	-	-	-
			Ber	*Zizyphus jujuba*	-	-	-	-
3	AM-28 to AM-35	Khairpur	Kandi/ Sangri	*Prosopis cineraria*	Khip	*Leptadenia spartum*	Lai	*Tamarix dioica*
			Kikar	*Acacia nitolica*	-	-	Akk	*Calatropis procera*
			Neem	*Azadirachta Indica*	-	-	-	-
			Khabar	*Salvadora oleoides*	-	-	-	-
4	AM-36 to AM-40	Sukkur	Kandi/ Sangri	*Prosopis cineraria*	Booi	*Aerva javanica*	Mallah	*Zizyphus nummularia*
			Neem	*Azadirachta indica*	Khip	*Leptadenia spartum*	Akk	*Calatropis procera*
			Kikar	*Acacia nitolica*	-	-	-	-
			Ber	*Zizyphus jujuba*	-	-	-	-
5	AM-41 to AM-51	Ghotki	Neem	*Azadirachta indica*	Khip	*Leptadenia spartum*	Akk	*Calatropis procera*
			Kikar	*Acacia nitolica*	Kandi/ Sangri	*Prosopis cineraria*	-	-
			Ber	*Zizyphus jujuba*	-	-	-	-

b) Section-II

Table 5-11: Major Floral Species Found along the Project Route Alignment in Punjab

Sr. No.	Sub-Section	District	Tree		Herb		Shrub	
			English/ Local Names	Scientific Name	English / Local Names	Scientific Name	English/ Local Names	Scientific Name
1	AM-52 to AM-62	Rahim Yar Khan	Sufaida	*Eucalptus camal dulensis*	Khip	*Leptadenia spartum*	Mallah	*Zizyphus nummularia*
			Shisham	*Dalbergia sissoo*	Kandi/ Sangri	*Prosopis cineraria*	Lai	*Tamarix dioica*
			Neem	*Azadirachta indica*	-	-	Akk	*Calatropis procera*
			Kikar	*Acacia nitolica*	-	-	-	-
			Ber	*Zizyphus jujuba*	-	-	-	-
			Khabar	*Salvadora oleoides*	-	-	-	-
2	AM-63 to AM-75	Bahawalpur	Kikar	*Acacia nitolica*	Arind	*Arundo donax*	Lai	*Tamarix dioica*
			Khabar	*Salvadora oleoides*	Khip	*Leptadenia spartum*	Akk	*Calatropis procera*
			Shisham	*Dalbergia sissoo*	-	-	-	-
			Ber	*Zizyphus jujube*	-	-	-	-
			Sufaida	*Eucalptus camal dulensis*	-	-		
3	AM-76 to AM-94	Bahawal-nagar	Kikar	*Acacia nitolica*	Khip	*Leptadenia spartum*	Kanir	*Cappris decidua*
			Shisham	*Dalbergia sissoo*	-	-	Mesquite	*Prosopis glandulosa*
			Neem	*Azadirachta indica*	Kandir	*Alhaji camelorum*	-	-
			Sufaida	*Eucalptus camal dulensis*	-	-	-	-
			Date palm	*Phoenix dactylifera*	-	-	-	-
			Kandi	*Prosopis cineraria*	-	-	-	-
4	AM-95 to AM-124	Pakpattan	Neem	*Azadirachta indica*	Kandir	*Alhaji camelorum*	Akk	*Calatropis procera*
			Kikar	*Acacia nitolica*	-	-	Mallah	*Zizyphus nummularia*
			Shisham	*Dalbergia sissoo*	-	-	Mesquite	*Prosopis glandulosa*
			Ber	*Zizyphus jujuba*	-	-	-	-
			Simal	*Salmalia malabarica*	-	-	-	-
			Sufaida	*Eucalyptus camaldu lensis*	-	-	-	-

Sr. No.	Sub-Section	District	Tree: English/ Local Names	Tree: Scientific Name	Herb: English / Local Names	Herb: Scientific Name	Shrub: English/ Local Names	Shrub: Scientific Name
			Popular	*Populus negra*	-	-	-	-
5	AM-125 to AM-150	Okara	Amaltas	*Cassia fisluta*	Kandir	*Alhaji camelorum*	Akk	*Calatropis procera*
			Neem	*Azadirachta indica*	-	-	Mallah	*Zizyphus nummularia*
			Kikar	*Acacia nitolica*	-	-	Mesquite	*Prosopis glandulosa*
			Mango	*Mangifora indica*	-	-	-	-
			Sufaida	*Eucalptus camal dulensis*	-	-	Mallah	*Zizyphus nummularia*
			Kikar	*Acacia nitolica*	-	-	-	-
			Shisham	*Dalbergia sissoo*	-	-	-	-
			Jaman	*Eugenia jambolina*	-	-	-	-
			Ber	*Zizyphus jujuba*	-	-	-	-
			Simal	*Salmalia malabarica*	-	-	-	-
6	AM-151 to AM-166	Kasur	Neem	*Azadirachta indica*	Kandir	*Alhaji camelorum*	-	-
			Kikar	*Acacia nitolica*	Khip	*Leptadenia spartum*	-	-
			Shisham	*Dalbergia sissoo*	-	-	-	-
			Ber	*Zizyphus jujuba*	-	-	-	-
7	AM-167 to AM-169	Nankana Sahib	Neem	*Azadirachta indica*	Booi	*Aerva javanica*	Mesquite	*Prosopis glandulosa*
			Simal	*Salmalia malabarica*				
			Shisham	*Dalbergia sissoo*				
			Kikar	*Acacia nitolica*				

5.3.2.2 Fauna

i) Mammals

Mammals found in the Project Area are mainly jackal (*Canis aureus)*, rabbit (*Lepus nigricollis*).

Porcupine (*Hystrix indica*) and wild boar (Sus scrofa) are common in the plains of Sindh and Punjab. Domestic animals include cows, buffaloes, sheeps, goats, cats and camels. Another important domestic animal of the area is donkey, which is used for cart pulling.

ii) Reptiles

Reptiles include snakes and small sized lizards which are a common sight in the area.

iii) Rodents

Squirrel (*Funambulus layardi*) and Mouse (*Mus musculus*) are the basic rodents found in the Project Area.

iv) Amphibian

Toad (*Bufo bufo)* and Frog (*Rana tigrina*) are commonly found in the Project Area. The sighting of various species of fauna (mammals and avifauna) was carried out during field survey as well as information from locals was obtained which is tabulated in the Table 5-12 and 5-13 given below

a) Section-I

Table 5-12: Major Fauna Species Found along the Project Route Alignment in Sindh

Sr. No.	Sub-Section	District	Fauna	
			English/Local Names	Scientific Name
1	AM-1 to AM-7	Matiari	Jackal	*Canis aureus*
			Rabbit	*Lepus nigricollis*
			Porcupine	*Hystrix indica*
			Snake	*Elapidae bungaris*
			Lizard	*Cnemidophorus spp.*
			Toad	*Bufo bufo*
2	AM-8 to AM-27	Sanghar	Rabbit	*Lepus nigricollis*
			Jackal	*Canis aureus*
			Indian Mongoose	*Herpestes javanicus*
			Snake	*Elapidae bungaris*
			Frog	*Rana tigrina*
			Lizard	*Cnemidophorus spp.*
			Mouse	*Mus musculus*
			Indian Gerbil	*Tatera indica*
3	AM-28 to AM-35	Khairpur	Jackal	*Canis aureus*
			Rabbit	*Lepus nigricollis*
			Pig	*Sus scrofa*
			Porcupine	*Hystrix indica*
			Snake	*Elapidae bungaris*
			Frog	*Rana tigrina*
			Mouse	*Mus musculus*
4	AM-36 to AM-40	Sukkur	Jackal	*Canis aureus*
			Pig	*Sus scrofa*
			Indian Mongoose	*Herpestes javanicus*
			Snake	*Elapidae bungaris*
			Mouse	*Mus musculus*
			Toad	*Bufo bufo*
			lizard	*Cnemidophorus spp.*
			Frog	*Rana tigrina*
5	AM-41 to AM-51	Ghotki	Jackal	*Canis aureus*
			Porcupine	*Hystrix indica*
			Pig	*Sus scrofa*
			lizard	*Cnemidophorus spp.*

Sr. No.	Sub-Section	District	Fauna	
			English/Local Names	Scientific Name
			Snake	*Elapidae bungaris*
			Mouse	*Mus musculus*
			Squirrel	*Dicentra Canadensis*
			Toad	*Bufo bufo*

b) Section-II

Table 5-13: Major Fauna Species Found along the Project Route Alignment in Punjab

Sr. No.	Sub-Section	District	Fauna	
			English/Local Names	Scientific Name
1	AM-52 to AM-62	Rahim Yar Khan	Jackal	*Canis aureus*
			Pig	*Sus scrofa*
			Porcupine	*Hystrix indica*
			Rabbit	*Lepus nigricollis*
			Indian Mongoose	*Herpestes javanicus*
			Snake	*Elapidae bungaris*
			lizard	*Cnemidophorus spp.*
			Mouse	*Mus musculus*
			Toad	*Bufo bufo*
			Frog	*Rana tigrina*
2	AM-63 to AM-75	Bahawalpur	Fox	*Vulpus vulpus*
			Squirrel	*Dicentra canadensis*
			Mouse	*Mus musculus*
			Jackal	*Canis aureus*
			Toad	*Bufo bufo*
			Snake	*Elapidae bungaris*
			Pig	*Sus scrofa*
			Frog	*Rana tigrina*
			Porcupine	*Hystrix indica*
			Rabbit	*Lepus nigricollis*
3	AM-76 to AM-94	Bahawalnagar	Jackal	*Canis aureus*
			Toad	*Bufo bufo*
			Snake	*Elapidae bungaris*
			Pig	*Sus scrofa*
			Frog	*Rana tigrina*
			Porcupine	*Hystrix indica*
			Rabbit	*Lepus nigricollis*
4	AM-95 to AM-124	Pakpattan	Mouse	*Mus musculus*
			Jackal	*Canis aureus*
			Snake	*Elapidae bungaris*
			Pig	*Sus scrofa*
			Frog	*Rana tigrina*

Sr. No.	Sub-Section	District	Fauna	
			English/Local Names	Scientific Name
			Porcupine	*Hystrix indica*
			Rabbit	*Lepus nigricollis*
5	AM-125 to AM-150	Okara	Jackal	*Canis aureus*
			Snake	*Elapidae bungaris*
			Pig	*Sus scrofa*
			Frog	*Rana tigrina*
			Porcupine	*Hystrix indica*
6	AM-151 to AM-166	Kasur	Mouse	*Mus musculus*
			Jackal	*Canis aureus*
			Snake	*Elapidae bungaris*
			Pig	*Sus scrofa*
			Frog	*Rana tigrina*
			Porcupine	*Hystrix indica*
			Rabbit	*Lepus nigricollis*
7	AM-167 to AM-169	Nankana Sahib	Jackal	*Canis aureus*
			Pig	*Sus scrofa*
			Snake	*Elapidae bungaris*
			Frog	*Rana tigrina*

v) Avifauna

Important resident bird species/avifauna found in Project Area of Sindh and Punjab are house sparrow, common crow, kite, dove desert lark, cattle egret, etc. District-wise list of avifauna is mentioned in Tables 5-14 and 5-15.

a) Section-I

Table 5-14: Major Avifauna found along the Project Route Alignment in Sindh

Sr.No.	Sub-Section	District	Birds	
			English/Local Names	Biological Name
1	AM-1 to AM-7	Matiari	Sparrow	*Passer domesticus*
			Crow	*Corvus splendons*
			Dove	*Streptopelia decaocto*
			Hoopoe	*Upupa epops*
			Grey Partridge	*Francolinus pondicerianus*
			Kite	*Elanus caeruleus*
			Quail	*Cortunix cortunix*
			Common Myna	*Acridotheres tristis*
2	AM-8 to AM-27	Sanghar	Dove	*Streptopelia decaocto*
			Kite	*Elanus caeruleus*
			Little Cormorant	*Phalacrocorax niger*
			Bulbul	*Pycnonotus cafer*
			Crow	*Corvus splendons*
			Sparrow	*Passer domesticus*

Sr.No.	Sub-Section	District	Birds	
			English/Local Names	Biological Name
			Peddy Bird	*Ardeola grayii*
			Grey Partridge	*Francolinus pondicerianus*
4	AM-28 to AM-35	Khairpur	Sparrow	*Passer domesticus*
			Crow	*Corvus splendons*
			Kite	*Elanus caeruleus*
			Quail	*Cortunix cortunix*
			Black Partridge	*Francolinus francolinus*
			Dove	*Streptopelia decaocto*
5	AM-36 to AM-40	Sukkur	Sparrow	*Passer domesticus*
			Crow	*Corvus splendons*
			Quail	*Cortunix cortunix*
			Grey Partridge	*Francolinus pondicerianus*
			Peddy Bird	*Ardeola grayii*
			Common Myna	*Acridotheres tristis*
			Hoopoe	*Upupa epops*
6	AM-41 to AM-51	Ghotki	Sparrow	*Passer domesticus*
			Crow	*Corvus splendons*
			Dove	*Streptopelia decaocto*
			Indian Moorhen	*Gallinula chloropus*
			Bulbul	*Pycnonotus cafer*
			Cattle Egret	*Bubulcus ibis*
			Kite	*Elanus caeruleus*
			Hoopoe	*Upupa epops*
			Grey Partridge	*Francolinus pondicerianus*

b) Section-II

Table 5-15: Major Avifauna Found along the Project Route Alignment in Punjab

Sr.No.	Sub-Section	District	Birds	
			English/Local Names	Biological Name
1	AM-52 to AM-62	Rahim Yar Khan	Sparrow	*Passer domesticus*
			Crow	*Corvus splendons*
			Dove	*Streptopelia decaocto*
			Hoopoe	*Upupa epops*
			Bulbul	*Pycnonotus cafer*
			Kite	*Elanus caeruleus*
2	AM-63 to AM-75	Bahawalpur	Sparrow	*Passer domesticus*
			Common Myna	*Acridotheres tristis*
			Dove	*Streptopelia decaocto*
			Crow	*Corvus splendons*
			Desert Lark	*Ammomanes deserti*
			Blue Kingfisher	*Alcedo atthis*

Sr.No.	Sub-Section	District	Birds	
			English/Local Names	Biological Name
3	AM-76 to AM-94	Bahawalnagar	Dove	*Streptopelia decaocto*
			Crow	*Corvus splendons*
			Sparrow	*Passer domesticus*
			Common Myna	*Acridotheres tristis*
			Hoopoe	*Upupa epops*
			Little Cormorant	*Phalacrocorax niger*
4	AM-95 to AM-124	Pakpattan	Sparrow	*Passer domesticus*
			Crow	*Corvus splendons*
			Quail	*Cortunix cortunix*
			Black Partridge	*Francolinus francolinus*
			Grey Partridge	*Francolinus pondicerianus*
5	AM-125 to AM-150	Okara	Sparrow	*Passer domesticus*
			Crow	*Corvus splendons*
			Quail	*Coturnix coturnix*
			Grey Partridge	*Francolinus pondicerianus*
			Parrot	*Psittacula krameri*
6	AM-151 to AM-166	Kasur	Sparrow	*Passer domesticus*
			Crow	*Corvus splendons*
			Quail	*Coturnix coturnix*
			Grey Partridge	*Francolinus pondicerianus*
			Parrot	*Psittacula krameri*
			Common Myna	*Acridotheres tristis*
			Hoopoe	*Upupa epops*
7	AM-167 to AM-169	Nankan Sahib	Little Cormorant	*Phalacrocorax niger*
			Sparrow	*Passer domosticus*
			Crow	*Corvus splendons*
			Dove	*Streptopelia decaocto*
			Peddy Bird	*Ardeola grayii*
			Kite	*Elanus caeruleus*

5.3.2.3 Endangered Fauna

a. Mammals

Some mammalian species which were once common in the tract have become extinct or near extinction in the area on account of excessive shooting, hunting and loss of habitat. These include Blue bull, Wolf, Wild boar, Hog dear, Chinkara and Black buck.

b. Birds

Birds like Tilor (*Houbara bustard*), Marbled Teal (*Marmaronetta angustirostris*), Black partridge (*Francolinus francolinus*), Jal Kookri/Coot (*Fulica atra*) and Falcon (*Falco peregrinus*) have been subjected to excessive hunting and catching on account of their good quality and tasty meat or their commercial value as a prey bird thus falling in the category of Endangered or Vulnerable species.

5.3.2.4 Wetlands in the COI

No wetlands which are notified by the GOP lie within the COI of the Project alignment in any Angle Marking of Matiari-Lahore Project, thus there will be no impact on any wetland biodiversity.

5.3.2.5 Game Reserves, National Parks and Wildlife Sanctuaries

The proposed T/L will not pass through or cross any protected area i.e. Game Reserves, National Parks, Wildlife Sanctuaries etc. However, proposed T/L passes at a distance of about 12 kilometers from Changa Manga Reserve Forest (RF) at AM-160. Proposed Project, therefore, will not cause any impact on the flora and fauna of the Reserved Forest.

5.3.2.6 Agriculture

The Project Area passes throough various types of land uses including agriculture, grass land, desert, etc. The major agricultural crops in Sindh Province include Rice, Wheat, Cotton, Sugarcane, Pea nut, Fodder crop and Vegetables. In Punjab Province, Maize is also grown in addition to the crops mentioned above. The district-wise detail of agricultural crops and yield is given in Socio-Economic Baseline part of the report.

5.3.2.7 Fisheries

Fishery activities were neither observed nor reported by the local inhabitants of the Project Area during field survey. As such, fishery discipline is conspicuous by its absence in the area; therefore, the Project will not pose any threat/impact to the Fishery Sector.

5.4 Socio-Economic Environment

Thecomponents of the human environment described in this section cover the socio-economic characteristics of the population, both provincially and locally in the COI. These components consider, among others, the political and administrative structures, the dynamics of the demography, the ethnicity/casts, religion and languages, the dwellings, education, health, landuse, land ownership, the socio-economic activities, the role of the women and the existing and planed infrastructure and development orientations.

Baseline condition is described based on the surveys conducted on sample population settled in the COI, i.e. of Section-I and Section-II.

To describe the baseline conditions and demographic characteristics of the population in the COI, proposed T/L route is mainly divided into two (02) sections as already mentioned.

In Sindh and Punjab rural areas due to cultural norms, direct consultation with the local women was not allowed by the locals. For the collection of baseline data, field visits were carried out in June and July, 2015.

5.4.1 Political and Administrative Settings of Section-I (Sindh) and Section-II (Punjab)

In both Sections potential administration system is more or less identical therefore, it is described under this head. Union Council (UC) is the lowest tier of the local government. A sherwan or village council in Pakistan is an elected local government body headed by a nazim (which is equivalent to a mayor) and a naib nazim (deputy mayor). Union councils are the fifth tier of government in Pakistan and are often known as "village councils" in rural areas, the territory represented by a village council usually comprises a large village and surrounding areas, often including nearby small villages. The term "union council" may be used for localities that are part of cities.

Headed by a union nazim, each union council has 13 elected members or councilors. In addition to four male and two female members elected directly, there are two male and two female representatives of the labour, a minority member, a union council nazim and his deputy known as union council naib nazim. Beside elected members, there are several government employees and functionaries in every union council, who report to the secretary of the union council. The territory of a union council or village council is usually part of a tehsil (a district subdivision).

Taluka/Tehsil Council is the next tier of local government. About 4 to 5 UCs fall in the Taluka/Tehsil Council (TC). Taluka/Tehsil is a sub-unit of the district, which is the highest tier of the local government system, dealing with the administrative matters at district level. In Sindh Province it is called Taluka Council and in Punjab it is termed as Tehsil Council.

A district is composed of 3 to 5 Taluka/Tehsil's and is governed by the District Coordination Officer (DCO). The local government system of Section-I and Section-II comprise UCs consisting of members directly elected through an open competition, which is also from the Electoral College for the selection of the members for the next higher tier. This reveals that UCs have a sizable representation from the vulnerable groups belonging to the local community including female members. Considering the social, geographical as well as the traditional settings of the area in the COI from Matiari to Nankana Sahib (near Lahore), the lives of the people in rural areas of Section-I are tribal, while the remaining rural areas have "Bradari system" which determines the socio-economic pattern of the people's life.

Union Council Nazim is responsible to collect and maintain statistical information for socio-economic surveys in the community and to consolidate village and neighbourhood development needs and priorities them into union-wide development proposals with the approval of the Union Council and make recommendations thereof to the District Government or Tehsil Municipal Administration, as the case may be. Union council nazim also manage O&M of public resources such as drinking water, including wells, water pumps, tanks, ponds and other works for the supply of water. Union council nazim have access to Tehsil Nazim and Tehsil Nazim have access to District Nazim. District Government take funds from Provincial Government and District Nazim allocate fund with the coordination of DCO to Tehsil Nazim and Tehsil Nazim allocate fund as per the need of the administrative set up at District, Tehsil and Union Council level. The administrative setup of district, tehsil and union council level is shown inFigure 5-15 a, b and c.

5.4.2 Approach and Methodology

Socio-economic and demographic characteristics of both provinces are assessed based on primary and secondary information. Primary data was collected through field surveys and secondary data obtained from relevant publish material such as DCRs of relevant districts. Following approach and methodology was adopted to conduct the socio-economic survey in the COI.

5.4.2.1 Sample Size

To document the socio-economic conditions of the population settled in the COI, socio-economic surveys of the selected households were carried out. One of the major steps after the identification of the villages and their estimated populations during the field visit was the calculation of sample size. Total 164 villages were found within the T/L COI (i.e. 250 m from either side in the centerline of the T/L) for Matiari to Nankana Saheb and socio-economic survey was conducted in these villages. Based on the reconnaissance, approximate a number of households and their population were estimated. Estimated population and households are given in Table 5-16.

Section-I

Table 5–16 (a): District-wise No. of Villages and Households at Section-I along T/L COI

Sr. No.	AM No.	Location/ Districts	Villages located along the Project alignment (Nos.)	Estimated No. of Households	Estimated Population (Nos.)
1	1 to 7	Matiari	6	250	1,700
2	8 to 27	Sanghar	34	7800	54600
3	28 to 35	Khairpur	14	5200	41600

Sr. No.	AM No.	Location/ Districts	Villages located along the Project alignment (Nos.)	Estimated No. of Households	Estimated Population (Nos.)
4	36 to 40	Sukkur	7	560	4200
5	41 to 49	Ghotki	8	270	1755
Total			**69**	**14,080**	**103,855**

Section-II

Table 5–16(b): District-wise No. of Villages and Households at Section-II along COI

Sr. No.	AM No.	Location/ Districts	Villages located along the Project alignment (Nos.)	Estimated Households	Estiamted Population (Nos.)
1	50 to 62	Rahim Yar Khan	9	3,000	24,000
2	63 to 74	Bahawalpur	12	3,500	26,250
3	75 to 94	Bahawalnagar	15	4,500	29,700
4	95 to 124	Pakpattan	20	3,820	26,740
5	125 to 150	Okara	22	6,200	46,500
6	151 to 166	Kasur	13	4,915	31,948
7	167 to 169	Nankana Saheb	4	1,700	11,050
Sub-total			**95**	**27,635**	**196,188**
Grand Total (Section-I+ Section-II)			**164**	**41,715**	**300,043**

From the total 41,715 households it was assumed that about 5% households (i.e. 8,343 nos.) may have some impact due to the implementation of the Project (i.e. digging, concreting, erection of Towers, stringing activities).

For determining the sample size of potential affected persons, the variability or proportion estimated based on the critical parameters under the study is essential to determine a statistically valid and representative sample size from the target population. A representative sample size is also important to derive meaningful results from the information collected in the field consisting of individual interviews, community/ group consultations and village level information.

In this context, of the total expected affected households of 83,43 nos. (5% of No. of total H/H) from Matiari to Nankana Saheb, a Sample size[13] of 450 households were determined

[13]Consideration: population is given and the population proportion is known.

$$n = \frac{NZ^2 \ P(1-P)}{Nd^2 + Z^2 \ P(1-P)}$$

Where, n = Sample size of potential affected households

N = Total number of potential affected households (1,288 nos.)

P = Population proportion (the value P= 0.50)

Z = Level of reliability (the value of Z at 95% confidence level is 1.96)

D = Maximum acceptable error (value: 0.045)

$$n = \frac{(8343)\ (1.96)^2\ 0.5\ (1-0.5)}{(8343)\ (0.045)^2 + (1.96)^2\ 0.5\ (1-0.5)}$$

n = 448 say 450 households

by using a statistical formula[14]. Based on the number of household sample size was proportionally divide in two sections Sindh and Punjab. In Section-I about 150 households and Section-II 300 households were selected as a sample.

The sample households were selected randomly from different categories of potential affected households, i.e., land owners, tenants, shopkeepers/ businessmen, labourers etc. To ensure the reliability and validity of the information, every head of the household in the COI was considered as a unit of analysis.

5.4.2.2 Data Collection

To maintain the quality of field data and representation, data collection tools/ techniques such as interview schedule, participatory rapid appraisal, consultations with the local community, cross-questioning and physical observations were utilized. The data was collected using both structured and semi-structured questionnaires. The structured socio-economic questionnaire was used for the collection of data from potential affected persons, while the semi-structured format was used for conducting consultations/ group discussions and village profile survey.

Five (05) teams were formed for the collection of baseline data. Each team was headed by an experienced sociologist. Efforts were made to include local persons belonging to the areas falling in the COI of the proposed T/L in the respective team. Two (02) teams were assigned the task to conduct socio-economic surveys in the COI falling in Section-I. Remaining three (03) teams were assigned the task to collect data in Section-II.

Data collection was started after four (04) days trainings of the survey teams, so that the quality of data collection into a requisite format/ unit of measurement could be maintained and accordingly the results could be derived. Baseline survey was carried out in the COI.

5.4.2.3 Public Consultation/Scoping Sessions

In order to ensure participatory development and to answer and clear out any apprehensions, myths and misconceptions of the locals, number of scoping sessions were conducted in the selected villages/settlements in the COI. Scoping sessions also provide support to extract qualitative information related to the perceptions, apprehensions and reactions of the local population and to build a sense of confidence and ownership of the Project.

5.4.2.4 Data Entry and Analysis

After the completion of the field surveys, all the questionnaires were scrutinized properly. Data collected on the basis of the above mentioned surveys were processed and analyzed using the computer software Statistical Package for Social Sciences (SPSS). SPSS provides a Powerful statistical analysis and data management system in a graphical environment, using descriptive menus and simple dialog boxes to do the analysis.

5.4.2.5 Results

The results generated through the data entry and analyses on SPSS were expressed in the form of tables and graphs. Analysis results are described in the form of frequency distributions. Description of the tables was made, the results related to different social and demographic parameters were analyzed and baselines established for the people in the COI.

This section provides baseline information on socio-economic and cultural parameters of the COI, which includes demographic parameters, settlement patterns, availability of basic amenities, existence of religious and cultural sites, indigenous people and the condition of women. Moreover, the results were also presented through maps, graphic illustrations and photographs. Following sections describe these baseline conditions.

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[14] Cristina Parel, et.al. 1973, "Sampling Design and Procedures, ADC, 630 Fifth Avenue, New York. 10020).

5.4.3 Socio-Economic Conditions of Section-I

5.4.3.1 Demography of Section-I

T/L in Section-I passes through some semi urban and mostly rural areas. In this section, 69 villages are located. Baseline conditions, demographic characteristics and socio-economic profile are described in below. AM wise detailed baseline profile is attached as **Annex IV**.

i. Population and Distribution

As per the last 1998 census, the estimated population of the districts where the T/L will pass is shown in Table 5-17. Data shows that highest population is living in Khairpur district which was 1,546,587persons and the lowest population was in Matiari district i.e. 253,747. As per DCR and socio-economic survey population details along average household size are shown in Table 5-17 below.

Table 5–17: District Wise Population and Average Household Size based on DCR and Socio-economic Survey

Sr. No.	AM No.	Districts	Population as Per DCR, 1998	Average Size of Household (No.) as Per DCR,1998 (No.)	Population as Per Survey	Average Size of Household (No.) as Per Survey (No.)
1	1 to 7	Matiari	253,747	5.6	1,700	6.5
2	8 to 27	Sanghar	1,453,000	5.8	54,600	7
3	28 to 35	Khairpur	1,546,587	6	41,600	8
4	36 to 40	Sukkur	908,373	6.5	4,200	7.5
5	41 to 49	Ghotki	970,549	5.5	1,755	6.5
		Total	**5,132,256**	**5.8**	**103,855**	**7**

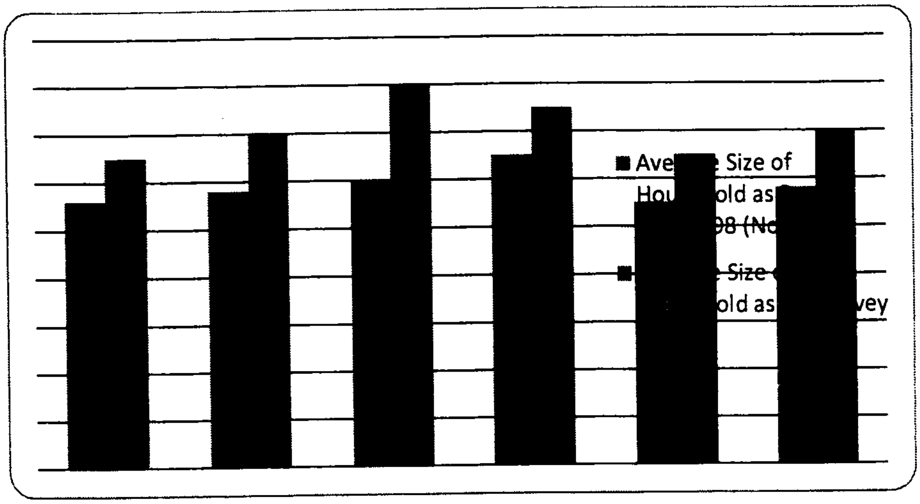
Above data shows that as per DCR total populations in the COI are 5,132,256persons. The average household size was computed 5.8 members per household.

As per socio-economic survey highest population in this section is residing in Sanghar district and lowest population in Ghotki district because in Ghotki district most of the T/L route is in desert area. 2nd highest population is living in Khairpur district which is 41,600 persons. Total population in the COI of Section-I is 103,855 persons.

Family/Household Size

As per DCR the highest average household size is 6.5 for Sukkur district and the lowest average household size is for Ghotki district which is 5.5. Because Sukkur is the main city of Sindh and there are lot of job or business opportunities available therefore, people of the other areas are settled there. Due to the availability of facilities such as health, education etc. while migration ratio from Sukkur to other cities are less as compared to other districts falling in the COI, which is a main cause of higher family size in Sukkur district. Based on the socio-economic survey highest average household size of Khairpur district (8) and lowest is in Ghotki district (6.5). Highest family size of Khairpur district shows that the joint family system is strong in this district. Variation in household size of districts DCR is due to the fact that DCR covers whole district including urban and rural areas. While T/L route is pass through mostly rural areas. Comparison of average household size in Section-I is also shown in Figure 5-16.

Figure 5-16: Comparison of Average Household Size



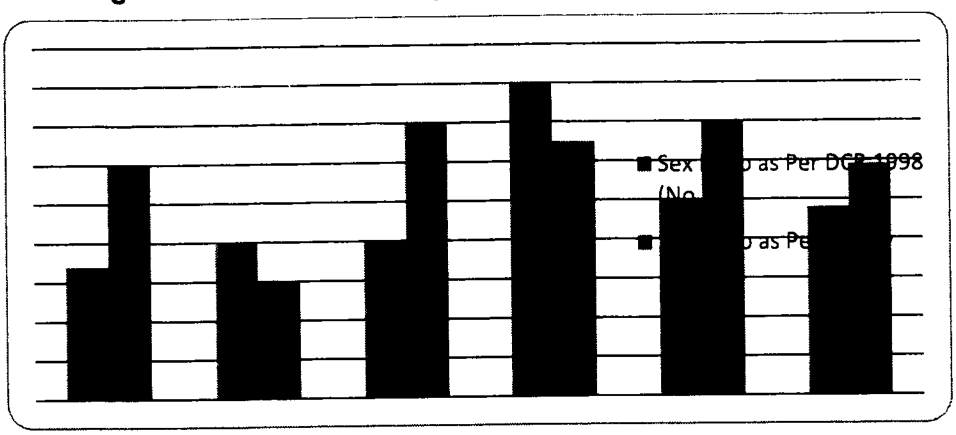
As per social survey maximum household size is for Khairpur and Sukkur districts which are 8 and 7.5 respectively. Result shows that joint family system is common throughout the COI, whereas only small percentage of families is living as a single family (called nuclear family system). In Khairpur and Sukkur districts, tribal system exists, therefore, people give preference to live as joint family. During the discussions with the locals of Khairpur and Sukkur, it was clarified that larger family size is treated as the strength of the family.

Based on social survey, overall average household size is concluded as 7 which is higher than DCRs average family size. The higher values of household size are based as most of the part of the proposed T/L will cross the rural area while in DCRs average household size is given of the whole district.

Sex Ratio

As per socio-economic surveys, the average sex ratio (males per 100 females) for Section-I was worked out as 114 which is higher as compare to average sex ratio based on the DCRs of 1998 where the sex ratio is 110.8. Details are given Figure 5-17.

Figure 5–17: Sex Ratio as per DCR and Socio-Economic Survey



Above figure shows that as per DCR the maximum sex ratio is in Sukkur district (114) and the lowest sex ratio is in Matiari district (109.4). As per social survey, maximum sex ratio in the COI of Khairpur district which is 113.

Based on the socio-economic survey, the lowest sex ratio in the COI is 109 and 112 which is for the Sanghar and Matiari districts. Socio-economic conditions of the rural areas of Sanghar and Matriari districts are not as good as compared to urban areas. Most of the earning male members of the families are not living there, they are outside from their houses and working in different cities and come back during the harvesting seasons. Majority of the people are employed or doing business in Sukkur, Hyderabad and Karachi cities. Hence the sex ratio in these areas are lower than others areas.

ii. Ethnicity/ Caste Groups

The core unit of social organization is the biraderi/caste group which is either defined on the basis of specific occupation or lineage. Occupationally defined caste groups are considered as lower status in the social setup which they are living. For instance occupationally defined biraderi/caste groups are Mochi (Cobbler), Machi (Fisherman), Nai (Barbar), Gujjar (Dairy and Livestock), Julahay (Weavers) while linage based biraderi/caste groups are Laghari, Baloch, Watoo, Chatha, Malik, Bhatti, Rajput etc.

There are number of tribes and caste group located in the Section-I. The social life of the population is traditionally on tribal lines. Many local and other tribes from Muslim and non-Muslim communities are settled in the COI of Section-I.

Based on the social survey, the population in Matiari district found lot of tribes which have strong caste system. The major caste/ethnic groups settled in the Section-I are Sommo, Jatt, Khusk, Khosa, Burdi, Machhi, Khaskali, Kohli, Beer, Dogar, Brohi, Bagrani, Lund, Kori, Rind, Kerio, Baloch, Awan, Mahar, Arain, Rajput, Jutt, Bhatti, Shar, Junejo, Sammats, Samas, Mahers, Mohris, Samejas, Raja, Bajeer, Sheikh, Memon, Soomro, Qureshi, Syed, Kalhora, Lakhah, Kolachi, Channa, Lund, Laghari, Chandio, Khosa, Bhutta, Talpur and Unnar among others. Summary of major casts existing in the COI are given in Table 5-18.

Table 5–18: Major Caste Groups/ Tribes Settled in the COI

Sr. No.	AM No.	Districts	Major Caste/ Tribes
1	1 to 7	Matiari	Jutt, Khusk, Khoso, Khaskali, Buridi, Balock, Khyber, Machhi,Talpur
2	8 to 27	Sanghar	Khoso, Pir, Kohli, Khyber, Dogar, Dehlo, Bheel, Dehri, Brohi, Bagrani, Talpur, Lund, Rajput, Arain, Jutt,
3	28 to 35	Khairpur	Megwan, Mahers, Maree Laghari, Chandio, Sheikh, Soomro, Syed, Kalhora, Channa and Lund
4	36 to 40	Sukkur	Sahata, Sammats, Samas, Mahers, Mohris
5	41 to 49	Ghotki	Kholi, Mhangwar, Maree, Raja, Bajeer, Sheikh, Memon,Soomro, Qureshi, Syed, Kalhora, Lakhah, Kolachi, Channa, Lund

It is worth mentioning here that the major castes/ tribes were important because they have a key role in decision making regarding the resolution of social issues of family matters. For instance, in Section-I, Landlord (locally named as Vadaira/Raise) and Shah as well as the head/ or elder of the respective tribe generally make decisions related to the social issues at village level as well as the social development works in their areas. It was assessed that prior to the initiation of any Project/ program, it is essential to involve these effective groups/ tribes at each stage from design, implementation and operation of the Project for the success of the Project.

iii. Languages Spoken in Section-I

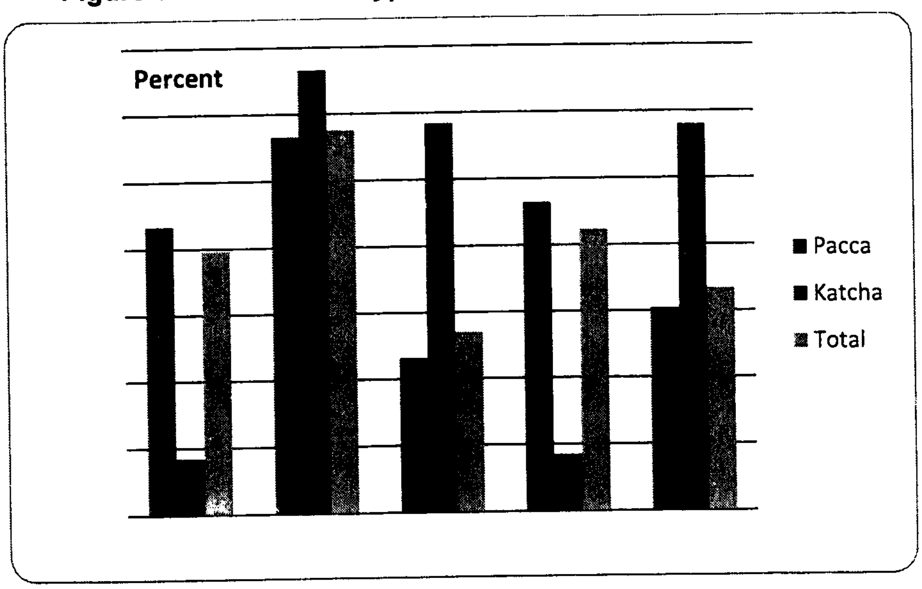
Sindhi as a mother tongue is spoken in the COI, however, Punjabi, Saraiki, Balochi and Pashto are also spoken in the areas near to the Punjab boundary i.e. Ghotki and Sukkur.Large number of Punjabi families is living in Sanghar district due to in Sanghar Punjabi language is common speaking.

iv. Dwellings

Housing condition is also an important parameter for the assessment of the living standard / household well-being of the locals. Information collected from primary as well as secondary sources shows that settlement pattern of the houses in all the district of Sindh Province is very simple.

In Section-I poor people are living in a hut consisting of mud or cattle walls and a roof of thatch with a hedge round it. It consists of living rooms, kitchen, store room, bathroom etc. The houses of Zamindar (Landlord) and well off people are built of sun dried bricks with a flat roof. It consists of a living room, with one or two side rooms which serves as box-rooms. The houses of the rich people are distinguished by ample accommodation and more grandeur along the same lines. In the big towns such as Matiari, Khairpur, Sanghar, Sukkur and Ghotki houses are usually made of burnt bricks and provided with necessary furniture and other luxury items. As per socio-economic survey details of different types of housing structures are shown in below Figure 5-18. Results shows that in the COI, poor people are living in Katcha houses made from baked bricks and wood or bushes while the houses of well off people are usually built of sun dried bricks with a flat roof. As per baseline survey, occupancy in different types of houses is shown in Figure 5-18.

Figure 5–18: Different Types of Houses as per Social Survey



Nature of Tenure

As per DCRs nature of tenure of the houses of the districts shows that the majority of people have their own houses and the only few percent people are living in rented houses. However, during the social survey It was observed that about 99% respondents had their own houses. While remaining 1% are tenents or labours who are working as employ under the landlord.

Decision Methods adopted in the Villages of the COI

The methods of the decision for social conflicts in the COI are panchayat, court, jerga, caste groups and others (method constituted at the spot considering major and scope of the conflicts). According to the collected information, panchayat is most commonly accepted method of decision in the COI. At some places such as Sanghar and Ghotki districts, the old traditional decision and conflict resolution method exist.

In the "Panchayat" system, team lead by village leader Vadaira, Raise and religious scholar make decisions based on investigations and witnesses. Details of decision making method in the COI are given in table 5-19 below:

Table 5–19: Decision Methods in the Villages

Sr. No.	AM No.	Location/ District	(% of Villages)			
			Panchayat	Court	Jerga	Within the Caste Group
1	1 to 7	Matiari	50	14	25	27
2	8 to 27	Sanghar	40	11	25	22
3	28 to 35	Khairpur	95	-	-	-
4	36 to 40	Sukkur	90	-	-	-
5	41 to 49	Ghotki	50	-	-	-
Average			65	-	-	-

Table 5-19 indicates that in the COI people prefer panchayat as compared to court or other legal system because this method is more effective. As per the locals, Panchayat provide timely justice while other methods are complex and require time as well as money.

v. Existence of Associations

The strong and effective village societies/associations and other community based organizations can play an important role in the designing, implementation and operation of community/social and development Projects. Based on the village profile, it was observed that on the whole, there is no single NGO is working in the villages of COI of Section-I.

vi. Cooking Method

As per DCR, different sources are being used for cooking purpose in the COI. Data reveals that majority of people more than 95 percent population are using locally available wood and animal dung for cooking purpose, while Gas is second highest source for cooking. While as compared to wood, only few number of people use kerosene oil because of high prices of kerosene oil. Reason to utilize wood for cooking is due to the fact that it is cheap and easily available in rural areas as compared to other methods.

vii. Role of Women

The emancipation of women is a campaign to give women equal rights and status with men. The emancipation of women i.e. their liberation from economic and sexual oppression, their access to higher education and their escape from narrow gender roles is not easily achieved due to tribal setup and remoteness in the area. Rural society of Sindh is dominated by men. Cultural tradition, social practices and low female literacy ratio have left women in a vulnerable position. Women are restricted to performing household work and excluded from decision-making both on the domestic front and at the community level. Women's access to education and health care is limited because such services are not available close to home in the COI. Women take active part in agricultural activities, collects fuel wood and fetch water, in addition to household work and family duties, but their due status is not given by the society.

Women in the COI are also vulnerable through economic, social and psychological poverty. Economic poverty is due to lack of assets and low endowment of human capital. Social poverty derives from the inability of the society to accept women's equality and their economic, political and cultural rights, while psychological poverty is a product of the subjugation of women, under the dictates of customs and traditions, which deprives them even of control over their own lives.

In the rural set-up women are kept under-educated or uneducated. They are mainly dependent on male members of the family for economic reasons and cannot take decisions regarding their own lives. Indeed, women cannot use their rights to caste vote during general elections, they have no say in the family matters and are not asked about their preference for marriage. Yet for the paucity of rights, women play a vital part in the society fetching water and firewood from distant places, nurturing children and cooking and cleaning for the family. Nonetheless, these conditions make communication with women within the tribal regions more difficult and there are numerous aspects of women lives in the region which need to be explored.

Major Issues faced by Women in the COI

Information which is collected through secondary sources and group discussion with locals shows that major problems faced by women in the area are lack of primary health care, the lack of education opportunities and the lack of access to clean water. Other problems faced by women included very labourious work such as woods collection for cooking and heating, working in agricultural fields and fetching and carrying water from distant places. These tasks not only affect their health but also take up a major portion of their time, which they could use in some other productive work.

5.4.3.2 Main socio-economic Activities in Section-I

Farm income can be classified as the income generated through selling of farm products such as crops, fodder and dairy products from livestock. The main source of income and livelihood of the locals falling in the COI is agriculture. Along agriculture, locals perform other work as a secondary source of income. The households earn income by doing farm activities i.e. by dong permanent job in public sector or private sector, business and other daily wage works. By adding both the incomes, total earned income of the households is estimated which is available with the members of the households for consumption or saving purpose. In rural areas, the main asset considered is livestock, since the farmers can sell an animal to have money to fulfil their urgent needs. Livestock also partially fulfills portion requirements of locals especially children and women. Details are given in Figure 5-19.

i. Structure of Occupation and Employment

Based on the field survey major occupations in the COI are agriculture / farming, Labour (Unskilled workers), service (government or private employ), business (small shop keeper) and livestock rearing (sale and purchase of livestock and dairy products). As per data collected for the baseline, it was noticed that agriculture/farming and unskilled labour is the main source of income for the locals. As discussed above, major part of the T/L passes through rural areas and majority of people are involved in agriculture activities or labour related to the field of agriculture. Details of occupations in the COI are given below:

Figure 5–19: Main Occupations in COI

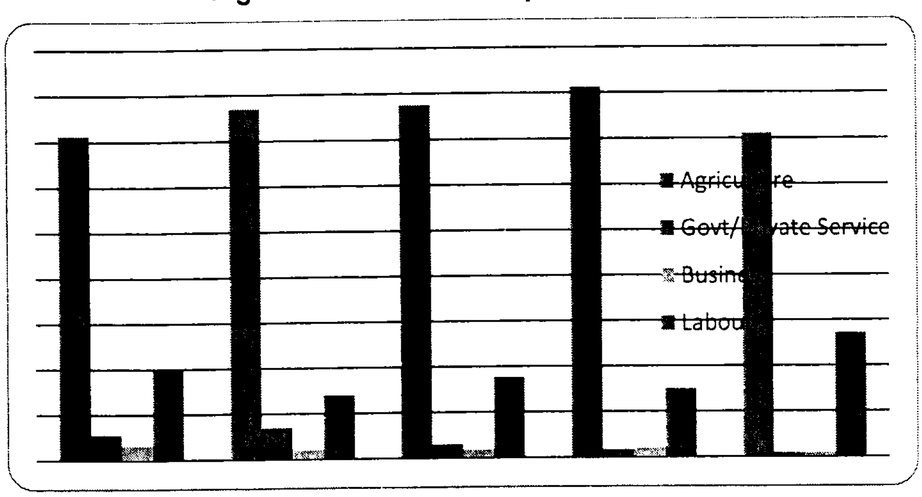


Figure reveals that, in the COI, maximum number of people more than 70 percent of the all the districts are attached to the field of Agriculture, while 2nd highest percentage of respondent are involved in daily wage labour and the lowest percentage are employed in Govt. and private sectors and remaining are doing business or fall in others sectors.

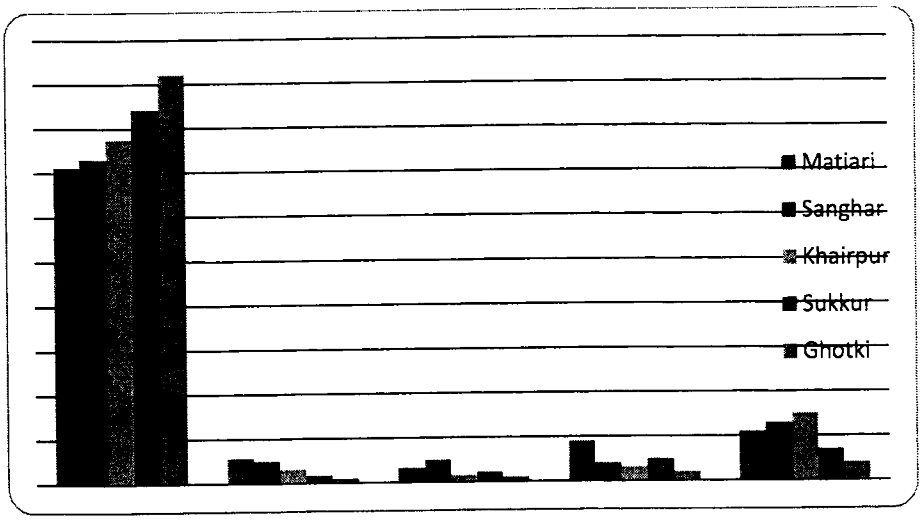
Another important thing is that majority of the locals are involved in multiple occupations as all are farmers but also are labourer and do some other business.

ii. Agriculture

Landuse Pattern

The optimum cropping pattern refers to the allocation of the cropped area under different crops during the year in order to attain maximum output within the existing resources. In general, there are four (04) main crops (i.e. wheat, cotton, Maize, sugarcane) being grown in the COI from Matiari to Ghotki. (Refer Crop Calendar Annex-VII).In addition vegetables, some fodder, sunflower, rose and orchards (Mango, Plump, Guava etc.) were also found under the cropping pattern in the COI. Details regarding the cropping pattern in the COI are presented in Figure 5-20.

Figure 5-20: District Wise Cropping Patterns as per Social Survey



iii. Other Activities

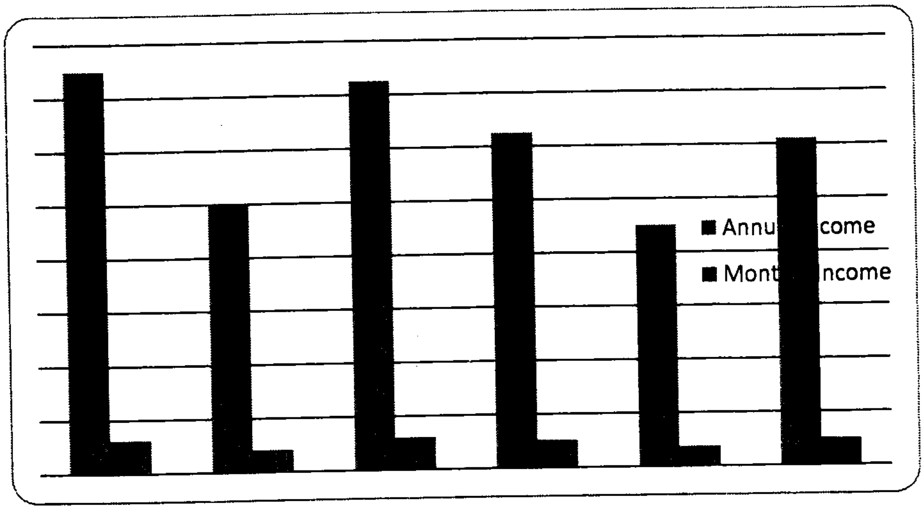
Household Livelihood

Average Annual Income

Generally income of the households consists of farm income and nonfarm activities. The farm income is obtained by selling crops. The income earned by conducting off-farm activities is referred as non farm income. The assessment of annual household income is one of the important indicators to measure the well-being/ livelihood of the household. During the field surveys, it was observed that in case of farm households, the major sources of income included the income from crops and livestock (dairy products). For non-farm or landless households, the main sources of income are the income from off-farm activities, such as business, Govt. or private employment, labour etc.

The survey results depicted in below Figure 5-21 reveal that in the COI, average annual household income is computed to be Rs. 122,000/- while the per month amount is Rs. 10,167/-. The average annual and monthly, per capita income is estimated as Rs. 28,477/- and Rs.2,373/- respectively. Details of average income in the COI are show in Figure 5-21.

Figure 5–21: Average Income in the COI



Household Expenditure

The annual expenditure and pattern of the expenditure provides an indication for assessing the standard of living of a household. The expenditure on food items includes cereals, pulses, flour, sugar, cooking oil/ ghee, milk etc., while the non-food items consist expenditure on education, medical treatment, clothes, shoes, cosmetics etc.

The survey indicates that on overall basis, the average annual household expenditure on both food and non-food items is computed to be Rs. 82,972/-. In case of food and non-food items, such proportion is to the extent of Rs. 64,050/- (77.2%) and Rs.18,922/- (22.8%) respectively.

Extent of Credit Utilization

Generally, the credit is obtained to supplement the income to meet the routine and some extra expenditure of the household including investment, social needs and other unforeseen situations. Credit is obtained from both the formal (banks) and informal sources (friends, relatives, land owner etc.)

As per the socio-economic surveys, majority of the respondents did not take loan during the last year and only 1 percent take loan for household matters such as for diseases or marriages etc.

5.4.3.3 Social Amenities and Infrastructure in Section-I

Considering the objective of the study, the profile of the villages has been interpreted in detail focusing on social and societal aspiration of the present time and the development of infrastructure demonstrates availability of social amenities at village level. These include road, electricity, dispensary/ basic health unit (BHU), school, Sui gas, drinking water facility, telephone and others.

The availability of the basic infrastructure and social amenities measures the development of the area and living standard of the people. During the social survey, data regarding the availability of village infrastructure including electricity, road, BHU, school, drinking water/water supply scheme, telephone, sewerage/drainage, fuel wood and sui gas were collected in order to identify the pressing infrastructural development needs of the villages located in the COI.

The survey results derived based on the 'village profile' summarized in Figure 5-24 shows that out of 10 villages / Goths, 60 to 80 percent population in the COI had access to roads, electricity, fuel wood and schools especially for boys, while the other facilities like health, sui-gas, drinking water and telephones were found at 12 percent population. Drinking water/ water supply schemes were also not available in most of the villages. In the COI from Matiari to Ghotki districts, drinking water is a major issue for the people especially in desert areas of Sanghar and Ghotki where people are forced to use pond water for drinking. The major sources of drinking water in the COI are streams, nullahs, pumps and tubewell etc. In some areas women have to fetch water from far away ponds and dug wells from their houses. Details of the availability of infrastructure in different villages are given in below Figure 5-24.

Education Facilities

During the field visit, it was observed that in the COI, educational buildings are available. Educational institutions were found but in poor condition. Due to the non-availability of students as well as teachers, most of the school buildings have collapsed or in a poor condition.

In the COI, most of the schools for girls and boys are of primary and middle level and in many areas children have to go at taluka headquarter for higher secondary education, which are not easy to travel for the vast majority of students especially girls.

Educational facilities are better in Matiari and Khairpur districts while other districts of the COI are considered educationally backward especially with respect to the female. The poor class may get education upto primary standard but they rarely go any further studies. The teaching staff of the schools of all the districts is mostly trained and medium of instruction at present is Sindhi and Urdu languages. Based on the socio-economic survey, details of education facilities in the COI are given below in Figure 5-24.

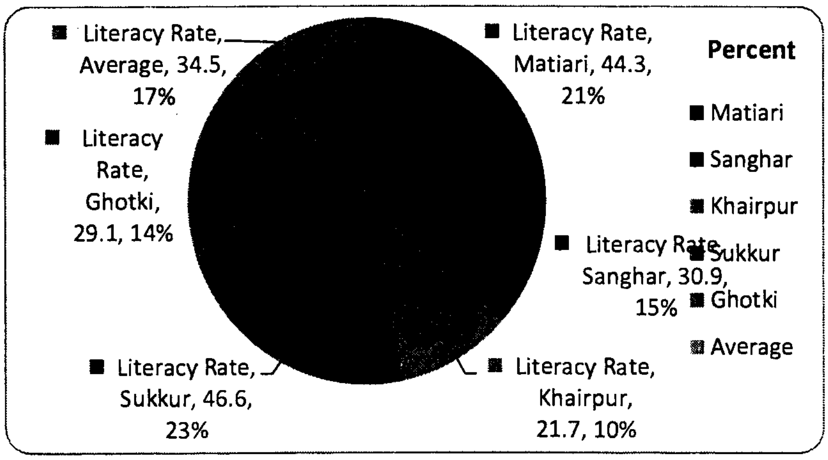
Literacy Rate

According to Pakistan's National Literacy Policy, "*a person is literate if he/she can read and write a paragraph of at least three lines in any regional or national language along with comprehension*".

According to DCRs the literacy rate of Sukkur district is highest (i.e. 46.6) among all districts (Figure 5-22). In Sukkur city, there are number of educational institutions. However, like other districts of Section-I, literacy ratio among women is not so good due to cultural restriction of women education.

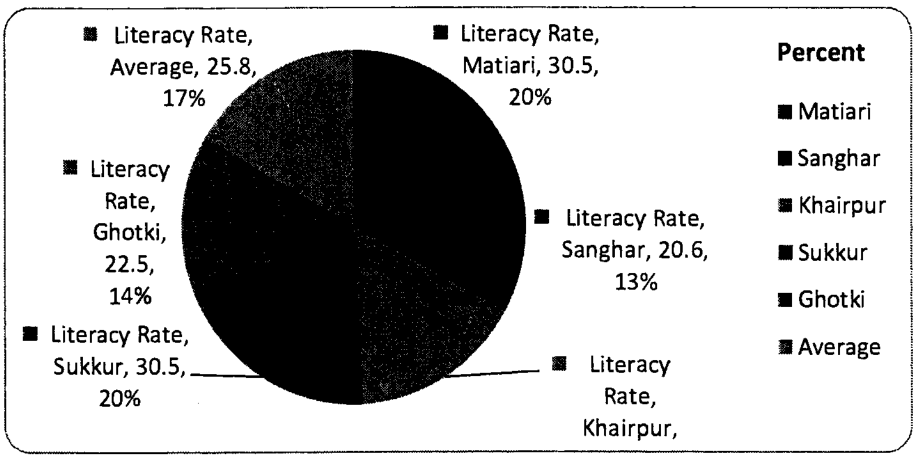
In the COI, the lowest literacy ratio is in Khairpur district which is 21.7 percent. Based on DCRs, district wise literacy rate are shown in Figure 5-22.

Figure 5–22: Literacy Rate as per DCR



As per socio-economic survey, highest literacy ratio was of Matiari and Sukkur district i.e. 30.5 percent as compared to other areas in the COI. Figure 5-23 shows the results of survey carried out in the COI.

Figure 5–23: Literacy Ratio as per Survey



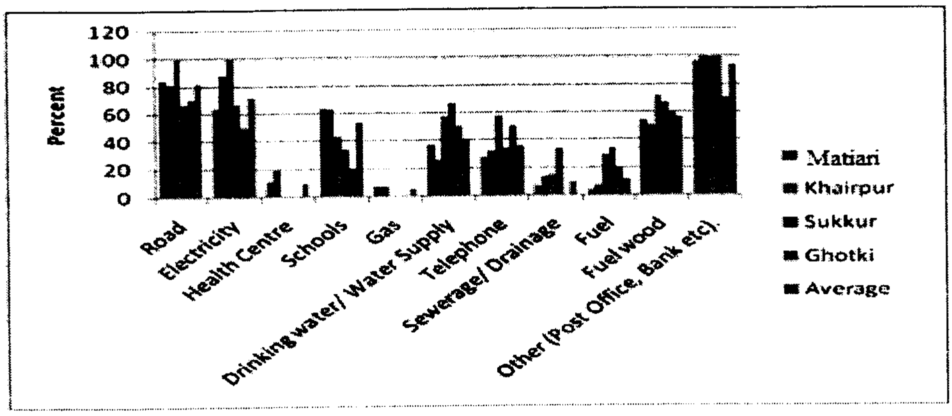
Based on the field survey, average literacy rate of the sample population is 14 percent, i.e. lower as compare to average literacy rate 28.6 percent based on DCRs. This variation is due to the fact that T/L mostly crosses the rural areas of Section-I.

Health Infrastructure

Health facilities are inadequate in the COI. The people in the COI have a tendency to get treatment from Indigenous Healers, due to the lack of suitable and sufficient health facilities. Bad sanitary conditions, insufficient medical facilities and meagre parental care, all contribute to the prevalence of ill health and high rate of mortality in the COI.

As per socio-economic survey, although health facilities area exist few villages of the COI but not so good. Buildings are available but without any health facility. In few villages of Matiari and Sanghar district BHUs are working to some extent. While in reaming district people have to cover long distance to gain health facility. This situation is much poor for women in delivery cases. Although majority respondent said that for delivery case they go to Lady doctor in nearby city but due to lack of proper facilities of transportation and road infrastructure it is not easy task. In the COI, private clinics exists which are run by dispensers and compounders. Based on field survey, health facilities available in the COI are described in Figure 5-24.

Figure 5–24: Availability of Infrastructure



Sanitation / Drainage Facilities and Solid Waste

Sanitation is poor in the area. There is no proper sewerage system available and only a few villages of the COI were observed to be connected with the proper sewerage system. In a majority of the cases, village's wastewater is disposed of into open spaces or nearby ponds. Ultimately, wastewater is drained into a pond/nullah, thus it becomes a source of pollution. Same is the case with solid waste there is no proper arrangement for disposed of solid waste.

5.4.3.4 Migration in Section-I

The process of migration especially internal migration in Pakistan is an old phenomena. It not only provides opportunities for employment but also improves the socio-economic conditions of migrant households. Lack of employment opportunities coupled with inadequate income from farming are considered the leading cause of migration.

Same is the case with the population residing in the COI. Locals in the COI are migrated to other cities of Pakistan or abroad due to the unavailability of economic resources. In Section-I, migration rate is high as compare to Section-II. There are four (04) main reasons of migration in the COI:

- Lack of job opportunities;
- Limited business opportunities;
- Economic Development; and
- Un-satisfaction from Agriculture production.

During the field visit, locals informed that they are forced to migrate due to lack of job and business opportunities. In the majority of cases, male members usually migrate. Some times whole families migrate to other areas. Although, if a person has moved to the city in practice, he retains his ties with his village and his rights there are acknowledged long after his departure. Typically, the migrant sends part of his earnings to the family he left behind and returns to the village to work at peak agricultural seasons. Even married migrants usually leave their families in the village when they first migrate. The decision to bring wife and children to the city is thus a milestone in the migration process.

Although this migration has had little effect, it has affected social fabric. While a man is away from his family, his wife often assumes responsibility for many day-to-day business transactions that are considered the responsibility of men.

5.4.3.5 Religious Archaeological and Historical Sites in Section-I

Religious Sites

Religious sites include mosques, shrines and graveyards. These are socially sensitive areas to deal with. The survey has exposed that the people of the Project Area are strongly attached to their religion and culture. Shrines and graveyards are regarded as sacred heritage and receive devoted attention from the people. As per social survey, it was observed that number of religious sites exists in the COI from Matiari to Ghotki. But all the sites are from the out side of the COI. Due to no impact is considered on these sites.

Archaeological Sites

No archaeological and any historical site was observed to exist within the COI, during the field visit.

Indigenous People

As per social survey no indigenous people are found in the COI.

5.4.4 Socio-economic Conditions of Section-II

5.4.4.1 Demography of Section-II

Socio-economic survey were carried out in the COI to establish the socio-economic baseline conditions, which will provide the basis for the estimation of potential impacts, monitoring and evaluation against which to appraise the mitigation measures.

i. Population and Distribution

As per 1998 census, the estimated population of the districts in Section-II where the T/L will pass is shown in Table 5-21. Data shows that maximum population is living in Rahim Yar Khan district which is 3,141,053 persons and the minimum population is in Nankana Saheb district i.e. 683,963. As per DCR and socio-economic survey, population details along average household size are shown in Table 5-21.

Table 5–21: District Wise Population and Average Household Size

Sr. No.	AM No.	Districts	As Per DCR		As Per Socio-economic Survey	
			Population	Average. Size of Household (No.)	Population	Average. Size of Household (No.)
1	49 to 62	Rahim Yar Khan	3,141,053	7.5	22,000	8
2	63 to 74	Bahawalpur	2,433,091	6.8	11,400	7.5
3	75 to 94	Bahawalnagar	2,061,447	6.7	42,000	6.5
4	95 to 124	Pakpattan	1,286,680	6.4	26,000	7
5	125 to 150	Okara	2,232,992	6.5	95,000	7.5
6	151 to 166	Kasur	2,375,875	7	91,000	6.5
7	167 to 169	Nankana Saheb	683,963	6.7	10,000	6
Total			**14,215,101**	**6.8**	**297,400**	**7**

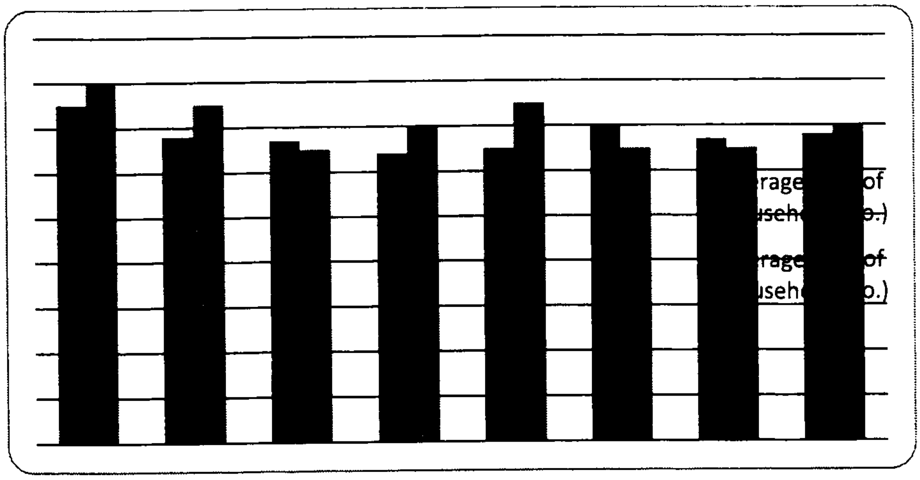
Above data shows that as per DCR total population of the districts along COI are 14,215,101persons. The average household was computed 6.8 members per household.

As per socio-economic survey, highest population in the COI is calculated as 95,000 persons of Okara district. Due to urban or semi urban area population density is high in Okara. The lowest population is 11,400 persons in Bahawalpur district due to the most of the part of TL pass through the rural in this district. Total population falling in the COI from Rahim Yar Khan to Nankana Saheb is 297,400.

Family/Household Size

As per DCR, the highest average household size is 7.5 for Rahim Yar Khan district and the lowest average household size for Pakpattan district which is 6.4. While based on socio-economic survey, highest average household size is 8 of Rahim Yar Khan district and lowest is 6 of Nankana Saheb district. Highest average household size is because Rahim Yar Khan is an important city of South Punjab. Rahim Yar Khan is a commercial and industrial center; it is connected to the rest of the country through Railway Transport and Air Traffic including the other industrial hubs such as Lahore, Karachi, Islamabad, Quetta and Faisalabad. Industries include fertilizer Such as Fauji Fertilizer Company, Fatima Fertilizer Company, cosmetics, glass manufacturing, cotton production and processing, large textile units, flour mills, sugar and oil mills and large-scale Power generation projects. There is also large number of educational institution as people of the other areas come for different purposes such as job or business opportunities and settled there. Based on social survey overall average household size is concluded 7 which is higher the DCRs 6.8. Comparison of household size is given in below Figure 5-25.

Figure 5–25: Comparison of Average Household Size



Most of the families in these districts where the T/L will pass are living in joint family system comprising grandparents, uncles, aunties and lot of cousins, whereas only small percentage of families are living as a single family (called nuclear family system). Nuclear family only exists near urban or semi urban areas. Although joint family system is undergoing a radical change with a greater influence of media and education but people of the COI do not feel good about this change. Because while living in a joint family system a lot of emotional attachments are enhanced and they feel that by separating in nuclear family system, their relations will damaged and family ties will be weakened.

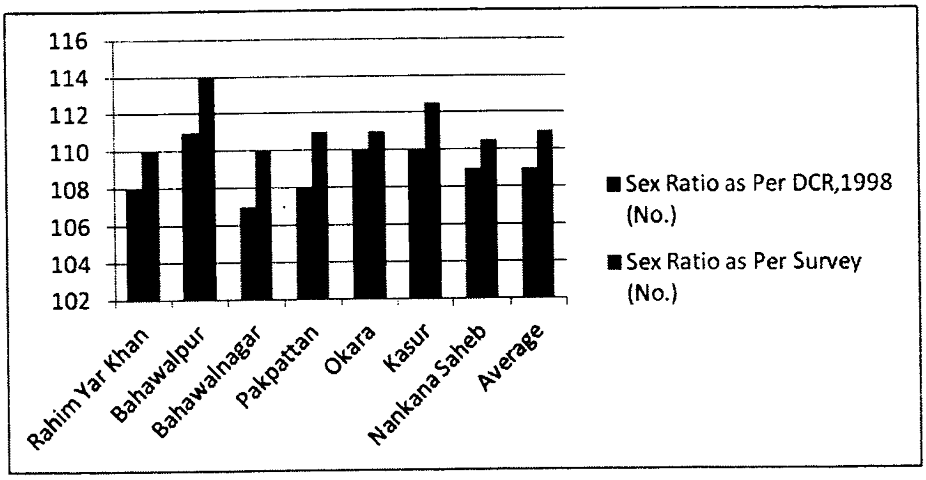
As per the locals, joint family system is basically a form of organization. In this organization there are defined norms and values to follow strictly by all the members. All the members have their defined tasks and responsibilities to perform. There is equal share of each and every member of the family in the available resources in the form of money, food and other requirements and locals feels better in joint family system as compare to nuclear family.

During the discussion with the locals, it was clarified that larger family size is also treated as the strength of the family.

Sex Ratio

As per DCR the sex ratio (males per 100 females) for these districts is shown in Figure 5-26. Maximum sex ratio is for Kasur and Okara districts which is 110 and the lowest sex ratio is 108 for Rahim Yar Khan and Pakpattan districts. While as per socio-economic survey, maximum sex ratio is calculated as 114 for Bahawalpur district which is higher as compare to 1998 DCR. Based on social survey, average sex ratio is high 111 percent as compare to DCRs 109 percent. District wise and socio-economic survey sex ratio details are given Figure 5-26.

Figure 5–26: Sex Ratio as per DCR and Socio-Economic Survey



Causes of Higher Sex Ratio in the COI

Above figure shows that sex ratio in the COI is higher as compared to female. Above figures for sex ratio are taken from census data and socio-economic survey carried out in the COI. The sex ratio depends on the factors such as the sex ratio at birth, differential mortality rates between the sexes at different ages and losses and gains through migration. As in other areas of Pakistan in the COI, sons are preferred because (i) they have a higher wage-earning capacity, (ii) they continue the family line; and (iii) they are generally recipients of inheritance. Girls are often considered an economic burden because of the dowry system, after marriage they typically become members of the husband's family, ceasing to have responsibility for their parents in illness and old age. The impact of son preference on the population sex ratio can be seen in above Figure 5-27.

ii. Ethnicity/ Caste Groups

Number of castes/tribes exists in the COI from Rahim Yar Khan to Nankana Saheb. Major castes in the colony area of Rahim Yar Khan are the Arain, Jat, Rajput and Gujjar. They have all come from the adjoining districts of East and West Punjab. The old settlers are The Joya, Wattoo, Daudpota, Baloch and Pathan. While in cholistan area of the district Dahar, Joya, Mehra and Kakar are inhabited. Summary of major casts in the COI are given below in Table 5-22:

Table 5–22: Major Caste Groups/ Tribes Settled in the COI

Sr. No.	AM No.	District	Castes
1	49 to 62	Rahim Yar Khan	Panwar, Paracha, Lodhi, Phularwan, Sukhera, Laleka, Mohal, Rajput, Arain, Jatts, Chishtis,Sial, Khakwanis, Cheema, Arain, Jat, Rajput and Gujjar
2	63 to 74	Bahawalpur	Syed, Qureshi, Baloch, Pathans, Rajput, Jat, Arain, Gujjar
3	75 to 94	Bahawalnagar	Mashadi, Kirmani, Bukhari, Abbasi,Qureshi, Rajpur,Jat
4	95 to 124	Pakpattan	Arain, Jat, Rajput, Watto, Hans, Bhattis, Chishties
5	125 to 150	Okara	Khrrals, Wattos, Arain, Gujjar, Sial, Rajput, Jat, Awan, Kumbo, Bhatti, Sheikh
6	151 to 166	Kasur	Kirmani, Bukhari, Abbasi, Watto, Hans, Bhattis Sial, Rajput, Jat, Awan,Kokar, Kumbo, Sheikh, Bhatti

Sr. No.	AM No.	District	Castes
7	167 to 169	Nankana Saheb	Watto, Hans, Bhattis, Arain, Jat, Rajput, Cheema, Arain, Jat, Rajput, Sheikh,

During the field survey, it was also observed that these major castes/ tribes were important because they have a key role in decision making regarding the resolution of social issues of family matters. For instance, Landlord (locally named as Sardar/Vadaira) as well as the head/ or elder of the respective tribe generally make decisions related to the social issues at village level as well as the social development works in their areas. It was assessed that prior to initiate any project/ program, it is essential to involve these effective groups/ tribes at all levels of the project starting from design, implementation and operation of the project for the success of the project.

iii. Languages Spoken

Saraiki and Punjabi as a mother tongue are spoken in the COI of Section-II, however, Balochi and Pashto are also spoken in the few areas.From Rahim Yar Khan to Bahawalnagar Saraiki is dominant language in the area while from Bahawalnagar to Nankana Saheb Punjabi and Urdu are spoken.

iv. Dwellings

Houses in the rural areas of Rahim Yar Khan to Bahawalpur can be classified into three (3) types; Katcha (made from wood and tree branches), Semi Katcha (made from unbaked bricks or few portion made from burnt bricks) and Cemented (made from burnt bricks or stones). Houses in the rural areas usually lack a kitchen and are even without a toilet facility. Houses made with wood and branches, are being replaced by semi-katcha to cement as their occupants gain economic prosperity. In rural areas, houses usually comprise one or two rooms, a veranda and animal penning area, which is fenced with tree branches. In the urban areas such as Rahim Yar Khan and Bahawalpur people live in cemented well designed houses.

As other areas of Punjab, housing structure from Bahawalnagar to Nankana Saheb usually are made of mud, wooden beams and bricks. There is one big room, which is used as living room and one or two smaller ones at the back used as store. People of the area generally live in villages rather than on the farms. There are usually a few wooden with a few chairs and occasionally sofa and tables in the houses of well to do Zamidars. In towns and cities, houses are built of bricks, cement and steel which is furnished with marble tiles and wood. As per DCRs, details of different types of housing structures are given below in Figure 5-27:

Figure 5-27: Different Types of Houses as per DCR

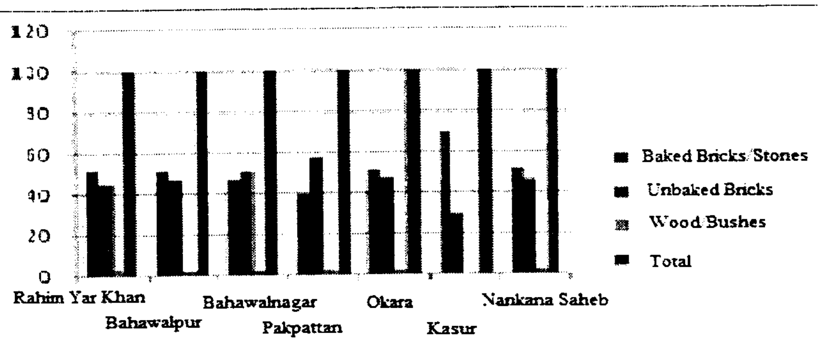
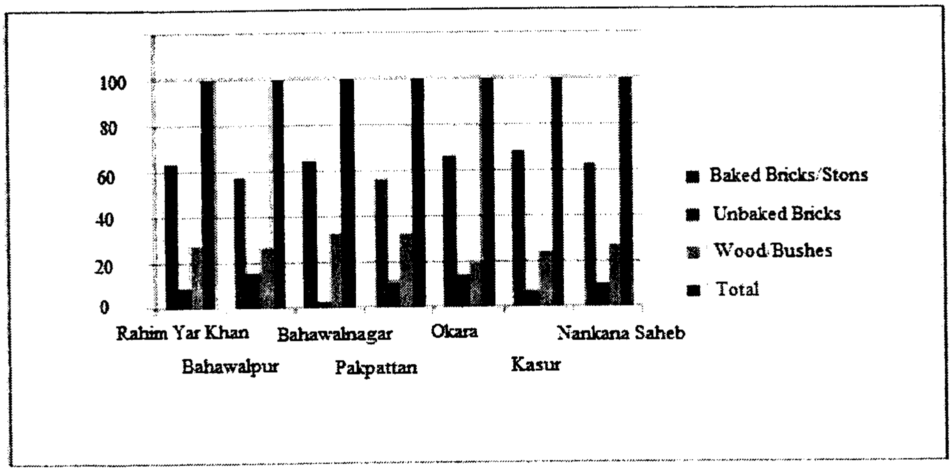


Figure 5-28 shows that in the COI large number of respondents 62.8 percent are living in Pacca houses which are made from bricks and blocks. While 27.2 percent are living in Semi Katcha houses made with mud and unbaked bricks. Theses category mostly exists in district Rahim Yar, Bahawalpur and Bahawalnagar. In last, only 10 percent respondent are living in Katcha house made with wood or bushes. This type exists in rural areas in the COI from Rahim Yar Khan to Bahawalpur. As per baseline survey, different types of houses are given below Figure 5-28:

Figure 5–28: Different Types of Houses as per Social Survey



Nature of Tenure

As per DCRs nature of tenure of the houses of the districts shows that the majority people 98 percent have their own houses and the only 2 percent people are living in rented houses.

It was observed during the field survey 100 percent respondents have their houses, there is no house on rent in the COI.

v. Decision Methods in the Villages

The methods of the decision for social conflicts in the COI are panchayat, court, jerga, caste groups and others (method constituted at the spot considering major and scope of the conflicts). According to the data collected during social survey in Section-II, panchayat is also most commonly accepted method of decision making in the COI.

The survey results presented in Table 5-23 reveals that in the COI informal and traditional methods were adopted by the villagers to resolve the social disputes amongst the caste groups, relatives and neighbours and other villagers.

In majority of the villages, 93.4 percent in the COI, social disputes are settled through the "Panchayat" system lead by village leader Vadaira and religious scholar. Details of decision method in the COI are given in below table 5-23:

Table 5–23: Decision Methods in the Villages

Sr. No.	AM No.	Location/ District	(% of Villages)			
			Panchayat	Court	Jerga	Within the Caste Group
1	49 to 62	Rahim Yar Khan	95	5	-	-
2	63 to 74	Bahawalpur	98.5	1.5	-	-
3	75 to 94	Bahawalnagar	97	3	-	-
4	95 to 124	Pakpattan	85	8	-	7

Sr. No.	AM No.	Location/ District	(% of Villages) Panchayat	Court	Jerga	Within the Caste Group
5	125 to 150	Okara	93	7	-	-
6	151 to 166	Kasur	92	6	-	2
7	167 to 169	Nankana Saheb	93	5	-	2
		Average	**93.4**	**5.1**	**-**	**1.6**

Table 5-21 indicates that in the COI, people prefer panchayat as compare to court or other legal system because this method is more effective. As per the locals, Panchayat provide timely justice while other methods are complex and require time as well as money.

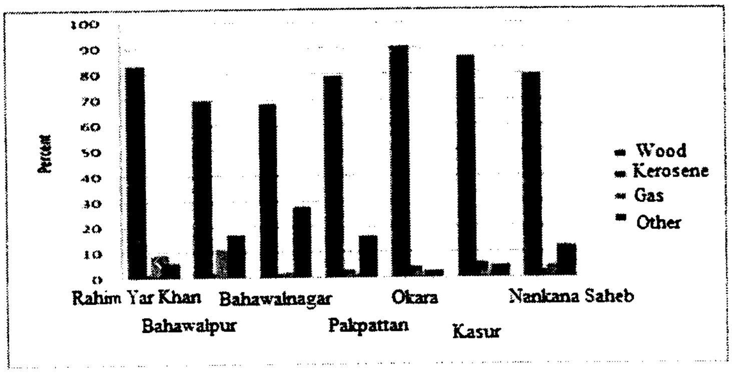
vi. Existence of Associations

The strong and effective village societies/associations and other community based organizations can play an important role in the designing, implementation and operation of community/ social and development projects. Based on the village profile, only few villages NGOs are working in the field of microcredit.

vii. Cooking Method

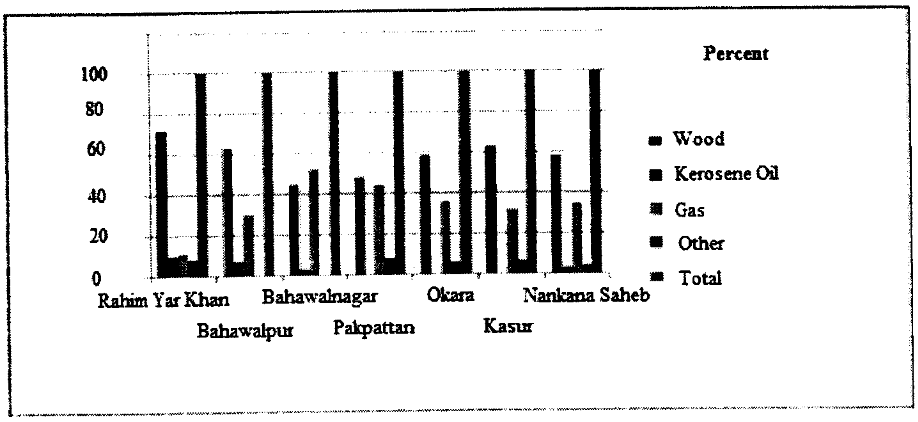
As per DCR, different sources are being used for cooking purpose in the COI. Data reveals that majority of people 79.6 percent population are using wood for cooking purpose in these districts while Gas is second highest source for cooking. As per DCR, different sources of cooking are shown in Figure 5-29.

Figure 5–29: Source of Cooking in the COI



Baseline survey also verifies the DCRs data. As per survey it was observed that majority 58.1 percent of the locals in the COI use wood for cooking while 34.2 percent used other sources such as bushes or Dunk as a major source of cooking (refer Figure 5-30). Due to high price only 3.2 percent people use Kerosene. Details of the sources of cooking in the COI are given below Figure 5-30.

Figure 5–30: Main Source of Cooking in the COI as per Social Survey



viii. Role of Women

The women and girls of the study area were observed busy in doing laundry, looking after the children, preparing food etc. There is a lack of employment opportunities for women. However, in city areas such as in Rahim Yar Khan, Bahawalpur, Pakpattan, Okara and Kasur, few women doing jobs in different professions like teaching, medical and Govt. and Private Sector were reported.

Women of the study area were asked about their skills. Majority of the respondents reported to have the skill of stitching and embroidery, which they have learnt from their elder ladies but their male members do not allow using their skill for commercial purpose.

It was assessed that socio-economic conditions of the women were not so good in the study area. All women showed their favour and appreciation for the proposed project.

Women were also asked about their marriages that either before marriage their permission is taken or not. Women of the study area reported that decisions regarding their marriages are made by their male heads and we have no objection regarding their decisions, as they are our parents, they know what is better for us, however, endogamy (marriage within family) is preferred.

5.4.4.2 Main Socio-economic Activities in Section-II

i. Structure of Occupation and Employment

Based on the field survey, major occupations in the COI are agriculture / farming, unskilled labour, service, business, shops and livestock rearing. As per data collected for the baseline, it was noticed that agriculture/farming and unskilled labour is the main source of the income for the locals. As discussed above, major part of the T/L passes through rural areas and majority people are involved in agriculture activities. Details of occupation in the COI are given below in Figure 5-31.

Figure 5–31: Main Occupation in the COI

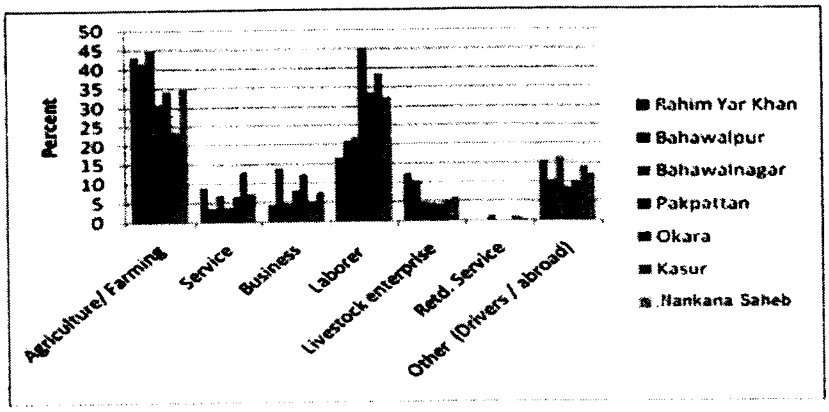


Figure 5-31 reveals that on overall basis, in the COI, 34.5 percent respondent are involved in agriculture, 32.1 percent are related to daily wage labour, while 7.4 percent are employed in Govt. and private sectors, remaining are doing business or activities in others sectors.

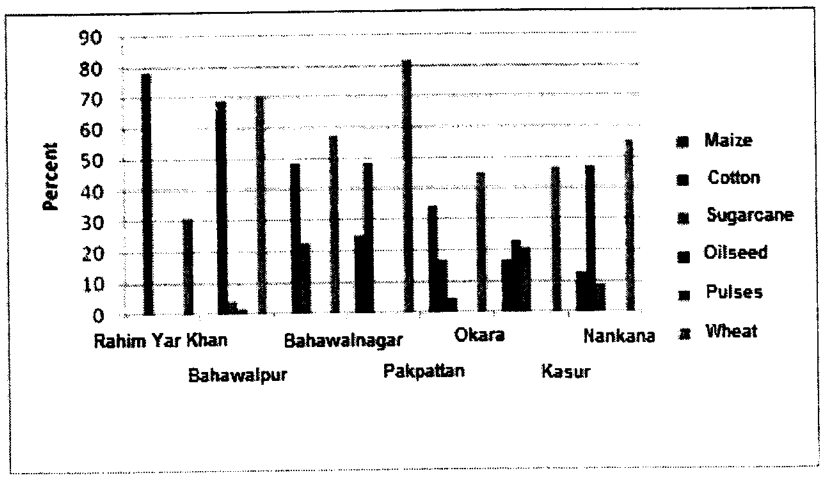
Another important thing is that majority of the locals are involved in multiple occupations as all are farmers but also are labourer and do other businesses.

ii. Agriculture

Landuse Pattern

The optimum cropping pattern refers to the allocation of the cropped area under different crops during the year in order to attain maximum output within the existing resources. In general, there are four (04) main crops (i.e. wheat, cotton, Maize, sugarcane,) being grown in the COI from Rahim Yar Khan to Kasur (Refer Crop Calendar as Annex-VIII). In addition vegetables, some fodder, sunflower, rose and orchards (Mango, Plump, Guava) were also found under the cropping pattern in the COI (Refer Fruit Calendar As Annex-IX) .Details regarding the cropping pattern in the COI are presented in below Figure 5-32.

Figure 5–32: Distribution of Cropping Pattern



Cropping Intensity

The cropping intensity[15] refers to the proportion of cultivated area being cropped during the year. In the survey, it was observed that average cropping intensity is estimated as 124.2 in

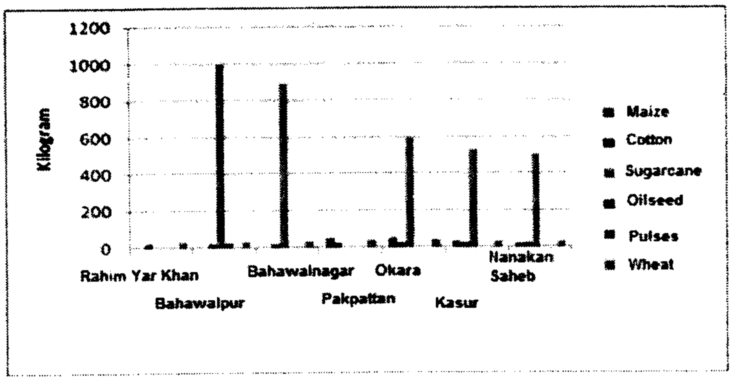
[15] Cropping intensity is computed by dividing the cropped area by cultivated area and multiplying by 100 and expressed in terms of percentage. This reveals the extent of cultivated area being cropped during the year.

the COI.

Crop Yield

Crop yield is one of the key performance indicators to assess the productivity of land. As discussed above, wheat, sugarcane, cotton and maize are being grown. Based on the results of the field survey, it was noted that overall basis, the average yield of sugarcane per acre is 1503.5 kg, wheat 36 kg, maize 63.3 kg and cotton34.2 kg. District wise details are shown in Figure 5-33.

Figure 5–33: Distribution of Average Yield of Major Crops in the COI



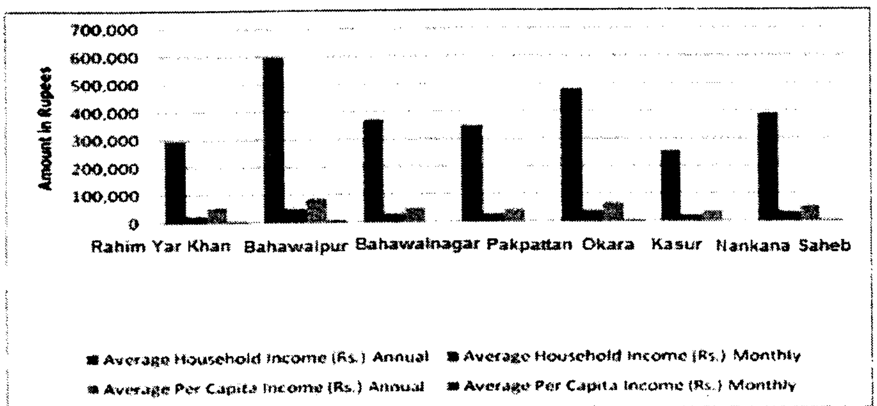
iii. Household Livelihood

Average Annual Income

Average household annual income is an indicator for assessing the livelihood/ well-being of a household. During the field surveys, it was observed that in case of farm households, the major sources of income included the income from crops and livestock (Dairy products). For non-farm or landless households, the main sources of income are the income from off-farm activities, such as business, Govt. or private employment, labour etc.

The survey results depicted in Figure 5-34 reveal that on overall basis, the average annual household income is computed to be Rs. 391,650/- while the per month amount is Rs. 32,638/-. The average annual and monthly, per capita income is estimated as Rs. 56,916/- and Rs.4,743/- respectively. Details of COI are given below Figure 5-34.

Figure 5–34: Distribution of Average Income of Sample Households

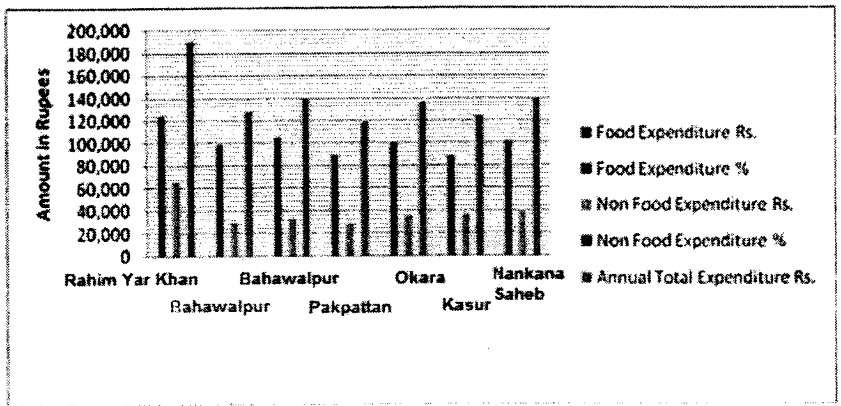


iv. Household Expenditure

The annual expenditure and pattern of the expenditure provides an indication for assessing the standard of living of a household. The expenditure on food items includes cereals, pulses, flour, sugar, cooking oil/ ghee, milk etc., while the non-food items consist expenditure on education, medical treatment, clothes, shoes, cosmetics etc. In this respect, survey results are presented in Figure 5-35.

The survey indicates that on overall basis, the average annual household expenditure on both food and non-food items is computed to be Rs. 139,010/-. In case of food and non-food items, such proportion is to the extent of Rs.101,081/- (73.3%) and Rs.37,929/- (26.8%) respectively (refer Figure 5-35).

Figure 5–35: Distribution of Monthly Expenditure



Extent of Credit Utilization

Generally, the credit is obtained to supplement the income to meet the routine and some extra expenditure of the household including investment, social needs and other unforeseen situations. Credit is obtained from both the formal (banks) and informal sources (friends, relatives, land owner etc.)

As per the socio-economic survey 4 percent took loan during the last year for household matters such as disease or marriage etc.

5.4.4.3 Social Amenities and Infrastructure in Section-II

The availability of the basic infrastructure and social amenities measures the development of the area and living standard of the people. During the social survey, data regarding the availability of village infrastructure including electricity, road, basic health unit/center, school, drinking water/water supply scheme, telephone, sewerage/drainage, fuel wood and sui gas were collected in order to identify the pressing infrastructural development needs of the villages located along the COI (Refer Annex-IV).

The survey results derived based on the 'village profile' summarized in Figure 5-38 shows that out of 66 villages, 85 to 90 percent of the villages in the COI had access to roads, electricity, fuel wood and schools especially for boys, while the other facilities like health, sui-gas, drinking water and telephones were found at 56 percent villages. Drinking water/ water supply schemes were also not available in most of the villages. The major sources of drinking water are hand pumps, streams, nullahs, pumps and tubewell etc. in the COI. In some areas of Rahim Yar Khan, Bahawalpur and Bahawalnagar districts, women have to fetch water from dug well or water ponds far away from their houses. Details of the availability of infrastructure in different villages are given in below Figure 5-38.

Education Facilities

During the field visit, it was observed that in the COI educational buildings are available. Educational institutions were found but in poor condition. Due to the non-availability of students as well as teachers, most of the school buildings have collapsed or in a poor condition.

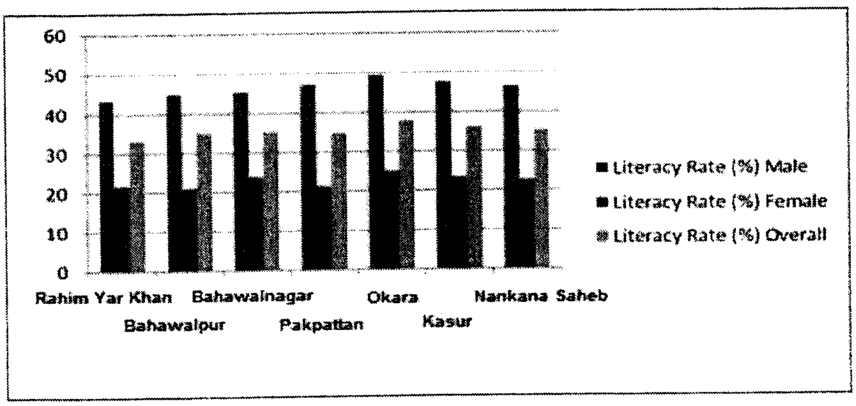
People of the COI get basic education at local level after that go to nearby city for higher education. All types of educational facilities are available in the district level. All the districts in the COI from Rahim Yar Khan to Nankana Saheb have number of education intuitions. Education facilities are better in Rahim Yar Khan, Bahawalpur and Pakpattan as compared to other districts, however, people of the COI give preference to Lahore for better education. Lahore is a first class place of learning in Pakistan. The world famous and the oldest university of Pakistan i.e. University of the Punjab located in this city. Besides these other famous institutions are Govt. College University, Lahore College for Women University, University of Engineering and Technology etc.

In the COI, most of the schools for girls and boys are primary and to middle level. While in most of the area for higher secondary education, children have to go Tehsil headquarter, which are not easy to travel for the vast majority of students especially girls.

v. Literacy Rate

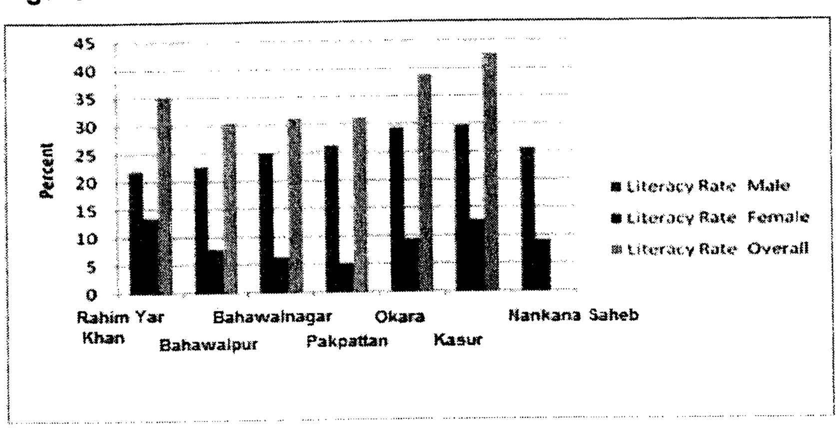
As per DCRs, the literacy rate of Okara district is highest i.e. 37.8 among all districts. There are two main reasons of higher literacy rate in Okara, first one is that in Okara number of educational institutions exists for both male and female and second reason is that Okara is just about 150 Km from Lahore. Due to the availability better education facilities in Lahore, locals residing in the COI of Okara districts prefer Lahore for education being nearest. In the COI the lowest literacy rate is Rahim Yar Khan district which is 33.1 percent. Based on DCRs district wise literacy ratio is shown in Figure 5-36.

Figure 5–36: Distribution of Literacy Ratio as per DCR



As per socio-economic survey of the COI, literacy rate of the Kasur district is the highest i.e. 42.4 percent as compared to other districts in the COI (refer Figure 5-37). Lowest literacy rate is Bahawalpur district i.e. 30.4 percent in which 22.6 percent in male and 7.8 percent in female. Below figure shows the results of survey carried out in the COI.

Figure 5–37: Distribution of Literacy Ratio as per Social Survey



Based on the field survey, average literacy rate of the sample population is 34.8 percent. It is important to disuses here that female literacy ratio among all districts of the COI is lower as compare to men. There are many cause of low literacy rate among women in which few is discussed below:

Causes of Low Literacy Rate among Women

Data shows that female literacy rate in all districts are lower as compare to male. There are many reasons of lower literacy rate among women such as first cause of women illiteracy is the increase in population, which is playing a negative role in this deprivation of female education. A family having more number of children and less income will prefer to educate the boys of the family, while the girls will be given embroidery or sewing skills. Secondly, there is also a misconception that females merely have to manage a home after being married where as males have to earn so education matters only for males but not for females. Thirdly, it have been observed that traditionally, women are considered as the asset of males of the family. So these males are responsible for taking decisions of their lives. In most cases, males do not allow their sisters or daughters to go to schools or universities. Additionally, some families do not like their daughters to study in co-education institutes thus depriving them of higher education. Fourthly, the social setup is a male dominated one. Girls cannot move freely thus any male of the family has to take responsibility of her care. This sometimes seems difficult to them. There is also a sharp division between female oriented work and male oriented work. Females are not allowed to work in all spheres of life therefore their education is not considered valuable. Fifthly, the number of schools and colleges for females are very less. Girls have to travel a long distance to reach the schools or colleges. For this reason most of the parents prefer to give them religious education. Lastly, every government talks about the importance of female education but none of them has given attention to it.

Health

Health facilities are inadequate in the COI. The people in the COI have a tendency to get treatment from Indigenous Healers, due to the lack of suitable and sufficient health facilities. Bad sanitary conditions, insufficient medical facilities and meagre parental care, all contribute to the prevalence of ill health and high rate of mortality in the COI.

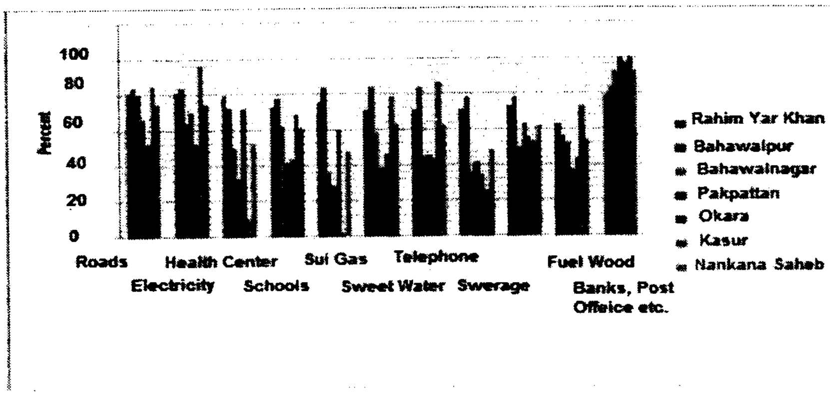
Being district headquarters, Bahawalpur, Bahawalnagar, Pakpattan, Kasur and Nankana Saheb are also well equipped with a network of hospitals and dispensaries established by the government and private sectors.

The Government of Punjab has maintained a number of hospitals and medical centers within the district in order to provide medical facilities to all. The government hospitals are reasonable in price and offer the best medical facilities. People of the districts of Bahawalnagar, Pakpattan, Okara, Kasur and Nankana Saheb give preference to Lahore for better medical facilities. Hospitals in Lahore are well equipped with all modern medical equipments and technology. Government hospitals of Lahore have been serving the province several decades. The provincial government is the administrative authority of these hospitals and takes care of the maintenance of medical aid within these hospitals. Some of the major hospitals of the city of Lahore are Lahore General Hospital, Jinnah Hospital, Fatima Memorial Hospital, Gulaab Devi Hospital, Lady Wallington Hospital and Mayo Hospital.

There are a number of private hospitals in Lahore. People from other district come to Lahore to get better medical facilities.

As per socio-economic survey, there is not a single Govt. health facility available in the COI from Rahim Yar Khan to Kasur. Based on field survey, health facilities available in the COI are described in Figure 5-38.

Figure 5–38: Availability of Infrastructure in the villages of the COI



Sanitation / Drainage Facilities and Solid Waste

There is no proper sewerage and sanitation system available in the COI and only a few villages of the COI were observed to be connected with the proper sewerage system. In a majority of the cases, village's wastewater is disposed of into open spaces or nearby ponds. Ultimately, wastewater is drained into a pond/nullah, thus it becomes a source of pollution. Same is the case with solid waste there is no proper arrangement for disposed of solid waste.

5.4.4.4 Religious, Archaeological and Historical Sites in Section-II

Religious Sites

Religious sites include mosques, shrines and graveyards. These are socially sensitive areas to deal with. The survey has exposed that the people of the COI are strongly attached to their religion and culture. Shrines and graveyards are regarded as sacred heritage and receive devoted attention from the people. No religious site is exist in the COI from Rahim Yar Khan to Nankana Saheb.

Archaeological Sites

No archaeological and any historical site was observed to exist within the COI, during the field visit.

Indigenous People

No indigenous people were identified during the field survey in the COI.

6 STAKEHOLDER CONSULTATIONS

6.1 General

Stakeholders, especially the local population, involvement is an important feature of the environmental assessment and can lead to a better and more acceptable decision-making regarding the Project design and implementation. Public involvement, undertaken in a positive manner and supported by a real desire to use the information gained to improve the Project design, will lead to better outcomes and lay the basis for on-going positive relationships between the stakeholders. Public involvement is necessary for smooth implementation of the Project. The local community support is also required for the success of the Project.

Given the dimension and nature of the Project, T/L Project management are committed for undertaking public consultation at local level as a part of Project planning/design, getting necessary environmental permissions/NOCs, land acquisition, compensation for land and other assets and management of infrastructures.

Under the proposed Project of T/L, public consultation was carried out for all accessible villages of COI. These consultations were conducted during the baseline survey carried out during the month of May, June 2015. The major categories participated in public consultation were local population, community groups, landowners, businessmen, tenants, women, vulnerable groups and potential Project affected persons (PAPs) belonging to the COI. The feedbacks and issues raised during the consultation were recorded and documented for developing the strategy.

6.2 Objective

As per Pak-EPA Guidelines for public consultations, consultations for EIA were carried out keeping in view the following major objectives:

- Sharing of information with government authorities and local communities on the proposed Project activities and expected impacts on the physical, ecological and socio-economic conditions of the COI;
- Understanding the stakeholders concerns regarding various aspects of the Project, including the existing situation, route alignment, land acquisition, compensation and the potential impacts of the construction-related activities and operation of the Project; and
- Recording the feedback of public, in order to develop a mechanism to address their issues and other local level concerns and incorporation of the outcomes in final decision making.

6.3 Identification of Stakeholders

Stakeholders were identified before the starting consultation. The major stakeholders related to the proposed Project are as under:

- NTDC;
- Agriculture Department Punjab;
- Agriculture Department Sindh;
- Forest, Wildlife and Fisheries Departments Punjab;
- Forest, Wildlife and Fisheries Departments Sindh;
- District and Local Governments of Punjab and Sindh;
- NGOs;
- Farmers;
- PAPs (men);

- PAPs (Women);
- General user of the Project Area (Like Nomad People, Drivers, Labourers etc.);
- SEPA;
- EPA Punjab; and
- Pak-EPA.

Details regarding roles and responsibilities of the concerned agencies and departments are given below Table 6-1.

Table 6–1: Role of Concerned Agencies/Departments

Project Stakeholder	Name	Roles
National Authorities	Pak-EPA	• Pak EPA is an attached department of the Ministry of National Disaster Management and responsible to implement the PEPA Act, 1997 in the country. • An Act to provide for the protection, conservation, rehabilitation and improvement of environment, for the prevention and control of pollution, and promotion of sustainable development. • Pak EPA also provides all kind of technical assistance to the Ministry of National Disaster Management. • Recently due to the 18th amendment Pak EPA has delegated all his Powers to the provincial EPAs. Now the Provincial EPAs are the responsible to the implementation of PEPA Act, 1997 and all its provisions.
	NTDC	• NTDC is the Project Proponent of the proposed Project. • NTDC operates and maintains nine 500 KV Grid Stations, 4,160 km of 500 KV T/Ls and 4,000 km of 220 KV T/Ls in Pakistan. NTDC also perform the following task in the country ; o Central Power Purchasing Agency; o System Operator; o Transmission Network Operator; and o Contract Registrar and Power Exchange Administrator.
Punjab and Sindh Authorities		
	SEPA and EPA, Punjab	• Sindh (SEPA) and EPA, Punjab are the regulator authorities and mainly responsible to develop and implement national environmental policies and strategies in order to integrate the environmental issues and sustainable development approaches into the legal and regulatory frameworks. • SEPA and EPA are responsible for the issuance of NOC of the Proposed Project. • SEPA and EPA, Punjab are also responsible for the compliance of EMMP and NOC provision during the construction and operation stages of the Project.
	Agriculture Department	• Ensuring food security • Enhancing productivity through better varieties and improved management practices • Promoting high value crops, fruits and vegetables

Project Stakeholder	Name	Roles
		• Promoting export of high value agricultural products • Promoting efficient use of water and other inputs • Improving soil health • Development of culturable waste lands • Ensuring fair returns for the growers in marketing of their produce
	Forest Department	• Protection, improvement and maintenance of existing forests • Increase forests by planting new trees • Extension and advisory services to the general public about tree plantation
	Wildlife Department	To save and protect wildlife
	Fisheries Department	• Conservation of fisheries reservoirs • Management and development of resources on scientific lines • Extension services to private sector

Under the proposed Project, public consultation was carried out in the villages of district Matiari (Sindh) to Nankana Saheb (Punjab). Total 67 consultative meetings were held with 320 participants and the major categories participated in these meeting were local population, community groups, landowners, businessmen, tenants, vulnerable groups and potential project affected persons. Majority of the people who participated in these consultations are mature/elderly persons because as per the local culture, elders have the right regarding any decision. Although, young people were also present during consultations, but their participation was little. Details of public consultations carried out with the PAPs/local community and other stakeholders are attached as Annex-X.

6.4 Public Consultation

A series of public consultations was required to get the feedback/ concerns of the different category of stakeholders including potentially affected persons, local community and other general public located in the COI and concerned officials. Thus, total 67 consultations/ group discussions were made with the PAPs/local community & general public. District-wise summary of consultations/ consultative meetings is presented in Table 6-2.

Table 6–2: List of Consultations with the Stakeholders

Sr. No.	Date	Venue	No. of Participants
1	June 08, 2015	Siakhart/Matiari	5
2	June 08, 2015	Wali Muhammad Jatt, Allah Baksh Khasal, Rasheed Khyber/Siakhart/Matiari	12
3	June 09, 2015	Goth Shah Nawaz, Haji Khuda Baksh Khoso/Mitha Khora/Matiari	13
4	June 10, 2015	Matho Dehro/Pur Fogar Shoro/Tandoadam/ Sanghar	10
5	June 10, 2015	Haji Khan. M. Der, Haji Zagir Dero/ Kund Dero/Tandoadam/ Sanghar	9

Sr. No.	Date	Venue	No. of Participants
6	June 11, 2015	Pir Baksh Brohi, Chono Bhamboro, Wali Bagrani/ Asgharabad/Sanghar	11
7	June 11, 2015	Haji Phetto Dhehyo, 25-B Jhamro, Dr. Manzoor, Jhamroi, Habib Mahar/ Khadro/Singhoro/ Sanghar	16
8	June 12, 2015	Faqer Pur Bakash Goth, Peer Bux Ghaho Deeh (Peer) Bux, Allahabayo Rajper, Karim Bux Aaradio/ Khenwari/Naro/Khairpur	14
9	June 13, 2015	M. Ali khan Bhambhro/ Sakandarabad/ Saleh Pet/Khairpur	11
10	June 14, 2015	Thikratto/Mubarakpur/Pano Aqal/Sukkur	7
11	June 15, 2015	Goth M. Murad, Mareagro/ Barota/Dharki/Ghotki	7
8	June 17, 2015	Chak No. 262/ P/Tehsil Sadiq Abad/ District Rahim Yar Khan	6
9	June 18, 2015	Chak No. 237, Chak No. 229/ Tehsil Sadiq Abad/ District Rahim Yar Khan	21
10	June 18, 2015	Chak 94,95 P, Tehsil Sadiq Abad/ District Rahim Yar Khan	13
11	June 26, 2015	Kahnewala Pul/ Drawar/ Yazman/ Bahawalpur	16
12	June 26, 2015	14 DRB/Yazman/ Bahawalpur	15
13	June 26, 2015	Chak No. 79/Chanan Pir/Yazman/ Bahawalpur	7
14	June 27, 2015	Chak 68,73, 74 /Yazman/ Bahawalpur	11
15	June 27, 2015	Chak 73-F, 85-Fateh,86, 87/Hasilpur/Bahawalpur	12
16	June 28, 2015	9-Chank, Mangowala, Khuda Bux, Soda Bux, Mahar Sharif, Chak Chupa, Chak Sarkari/Chistian/Bahawalnagar	15
29	June 28, 2015	Chak Shah Wala/ Bahawalnagar/ District Bahawalnagar	8
30	June 29, 2015	Chak Khaimgarh/Tehsil Chistian/District Bahawalnagar	6
31	June 29, 2015	Ali Shair/ Tehsil Bahawalnagar/ District Bahawalnagar	7
32	June 29, 2015	Basti Zakheera/ Chak Momin Abad/Tehsil Bahawalnagar/District Bahawalnagar	5

Sr. No.	Date	Venue	No. of Participants
33	June 29, 2015	Sharif Kot/ Tehsil Bahawalnagar/ District Bahawalnagar	1
34	June 29, 2015	Mari Mian Sahib/Tehsil Bahawalpurnagar/ District Bahawalnagar	4
35	June 29, 2015	Kot Lamphar/Tehsil Bahawalnagar/ District Bahawalnagar	2
36	June 29, 2015	Kond Qadir, Tehsil Arif Wala, District Pakpattan	3
37	June 30, 2015	Ali Shah, Tehsil Arif Wala, District Pakpattan	4
38	June 30, 2015	Mari Habit, Tehsil Arif Wala, District Pakpattan	4
39	June 30, 2015	Chak Hota, Tehsil Pakpattan, District Pakpattan	8
40	June 30, 2015	Basti Bittian Chakgan, Col Shah, Heman Maruka, Chak Joya, Mouza Kala Pathan (Goan Kot Ahmed Hussain)/Arifwala/Pakpattan	15
41	June 30, 2015	Moaza Jhan, Taie Chak Jawandar, Kot Radha Kishan, Chak Khamma Dogar/Pakpattan/Pakpattan	10
42	June 30, 2015	33 SP, Natho wala Kho-32 SP, Moza Bonga Sharif, Chak 55P, Nosher Kot, 60-D Khokharwala/Pakpattan/Pakpattan	14
43	June 30, 2015	40-D, 42-D, 43-D, Narranwala/Depalpur/Okara	11
44	July 01, 2015	7/1L, 2/1-L, 15-1-L/Renala khurd/Okara	12
45	July 01, 2015	Bopawala Chak 23, Jasherb Chack 24, Chak Khodian-41/ Pattoki/ Kasur	8
46	July 01, 2015	Chitti/Nankana Saheb	4

6.4.1 Concerns/Feedback (Section I & II)

Feedback received during public consultation includes both Project related concerns and other/general concerns.

Project related concerns and suggestions are related to the willingness of people to accept project, livelihood, electricity and compensation/relocation/resettlement while concerns include drinking water supply and sewerage, health facilities, road infrastructures, education, women issues, agriculture and security.

Consultation with Affectees of Converter Station in Matiari

- Affectees told that proposed land for converter station is a very fertile land for agriculture activities, therefore they are not willing to lose this land;

- Land owners suggested that local govenment should consider nearby land which not fertile;
- If this land has been finalized for proposed converter station than compensation should be as per existing market prices;
- The land being considered is located on the N-5 and have sweet ground water, hence the prices are very high;
- Initially 300 acre land was selected for converter station and now it has been reduced to about 210 acre;
- Affectees requested that proposed converter station land have orchards of banana, mangoes and dates that provide good income and this is the major source of income;
- Affectees demanded good compensation of fruit and ornamental trees;
- As per the locals they earn more than 3 lacs/acre per year from falsa and banana trees;
- Due to the acquisition of land their livelihood will be lost forever;
- Afectees demanded good compensation should be provided so that we can purchase alternative land easily;
- The major source of irrigation water is Matiari Minor that originates from Rohri Canal and water is almost available for 12 months;
- Tube-wells are also installed to supply water to the orchads during the shortage of the canal water;
-
- Owners also sell soil form the barren lands in the site proposed for the converter stations;
- Approximately 350 acres alternative land for converter station is also available near (Chandan Mori, Matiari) about 3 to 4 Km away from this site, that is less costly and the owners are willing to sell on account of receiving the handsome compensation that is of course will be less as compare to the actual land to be acquired;
- Some locals demanded that alternate land in nearby areas instead of market price will be acceptable to them. Some showed concerns that cash compensation should be given to the PAPs directly and political interference should be avoided;
- Affectees pleased that the agricultural land is their sole source of income and we do not possess any technical and vocational skills. Therefore by selling this land, we will become idle and will not be able to fulfil the basic needs of our family. People are very worried and most of the people are on bed due to depression;
- Affectees demanded that subsides electricity should be provided to the affected people of converter station;
- A few people said that their skilled children should be given employment opportunities during the construction stage of the proposed plan;
- Affectee told that market price of this land is about 40 to 50 lac per acre; and
- Affectee said that compensation should be paid of all effected structures, trees and tube-wells.

Consultations in the COI

- Compensation for loss of crops due to the project activities should be provided;
- Crops compensation should be provided in case of affected crops ;
- Compensation of trees should also be given;
- Project should provide the cheap electricity to the local people especially affected persons;

- There should be transparent and fair compensation;
- All actions associated with the project should be through proper consultations;
- There should be a continuous community consultation program throughout the project implementation period;
- There should be employment opportunities for skilled and unskilled local people, preference should be given to the project affected persons;
- Vocation training / educations needs to be provided to local women, so that they could be able to support their families by supplementing their household income;
- Generally, the basic infrastructure like roads, electricity, schools, gas supply, dispensary and sewerage / draining is limited along the project route alignment. The project may consider some appropriate measures for the infrastructure development;
- WAPDA may allow the affectees to install their private tubewells on electricity with subsidized flat rates;
- With ensured provision of electricity to private tubewells will help to enhance the crop production in the area;
- Electricity and irrigation water and electric tubewells are needed for the increased productions of crops;
- Generally, people along the route alignment have no major concerns associated with this project. However, they desired for the compensation on the loss of assets based on the current market rates as well as replacement cost;
- The proposed T/L project is good project for people and the country as price of electricity will be reduced;
- To participate local people wherever possible in jobs during the construction of project. Thus, income generating activity of the area will be enhanced;
- There should be compensation of affected land, crops and tress for the land owners and leaseholders;
- Compensation should be given to affectees for land and crops;
- Chances of some environmental effects like noise / vibration and dust emissions to the nearby community;
- There may be some magnetic effects arise during the operation phase of the project.
- A large number of women are involved in working in agriculture fields, so that their routine activities should not be disturbed;
- According to stakeholders including APs, project alignment should have sufficient distance from villages and public infrastructure;
- The installation of Tower should be at the edge of the field rather than in the centre of field, so that the disturbance to farming activities could be minimized;
- No major effect on land or crop will occur if the project is implemented after crop harvest;
- Overall the project is good for the villagers and the country;
- No serious concerns with the project because this project will increase the employment and will reduce the load shedding issue of the country;
- If possible, to provide sewing machines to local women as an income generation activity.
- Compensation should be provided to land owners for affected crops;
- Need schools for boys and girls in the villages those have no education facility; and
- Requested for Benazir income support program to supplement their household income / livelihood.

A. Project Related Concerns/Feedback

i. People's willingness

The whole country is suffering from energy crisis. Continuous Power shutdown is badly affecting daily life of the people. People in the COI are quite happy with this Project. Most of the people along Section-I promised their cooperation and support for the proposed Project. According to respondent, such projects are important for the prosperity of people and country. People even demanded that this Project should be implemented as soon as possible. For the consulted communities this Project is more attractive than adverse impacts. Few respondents are even willing to bear minor losses due to this Project.

Very few people have negative views about government Projects, as according to them land value would be reduced due to the construction of T/L in the Project Area. Development Project in Area would be ceased due to the construction of Towers.

ii. Livelihood

In the COI, farming, labour and small businesses are the main sources of livelihood. Majority of the respondents are poor and they told that there are very few employment opportunities. Therefore, economic conditions are not so good. Pakistan is an agricultural country and about 90 percent population in rural areas are using tube-well for irrigation purposes as canal water is not enough. People of the Matiari, Sanghar, Khairpur, Sukkur in Sindh and Rahim Yar Khan, Bahawalpur and Bahawalnagar in Punjab told during consultation that due to shortage of canal water in the area, they are forced to use lift irrigation which is based on electricity. Load shedding has badly affected agriculture activities in these areas. Locals told that thousand of labourers are becoming jobless as small cottage industries are shutting down due to load shedding and locals have to close down their private businesses. Electricity shortage has severely affected the livelihoods of thousands of families along the COI. As per respondents in the COI, proposed Project implementation will have positive impact on livelihood as it will trigger income generating activities and crop production will also increase as it depends upon the availability of water. People in the COI said that employment opportunities during implementation phase of the Project should be given to them and government should provide jobs opportunities to poor people residing in the Project Area, on priority.

iii. Compensation/Relocation/Resettlement

In case, crops and trees are damaged due to T/L Project, proper compensation should be paid. If any community or private structures are affected, it should be relocated and compensated properly. Locals demanded that the T/L should be kept away from residential areas so that resettlement issues are avoided.

iv. Electricity

Electricity is not available in most of the villages of Khairpur, Sukkur and Ghotki. It was suggested that electricity should be provided to all the villages in the route alignment of T/L. According to locals, provision of electricity will reduce many constraints of daily life. It will initiate development in the area and increase the living standard of locals.

B. Other Concerns/Feedback

Basic amenities of life are not available in most of the villages in COI from Matiari to Lahore section. Medical facilities, proper education system, road infrastructure and electricity are not present in many areas along Project corridor.

i. Water Supply/Drinking Water/Irrigation Water

Locals of the southern Punjab informed that water scarcity is a big issue in most of the settlements, accessible ground's water is neither good for drinking nor for irrigation of crops. In some areas such as Bahawalpur, Bahawalnagar and Pakpattan, drinking water is brackish which cause water borne diseases. Locals demanded that clean and safe drinking water should be provided through water supply system or water filtration plants.

People told that irrigation water disputes are common in COI. Water distribution is not transparent due to influential people of area. People residing at canal tail do not receive sufficient water for irrigation.

ii. Sewerage System

There is no proper sewerage system in most of the villages in the COI. Absence of proper sewerage system results in epidemic health problems. Locals demanded that sewerage system should be installed to improve sanitation condition of rural areas.

iii. Health/Medical Facilities

Water borne diseases are common in most of the villages along route alignment. Diseases such as jaundice, hepatitis, fever, tuberculosis and stomach disorders etc. are common in these areas. Hospitals are mostly far away while dispensaries are not fully equipped. Maternity homes are not available. Due to inadequate health facilities, majority of the patients couldn't get proper treatment. People have to travel long distances to get health facility. In Section-I, more than 90 percent villages have no health facility. People demanded that health facility should be provided to the locals.

Livestock rearing is main source of income in many areas in the COI. There are no veterinary hospitals near settlement. Any disease outbreak among livestock directly affects the households. So veterinary centers should be provided in areas where livestock rearing is common.

iv. Public Infrastructures/ Roads

Transportation and road infrastructure is very poor in the COI. Most of the settlements have Katcha tracks. People have to travel longer distances by foot. During rainy season, travelling on Katcha tracks become difficult. It was demanded that roads should be constructed and public transport should be provided to facilitate the local people.

v. Education

Education facilities are very poor in the COI. Schools are not present in villages and boys and girls have to travel long distances for education. Schools are devoid of proper infrastructure and learning aids. Many students could not join the college. It was suggested by locals that proper education system should be introduced along the COI especially for girls.

6.4.2 Concerns/ Feedback of Focus Group Discussions

Project related concerns and feedback by the women in the COI is presented below:

A. Project Related Concerns/Feedback

i. Willingness

Women have also shown positive approach towards the proposed Project, as it will help in the development of country by providing more electricity.

ii. Privacy

Women have discussed their privacy issues, as according to them when outsiders will come into their area during construction phase they will have to restrict their mobility. Project should not be implemented during the harvesting season as during that season they have to go out to help male members in the fields.

iii. Employment

It was demanded by the locals that Govt. should provide job opportunities of literate women in education and health sectors. Women demanded that if possible during construction stage of the project their male member should be provided skilled and unskilled job opportunities.

B. Other Concerns/Feedback

i. Awareness

Most of the women expressed a desire to expand the magnitude of their work and responsibilities; due to lack of opportunities, mobility, illiteracy and poverty. Though they have access to information and agricultural knowledge about farming and livestock activities which has come to them through word of mouth and over time, their main obstacle is their exclusion from using their knowledge and information

ii. Education

Lack of income and mobility is the main hurdle in sending the girls to school. High schools and collages were also not available which has also reduced the women literacy status. Males get preferential treatment regarding formal education as compare to females.

iii. Income

Women have complained that usually they receive no wages at all, sometimes only food for work and men and women are not paid equally for their services. They have seen agricultural work opportunities squeezed year by year and because they have no alternative but to suffer continuing impoverishment.

Women unanimously complain of restricted earning opportunities outside agriculture due to cultural and social pressure. They go in groups or are accompanied by a male family member.

Women of Project Area repeatedly complained of lack of alternate working opportunities to agriculture, as well as lack of social and professional mobility. Social norms leading to restricted mobility in search of other work is one of the stumbling blocks to women's employment.

iv. Health

Women along Project corridor were facing major health problems. Most of women are facing maternity problem. In most of the cases medical facilities are far away. Women access to these health facilities is not possible because they couldn't travel long distance.

Majority of the area, crossed by the T/L is poor; people have great expectations towards the Project. Moreover, having the opportunity to express them has enabled the people to communicate all the frustrations they are living day by day.

7 IMPACTS ASSESSMENT AND MITIGATION MEASURES

7.1 General

This Chapter identifies the potential environmental and social impacts due to the implementation of the proposed Project on the physical, ecological and socio-economic environment. This Chapter also suggest/propose the mitigation measures that will help to avoid, reduce and mitigate the Project's adverse environmental and social impacts due to the proposed T/L Project.

The impacts of the proposed Project are divided into two (02) major components which are given below:

- Transmission Line (T/L); and
- Converter Stations.

7.2 Tools used for Impact Assessment

The methodology has been described in Chapter-1. Following tools were used for the identification of the Project potential environmental and social impacts:

7.2.1 Project Screening Checklist

The first step in the identification of potential environmental and social impact is to classify the significant and insignificant potential adverse impacts. The insignificant potential adverse impacts are screened out using the impact screening checklist.

The Project has been broadly classified into two major components i.e. proposed T/L and proposed Converter Stations. The potential impacts and their mitigations measures are also described separately. Other components such as Contractor Camps, Vehicle/Storage areas, Quarry areas etc. are considered as a part of T/L.

Based on the findings of desk studies, processed satellite imageries, previous studies, screening checklist for the impacts were prepared to screen out the significant and insignificant impacts of the proposed Project on physical, ecological and socio-economic environment. After the completion of field visits, compilation of baseline information, processing of available Google Earth Satellite Imagery, the screening checklist was filled to screen out the impacts of the proposed Project during the construction and operation stage with and without mitigation. The filled screening checklist is given as Annex-XI.

7.2.2 Project Impact Matrix

A Project impact matrix helps in identifying the potential temporal impact and screens the Project for environmental and social soundness. Spatial based impacts are identified using Overlays discussed in the next head. Each Project activity is screened separately with regard to its construction and operation phases and according to the various physical, ecological and social parameters. Matrices are used to identify temporal impacts. These impacts are categorized on the basis of nature, magnitude /severity, extent, timing, duration, uncertainty and reversibility. Table 7-1 shows the categorization of impacts.

Table 7–1: Categorization of Environmental Impacts

Sr. No.	Nature Category	Magnitude /Severity Category	Extent Category	Timing Category	Duration Category	Uncertainty Category	Reversibility Category
1	Indirect	Low	Site-specific	Short Term	Temporary	Low Probability	Reversible
2	Direct	Moderate	National	Medium Term	Permanent	Medium Probability	Irreversible
3	Cumulative	High	Local	Long Term		High Probability	
4	Residual		Regional				
5	Synergistic		Trans-boundary				

Annex-XII provides the Project Impact Matrix. The classification criteria used in the Project Impact Matrix for the environmental impacts of the proposed Project activities is given below in Table 7-2.

Table 7–2: Impacts Classification Criteria for Project Impact Matrix

Positive	Level	Adverse
O	Insignificant / No Impact	o
•	Low	x
●	Medium	
⬤	High	

7.2.3 Overlays

In order to identify the spatial based (location based) impacts, overlays are used. An overlay is based on a set of transparent maps each of which represents the spatial distribution of environmental characteristics (for example susceptibility to erosion). Information for an array of variables is collected for the standard geographical units within the COI and recorded in a series of maps typically one for each parameter. These maps are overlaid to produce a composite map. The resulting composite maps characterize the area's physical, ecological, socio-economic and other relevant characteristics relative to the location of the proposed Project. Software used for the overlays are Arc View and AUTOCAD. For the subject Project digitized available Google Earth Imageries and ARC GIS was used to prepared overlay maps. Land-use map prepared for overlays of the COI and Converter Stations are attached as Figure 5-1 and 5-2.

7.2.4 Delineation of Project Corridor of Impact (COI)

Before proceeding to the environmental analysis of the Project, it is imperative to delineate the COI. The COI has already been described in Chapter-1. There are two (02) types of Project corridors which have been used for the environmental baseline information, impacts assessment and mitigation purposes and is described briefly as under:

7.2.4.1 Corridor of Impact (COI)/ Area of Influence

COI is a limit which identifies the area where direct and indirect impacts of the Project activities are envisaged like existence of forests, game reserves, wetlands, archaeological sites etc. COI also includes the ROW. This limit varies from a 200 m wide strip to 1 km or even more for collection of baseline information, impacts assessment and mitigation measures of physical, ecological as well as social resources.

Apart from the COI, which is along the centerline, area identified for the Construction/Contractor camps, vehicle, equipment yard, material quarry areas and access tracks are also considered for the study and termed as Project Area. Therefore, in this report COI also means the Study Area or Area of Influence.

Study Area for the Converter Stations is the area to be acquired for the construction as well as the adjoining area where the Project activities may have impact on the environment.

As the location of Construction/Contractor camps, vehicle, equipment yard, material quarry areas and access tracks have not been defined yet, so impacts evaluated due to these facilities in this section will be of generic nature. Converter Station Site Selection Criteria is provided in Section 3.6.

7.2.4.2 Right of Way (ROW) / Project Area

ROW is the corridor where direct impacts of the proposed T/L due to the construction of Towers are envisaged. In the ROW there will be direct impact on the environment like relocation of the physical infrastructure, clearing of vegetation, cutting of trees, loss of crops due to the installation of Towers and some indirect impacts on shrubs, ornamental trees etc. are also envisaged. ROW is taken as 100 m wide strip through which the T/L will pass. Similarly, Project Area is the area to be acquired for the construction of Converter Stations.

7.3 Positive Impacts

With the implementation of the proposed Project, the following major positive impacts are foreseen:

7.3.1 Availability of Electricity and Reduction in Load Shedding

Construction of new T/L will indirectly increase the supply of electricity by despatching Power from Thar to the major load distribution centers i.e. Lahore. This will increase the electricity in the national grid and will help to reduce the load shedding thereby improving the overall electricity situation in the country.

7.3.2 Employment Opportunities

During construction phase and operation phase, jobs will be created for the unskilled and skilled labour. Locals will be employed in these jobs to fulfill skilled and unskilled labour requirements. This will bring prosperity among locals and help in increasing the confidence of locals towards development Project.

During the construction phase, the locals can also open small shops, workshops etc., to provide daily needed bread and butter for the workers, hence business opportunities will be generated along the COI.

Development of quarry areas will also create jobs and business opportunities for the locals. This will also be a positive impact for the locals.

7.3.3 Infrastructure Development

The construction of the Converter Stations will help towards the development of infrastructure, business and routine life in these regions especially the Tharparkar area which is an under developed and remote area. Locals will be benefited by this, as this will contribute to their livelihoods. Moreover, access roads/tracks developed for the construction/installation of Tower will also be utilized by the locals.

7.3.4 Increase in Land Value

Construction of new T/L and Converter Stations is expected to increase the land value, due to the increased accessibility, especially in villages where little or no road infrastructure is present. Land owners will have an opportunity to sell their land at increased prices and start new businesses.

7.3.5 Socio-Economic Uplift

Development of business during the construction stage will cause socio-economic uplift of the locals along the COI. The socio-economic impacts like employment, education, living standard and cultural uplift during the interaction with locals are the indirect benefits due to the Project implementation. T/L will create new job opportunities for local residents during the construction stage of the Project. This will uplift the socio-economic situation of the area hence living standard of the local population will improve.

7.3.6 Indirect Benefits

There are many indirect benefits associated with the proposed Project. The benefit of decrease in electricity load shedding will facilitate other services, such as health facilities, schools, water supply etc., which are dependent on electricity. This will also result in the improvement of the socio-economic conditions of the locals. Expansion of the industrial base is also expected.

Indirect positive impacts of the proposed Project on environment and social settings of the Project Area are as under:

- Due to the implementation of the Project, availability of electricity will be increased;
- Due to increased electricity availability opportunities will be available to develop a large area of barren land into agriculture land by installation of tubewells. This will not have any significant adverse impact on the biodiversity of the area;
- Expansion of the industrial base is expected due to the availability of electricity;
- Better quality of life will be available for the residents of the Study Area; and
- Electrification of a number of villages where the present day basic necessities are not available, will result in the spread of knowledge, education and provide recreation through mass media communication by television in the rural areas of the country.

7.4 Potential Adverse Impacts of Transmission Line

Apart from positive impacts of the T/L on the environment, there are some potential significant adverse environmental and social impacts on the local environment. The proposed Project broadly can be divided into three (03) stages i.e. Pre-construction/ Planning and Design Stage, Construction Stage and Operational Stage. The Pre-construction Stage includes all stages before the construction Stage (i.e. land acquisition, site investigation work i.e. topographical, geotechnical, seismic studies etc.); Construction Stage includes all stages from mobilization of Contractor to the completion of Project; and Operation Stage starts after the Construction Stage which includes the inspection and repair works.

Adverse impacts envisaged at these three (03) stages of the proposed T/L Project Section-I, II along with their proposed remedial or mitigation measures are detailed below.

7.4.1 Adverse Impacts during Planning and Design Phase

Potential adverse impacts during the planning and design stage of the Project are given below:

7.4.1.1 Physical Environment

i. Permanent Land Acquisition

Permanent land acquisition by NTDC will be required for the proposed Coverter Stations. About 215 acres of land will be requied for the Converter Station at Matiari. Land has been selected and Section 4 has been notified. Land is partially owned by the Privately and by the Government. As per information available so far about 88 acres of this piece of land is privately owned rest is owned by the Government.

The proposed T/L will not involve the permanent land acquisition as per NTDC practice in the light of LAA and Telegraph Act, 1910. No permanent land acquisition will be made for the land at the Tower footings as the landowner will be allowed to use the area under the Towers after the installation. T/L Section II is mostly passing over the agriculture land. During the previous studies on the other similar Projects, it was particularly observed that people are using the land under the Towers for agriculture purposes.

<u>Mitigation</u>

During the route identification and optimization studies, efforts were made to avoid the spotting of Towers as well as T/L alignment over houses and populated areas. No specific mitigation measures can be suggested as no land will be acquired on permanent basis. Impacts and mitigation due to temporary acquisition of land is given below.

ii. Temporary Acquisition of Land

The Contractors will require temporary land acquisition for:

- The development of Contractor camps and facilities i.e. storage, workshops, equipment parking and washing areas;
- Aggregate quarries; and
- Access roads/tracks for haulage, transportation etc.

The approximate area required for the establishment of one Contractor's camp facilities will be 5000m^2 (refer Section 4.4.3)at the different locations. Land utilization for Project activities and subsequent operation of Project may induce temporary as well as permanent changes in the existing landuse pattern. This impact can be categorized as direct, low, site-specific, short term, temporary, medium probability and reversible.

Mitigation

The land for above mentioned facilities should be selected and leased prior to the start of construction phase. Land for above mentioned facilities will be directly rented from the private landowners by the Contractors. The provisions of the Land Acquisition Act (LAA), 1894 will not be involved as the acquisition of the land will be temporary and will be covered by short-term lease agreements between the landowners and Contractor. Rental terms should be negotiated to the satisfaction of the concerned landowners and the agreement should be in local language to make the process clear.

NTDC staff will monitor the process of site restoration of the land after the construction phase and will ensure through the terms of the Construction Contracts that landowners are compensated according the terms of the lease agreements and the site restoration plans agreed upon by the Contractors are duly carried out. Photographic documentation of the existing land prior to the temporary acquisition should be available which will be beneficial to resolve the restoration conflicts between the landowner and the Contractor. A mechanism for Redress of Grievance is also provided in the Section 8.11 to resolve the conflicts between the landowner and the Contractor. This record should be available at the office of NTDC Environmental & Social Expert Project office.

In addition, the following general guidelines should be followed to minimize the impacts on the landuse:

- Project facilities should be located at a minimum distance of 500 m from the existing settlements, built-up areas, wildlife habitats, archaeological and cultural monuments as the case may be.
- Prior to the commencement of the construction activities, the Contractor should submit a development plan to the Engineer-incharge and the concerned EPA (if required) for its scrutiny and approval; and
- As far as possible, waste/barren land i.e. areas not under agricultural or residential use and natural areas located at high elevation should be used for setting up the Contractor camps.

7.4.1.2 Ecological Environment

i. Vegetation Cover and Fauna

During the planning and design phase of the Project, limited vegetation cover will be removed and some shrubs/trees/fruit trees will be removed for setting up the temporary camps, material storage areas and for the development of the temporary tracks. This may affect the existing vegetation to some extent in Section II of the proposed T/L.

During the site investigation work i.e. topographical, geotechnical, seismic studies etc. the fauna may be affected insignificantly in Section II and some parts of Section II. Clearing of vegetation cover might affect the habitat of animals residing in the bushes and scattered grass.This impact can be categorized as direct, low, site-specific, short term, temporary, low probability and reversible.

No specific measures are required for the insignificant impact; however, use of good engineering practices such as use of equipments to cause minimum noise and damage to the vegetation will further minimize the impact.

7.4.1.3 Socio-Economic Environment

During the planning and design phase of the Project it is anticipated that there will not be any potentially significant adverse impact on the socio-economic environment. Locals may be temporarily disturbed due to the field investigations and drilling activities. This impact can be categorized as indirect, low, site-specific, short term, temporary, medium probability and reversible.

No mitigations measures are required. Good engineering practices along with above suggested mitigation are required to avoid and reduce these low adverse impacts.

7.4.2 Adverse Impacts during Construction Stage

7.4.2.1 Physical Environment

i. Ambient Air Quality

Ambient air quality will be affected by the fugitive dust and emissions from the construction machinery and vehicular traffic during the construction phase. These impacts are envisaged mainly for Section I and Section II. Emissions may be carried over long distances depending on the wind speed, wind direction, temperature of the surrounding atmosphere, atmospheric stability, topography, occurrence of any significant obstruction such as buildings and type of terrain. The critical sources of air pollution during the construction phase are:

- Quarry areas that generate fugitive dust during the excavation; and
- Construction material haulage trucks that generate dust, particularly during the loading and unloading processes.

This impact can be categorized as direct, moderate, local, medium term, temporary, high probability and reversible.

Mitigation

The following effective measures need to be adopted for controlling the potential adverse impacts on ambient air quality:

- The existing quarries should be used to borrow the aggregate materials;
- Concrete batching plants should be equipped with dust control equipment such as fabric filters or wet scrubbers to reduce the level of dust emissions;
- Ensure the proper and periodic tuning of the vehicles;
- Dust emissions from trucks will be reduced by a regular sprinkling of water for keeping the dust settled at least twice a day;
- Haul-trucks carrying sand aggregate and other materials will be kept covered with tarpaulin to reduce the dust pollution;
- NTDC should set up a system to monitor the air quality along the Project corridor in accordance with the accepted local and international standards. The system will cover protocols for sampling and analysis, assessment of air quality at sensitive locations, reporting and information sharing. NTDC will coordinate all the efforts in this area with the concerned EPAs and the local authorities; and
- NEQS provisions for ambient air quality, stack emission, noise levels and vehicular exhaust should be used for reference during the construction works.

ii. Noise Level

Noise generated by the construction machinery during the construction stage is likely to affect the COI particularly the sensitive receptors like nearby schools, hospital etc. This impact will be more pronounced in Section I and Section II.

This is a potentially significant adverse environmental and social impact of temporary nature. This impact can be categorized as direct, moderate, local, short term, temporary, high probability and reversible.

Mitigation

As the proposed T/L route some sections are passing near houses, so special care must be taken for noise producing activity by providing casing to the noise generating part of the machinery or use of noise absorbing materials. Properly tuned vehicles and oiling of moving part of equipment may also reduce the noise levels. Construction timing should be coordinated with locals. Normally noise generating activities are allowed from 9 AM to 5 PM during day time to avoid disturbance to humans as well as fauna.

NTDC will also set up a system to monitor the noise levels in the COI near the construction activities to facilitate the concerned EPAs in enforcing the noise standards as prescribed in the NEQS.

iii. Liquid and Solid Waste from Construction Camps

Approximate proposed strength of the labour in all camps is 179 persons (refer Section 4.4.4). These persons will be involved during hauling and installation stage. As a general rule the water consumption will be about 20gallon/capita/day (75.7 liter/capita/day) and will subsequently generate about 70 to 80% of this water as sewage.

Total amount of water required for the camps domestic and drinking water requirements are not much. However, a proper planning should be done for the source of water to be used to provide water for the camp area. Groundwater should be the first priority after Pumpout Test and resistivity survey if it is available at reasonable depth, quantity and quality. Similarly if the sources are far apart then option of Bowser trucks should be considered. Regular sampling and testing of water against the drinking water quality guidelines are recommended.

Disposal of wastewater without treatment will pollute the soil and groundwater. Hence water demand will be 13.5 m^3/day and estimated generated wastewater will be about 10.16 m^3/day.

Based on the rough estimate, labour camps will generate 0.5 kg/person/day solid waste of domestic nature comprising kitchen waste, garbage, putrescible waste, rubbish and small portion of ashes and residues. Estimated quantity of solid waste will be about 89.5kg/day. Improper waste management activities can increase disease transmission, contaminate ground and surface water and ultimate damage to the ecosystem.

This impact can be categorized as direct, moderate, site-specific, short term, temporary, high probability and reversible.

Mitigation

To dispose the liquid and solid waste generated from the construction activities, the following steps should be taken by the Contractor:

- Domestic and chemical effluents from the construction camp should be disposed by the development of on-site sanitation systems i.e. septic tanks along with soakage pits. Proper monitoring to check the compliance of NEQS will be carried out;
- Sewage from construction camps will be disposed of after proper pre-treatment and processes such as soakage pit;

- All the solid waste from the camps should be properly collected at source by placing containers and disposed of through proper solid waste management system. The Contractor will coordinate with local representatives and administration concerned department for the disposal of solid waste;
- The concerned department must develop a plan of action for transporting the waste to the disposal site for final disposal. It is the responsibility of the concerned department to ensure that the disposal site is properly lined to prevent the leachate from contaminating the groundwater;
- Secondly, the disposal site must be located away as far as practical from populated areas and regions that have a high density of Wildlife;
- Toxic waste will be handled, stored, transported and disposed separately;
- The waste will be properly sealed in containers with proper labels indicating the nature of the waste; and
- Solid waste will be segregated at source so that it can be re-used or recycled.

iv. Soil Erosion

Construction activities such as clearing and grubbing, excavation, filling, laying down concrete foundation for Towers and setting up construction camps will affect the existing soil condition in the COI. The clearing of vegetation can also loosen the soil and make it more susceptible to erosion due to wind and rain. There is also a possibility of silt runoff during rainy season causing soil erosion. During the rain, the eroded soil mix with stagnant water to transform into slush, which can affect movement of vehicles and machinery and construction work as well as limit the movements of local people.

Soil erosion may also occur in the workshop areas as a result of improper drainage system of equipment washing-yards and improper management of construction activities. This impact can be categorized as indirect, moderate, site-specific, long term, permanent, high probability and irreversible.

Mitigation

Good engineering practices will help to control or minimize the soil erosion both at the construction sites and in peripheral areas, particularly at the Tower foundations and along the haul tracks. All the disturbed areas need to be protected against soil erosion by stripping and stockpiling of all the available topsoil for later re-vegetation. Special slope protection measures should be adopted in the sensitive areas i.e. desert or semi-desert areas Section-I and Section-II. Site restoration plan for the Project should be strictly followed.

Siltation of Natural Streams and Irrigation Channels

Natural streams and irrigation channels mostly in SectionI and Section-II may be prone to increase in sedimentation and silt due to excavated material (loose aggregate) with the runoff from the construction area, workshops and equipment washing-yards.

The irrigation/drainage channels and natural streams running along the Project corridor in the Project Area may also become silted, if unmanaged excavation is carried out for the Tower foundations and other construction activities.

This impact can be categorized as indirect, moderate, site-specific, long term, permanent, high probability and irreversible.

Mitigation

The excavated material will be managed by ensuring proper storage areas located far away from the water bodies. It will not cause the siltation of the irrigation channels. All the areas disturbed due to erosion need to be protected against soil erosion by stripping and stockpiling of all the available topsoil for later re-vegetation. At sand dunes, proper slope protection should be provided to reduce the erosion of the slopes.

v. Soil Contamination

Land may be contaminated due to the spillage of chemicals, fuels, solvents, oils, paints, concrete, solid waste generated at campsites etc. This normally happens when these materials are transported in open or loosely capped containers.

The possible contamination of soil by oils and chemicals at camp sites, workshop area and equipment washing-yards may limit the future use of land for agricultural purposes. This impact can be categorized as direct, moderate, site-specific, long term, permanent, high probability and irreversible.

Mitigation

The following practice will be adopted to minimize the risk of soil contamination:

- The Contractors will be required to instruct and train their workforce in the storage handling and management of materials and chemicals that can potentially cause soil contamination;
- Material Safety Data Sheets (MSDS) should be strictly followed during handling and storage of chemicals;
- Soil contamination due to concrete transportation will be minimized by placing all containers in casings; and
- Solid waste generated at the camp sites will be properly treated and safely disposed only in the demarcated waste disposal sites/areas.

vi. Public Infrastructure

Construction stage of the proposed Project may affect the existing infrastructure within the ROW of the T/L where Towers are to be installed and stringing activities. List of infrastructure falling with ROW (100 m) is given in Table 7-3 attached at the end of this Chapter. Exact number will be identified after the finalizaiton of the spotting of Towers.

Road Crossings

Field surveys revealed that the proposed T/L will cross some roads, the details of road crossings are provided in the Table7-3. At the time of stringing of proposed T/L, interference to the traffic movement is expected. This will be a significant adverse physical and social impact during the construction stage. This impact can be categorized as direct, moderate, local, medium term, temporary, high probability and reversible.

Mitigation

During the detailed design stage, NTDC will coordinate with NHA and local road department/authorities for the installation of the Towers and during stringing of the conductors where the line is crossing the existing roads for the provision of alternate traffic route and management. NTDC will provide adequate line clearance from the road. Further, during the installation process, proper traffic management plan will be prepared to avoid the traffic hazards and the construction should be carried out in off peak hours.

Canals

The proposed T/L will also cross the canals at different locations (Refer Table 7-3). Crossing of canal will not have any significant adverse impact on environment during the stringing action stage.

Mitigation

No specific mitigation measure can be suggested for this impact. Moreover, it is suggested that no Tower footings are to be spotted in the canal or river beds.

Power Transmission Lines

The selected route of the proposed T/L involves the crossings of the some existing T/L (Refer Table 7-3 at the end of this chapter). Crossing may be dangerous during the stringing action and operation stage, if proper clearance is not provided at the design stage of the Project. This impact can be categorized as direct, low, site-specific, short term, temporary, low probability and reversible.

Mitigation

Special care is required during the construction of Towers as well as stringing of conductors. During the stringing of conductors, temporary shutdown of the existing T/Ls will be ensured to safeguard the workers and the surroundings. A proactive coordination is required between the construction staff and relevant Grid Station operation staff to ensure the shutdown schedule.

vii. Impact on Water Resources

This section explains how COI will be affected in terms of the water resources use and water body contamination. It also describes the mitigation measures to manage these impacts.

Contamination of Surface and Groundwater

Surface and groundwater resources may get contaminated by the fuel and chemical spills, or by solid waste and effluents generated by the kitchens and toilets at the construction camp sites. Moreover, runoff from the chemical storage areas may also contaminate the surface water bodies. This impact can be categorized as direct, moderate, local, medium term, temporary, high probability and reversible.

Mitigation

As a mandatory step, all the effluents should be disposed as per the requirements of NEQS. Moreover, to reduce the risk of surface and groundwater contamination, good management practices will be adopted to ensure that fuels, chemicals, raw sewage and wastewater effluent are disposed of in a controlled manner. These measures are described below:

- Construction camps should be established in areas with adequate natural drainage channels in order to facilitate the flow of the treated effluents after ensuring that NEQs are met;
- Wastewater effluent from the Contractors' workshops and equipment washing-yards should be passed through gravel/sand beds to remove oil/grease contaminants before discharging into the natural streams. According to the NEQS, the BOD concentration in sewage must be brought down to less or equal to 80 mg/l before being discharged into a natural stream having capacity to dilute the effluent. For wastewater apart from BOD, COD of 150 mg/l should also be checked; and
- Similarly, if the sewage after treatment is to be discharged on to the land it should meet the requirements of the NEQS for disposal of wastewater.

7.4.2.2 Ecological Environment

The impacts on the flora and fauna and corresponding mitigation measures are given below:

i. Impacts on Flora

Trees and Shrubs

T/L section passing through agriculture land i.e. Section-I and Section-II, where trees have been raised by the farmers along the boundaries of their agricultural fields or along the water channels. Some orchards (mostly Mangos, Banas, Guava and Citrus in Sindh and Punjab etc.), also exist. Trees also exist along the highways and canals, where these trees have been grown by the Government Departments. Sporadic growth of trees, coming within the COI have to be removed if these are located within the Tower foundations during construction. As these are small in number, their removal will cause no significant adverse environmental impact. With the erection of T/L Towers, tree need to raised away from the location of Towers.This impact can be categorized as direct, low, site-specific, long term, permanent, high probability and irreversible.

Mitigation

Following mitigations are suggested:

- Land holders should be paid reasonable compensation for the loss of their standing trees, in accordance with the prevailing market rates. This will mitigate the financial losses of the land holders. They should be encouraged to plant new trees, outside the ROW of the T/L;
- Existing access tracks to the Tower sites should be used and new paths should be constructed only in case, no existing path is available;
- While making paths for carriage of equipment and material to the site of Towers, care should be taken that minimum land is utilized and minimum area of crop is disturbed. cutting of trees should be avoided by making diversions;
- Areas for construction camps, established for labour and other personnel, should be kept to the minimum. The camp sites should be located in plain areas, with minimum vegetation cover. Clearing of land and cutting of trees and vegetation should be avoided as far as possible;
- Staff and labour should be strictly directed not to damage any vegetation such as trees or bushes. They should use the paths and roads for travel and should not go for short cuts through the fields;
- Special measures need to be adopted to minimize impacts on important resources, such as activities during critical periods of migration, breeding and feeding;
- While setting up construction camps, for the erection of Towers, stringing of conductors or Converter Stations, care should be taken that no obstruction is placed in natural streams nullah or natural drainage;
- Vehicle speed should be controlled to avoid any damage to existing vegetation, environment and to avoid accidental mortality of small mammals and reptiles; and
- Shrubs and herbs existing within the COI will be subjected to a significant adverse impact as these may be tangled and destroyed due to the movement of heavy vehicles. These shrubs may also be subjected to cutting for use as firewood in the labour camps to be set up along the proposed T/L route.

ii. Impact on Fauna

Mammals and Reptiles

During the construction phase, there are no significant adverse impacts on the big mammals and reptiles of the area due to the activities involved in the construction of access roads, Towers, stringing of conductors, movement of labour, carriage of goods and machinery to various sites, within the COI of T/L route.

Mammals such as wild boar, jackal etc. will move away from these areas. Same will be the case with reptiles; some reptiles might be killed during the digging and dragging operations. Movements of the mammals and reptiles to the Project Area will be restricted during the construction phase. This impact can be categorized as direct, moderate, local, medium term, temporary, high probability and reversible.

Mitigation

Following measures are suggested:

- Hunting and harassing of wild animals will be strictly prohibited and the Contractors will warn their labour not to indulge in any such activity;

- Activities such as construction of Towers, stretching of conductors and carriage of materials will not be allowed during the night in the Wildlife sensitive areas;
- Lights used in the camps during the construction will be kept to the minimum. In the Wildlife sensitive areas, upward scattering lights will preferably be used; and
- Vehicle speed should be controlled to avoid incidental mortality of small mammals and reptiles.

Avi Fauna

Birds like Tillor (*Houbara bustard*), Marbled Teal (*Marmaronetta Angustirostris*), Black partridge (*Francolinus francolinues*), Jal Kookri (*Fulica Atra*) and Falcon (*Falco peregrinus*) exist in and around the COI. These birds have been subjected to excessive hunting and catching on account of their good quality and tasty meat or their commercial value as a prey bird.

These birds will try to find shelter and food somewhere else and will tend to move away from the route of T/L due to the activities mentioned above for fear of being hunted / trapped or killed. This impact can be categorized as indirect, moderate, local, medium term, temporary, high probability and reversible.

Mitigation

- Trees having habitat of birds should not be allowed to cut;
- Special mitigation measures needs to be adopted to minimize impacts on the birds, such as avoiding construction activities during the critical periods of breeding and feeding; and
- Staff working on the Project should be given clear orders not to shoot, snare or trap any bird.

Migratory Birds

Construction of the proposed T/L will not have any pronounced impact on the migratory birds because their migration route (Green Flyway International) along River Indus is quite far away. The proposed T/L route is also away from any major water bodies, therefore, no impact on the migratory birds are foreseen.

Mitigation

As the proposed alignment of the T/L is far away from the established route of the migratory birds from Siberia to the major wetlands in Sindh, which is normally along the River Indus, no mitigation measures are foreseen at this stage.

iii. Impact on Reserve Forests

The proposed T/L will no cause any major impact on the flora and fauna of the any Reserve Forest. So, no mitigation measures are foreseen at this stage.

7.4.2.3 Socio-economic Environment

This section describes the impacts of the proposed Project during construction stage on the local communities, construction workers, indigenous and vulnerable people as well as on structures or sites of cultural and religious significance.

i. Agriculture

Based on the Google images and field surveys, the total cultivated area, which will be affected due to this Project, is nearly about 16,500 hectares, which forms about 38.8% of the total area coming in the COI. The agriculture of the tract in Sindh and Punjab will receive significant adverse impact due to various operations such as movement of heavy machinery, erection of Towers, dragging, stretching and stringing etc. This impact can be categorized as direct, moderate, site-specific, medium term, temporary, high probability and reversible.

Mitigation

Land holders will be paid compensation for the loss of their standing agricultural crops in accordance with the prevailing market rates as per LAA, Telegraph Act, NTDC practices, Land Acquisition and Resettlement Framework (LARF) and Land Acquisition and Resettlement Plan (LARP) specific to the Project. The landholders will also be allowed to salvage the agricultural crops and other vegetation from the affected fields.

ii. Loss of Crops

The damages may occur to existing crops during the construction stage due to the following activities:

- Considerable vehicular movement for the transportation of materials/water and steel work will be involved at the time of concreting of Tower foundations. This movement and storage of materials will cause damage to the existing crops; and
- The stringing of conductors involves movement of equipment and vehicles along the corridor, which may involve the cutting of trees and considerable damage to the existing crops.

Since the Project is at the feasibility stage and detailed design is to be carried including the exact spotting of the Towers on ground. So in the absence of the availability of the spotting of Tower (project foot print), it is very difficult to calculate the exact amount of the crop losses. However, based on the route alignment, field visits, maps and experience of similar Projects already implemented, it is estimated that about 16,500 hectare of crops of agriculture land in the COI is required to be cleared due to construction of the footings, field investigations, stringing of conductors, accessibility tracks/roads. Approximately 75% of the proposed T/L is passing through desert while 25% is passing through plain area. It is also estimated that the Project activities will continue round.the year at each Tower from the start of survey to the stringing of conductors. So the affectees will lose their crops and fruits may be for two or more seasons i.e. *Rabi (Spring Harvest)* and *Khraif (Autumn Harvest)*. The major crops which are being sown in the Project Area are wheat, rice, cotton, maize and vegetables apart from the Orchards of Banana, Mango, Citurs etc. This impact can be categorized as direct, moderate, site-specific, medium term, temporary, high probability and reversible.

Mitigation

The following measures are recommended to minimize the impact of crop losses.

- Compensation for the loss of crops to the land owners and cultivators as the case may be will be paid, in accordance with the prevailing market prices and uniformity in rates will be ensured within the local areas;
- The whole process of the payment to the farmers should be made transparent, judicious and without any discrimination or favour;
- Minimum possible area should be disturbed for the construction of new paths or roads for carriage of machinery and materials; and
- As far as possible, barren land without any crop should be selected for the camp sites and disturbance to the crops and natural vegetation should be avoided as much as possible.
- Orchards compensation is a complex issue. However, efforts should be made to avoid damage to fruit trees other wise compensation for the whole is required. Similarly, banana plant/tree if damaged needs to be compensated on loss of tree basis.

iii. Conflict over Resources

It is anticipated that local water resources will be utilized to meet the camp and construction requirements, bringing its use into competition with the local use especially in the desert areas of Sindh and Punjab province i.e. Section-I and Section-II where the water availability is limited. This may cause conflicts between the locals and the Contractors. This impact can be categorized as direct, low, local, short term, temporary, low probability and reversible.

Mitigation

The following measures will be carried out to mitigate the impacts of tapping local community water resources, where required:

- In areas of concern where the potable water is in short supply; the water will be provided through vehicles from the nearby cities;
- As already mentioned in the mitigation of temporary land acquisition impact, the camps should be located at least 500 m away from the nearest local settlements to prevent the contamination of community-owned water resources;
- Approval from the local administration and representatives of the concerned irrigation departments or other relevant authorities will be obtained before using the local surface water resources;
- The Contractors will be required to maintain close liaison with the local communities to ensure that any potential conflicts relating to the common resource utilization are resolved quickly; and
- Guidelines will be established to minimize the wastage of water during the construction activities and at campsites.

iv. Impacts on Local Communities/Workforce

Local communities will be affected during the construction phase as follows:

- During the construction phase, the general mobility of the locals and their livestock in and around the COI will be affected temporarily on specific locations. The movement of the Towers and conductors from the stocking area to the construction site may cause traffic problems on the road for the locals. This may affect their mobility at times. During the stringing operations, interference to the traffic movement is also expected. This will have low adverse impact on the locals on temporarily basis;
- Community have to face the noise and dust problems during the construction activities, which may have adverse impact on the health of the locals. However, these impacts are of temporary nature;
- Induction of outside workers by the Contractor may cause conflicts with the locals on the cultural issues related to social and gender due to the unawareness of the local customs and norms. These issues may adversely affect the construction phase of the Project. This is a medium adverse social impact of temporary nature; and
- Theft problems to the community by the Contractor's workers and vice versa may also create social issues if outside labour is used by the Contractor.

Overall these impacts can be categorized as direct, moderate, local, medium term, temporary, high probability and reversible.

Mitigation

Potential social conflict between the outside labour and local community may be avoided by implementing the measures listed below:

- During the construction phase, mobility of the workers in the nearby areas should be strictly restricted by the Contractor to avoid any inconvenience to the local communities. The Contractor should select specific timings for stringing so as to cause least disturbance to the local population considering their peak movement hours; and

To avoid pollution problems due to noise, smoke and fugitive dust following mitigation should be followed:

- Use of good engineering practices such as water sprinkling, encasement and provision of silencer and mini stacks of generators etc. should be adopted to avoid inconvenience to the locals due to noise, smoke and fugitive dust; and

To avoid conflicts between Contractor staff and locals, following mitigation should be adopted:

- Contractor will take care of the concerns of the local community and the sensitivity towards the local customs;
- Good relations with the local communities will be promoted by encouraging the Contractor to provide opportunities for skilled and unskilled employment to the locals, as well as on-job training for workers. Contractor will restrict his permanent staff to mix with the locals to avoid any social issues;
- Local vendors will be provided with regular business by purchase camp site goods and getting services from them; and
- The Contractor will warn the workers not to indulge in any theft activities and if anyone gets involved in such activities, he will have to pay heavy penalty and would be handed over to the police. Similarly at the time of employing, the Contractor has to take care that the workers should be of good repute. The Contractor camp should be fenced properly and main gate will be locked at night with a security guard at guard to avoid any theft incidence.

v. **Loss of Income**

- During the construction activities of the Tower foundations, erection and stringing of conductor, people will suffer loss in their annual income due to the loss of crops, trees etc.;
- The land under the Towers during the operation stage may restrict the current landuse for agriculture purposes;
- The restriction of plantation of trees above 2.5 m height during the operation stage may also cause the inconvenience to the locals; and
- Due to the erection of Towers and the passing of T/L, the value of land may decrease on the long term basis.

This impact can be categorized as indirect, moderate, local, medium term, permanent, high probability and irreversible.

Mitigation

- Fair, prompt and negotiated compensation for the crops and trees on private land will be provided to the affectees. Generally, the area is devoid of forest and very few trees exist along the Project corridor. However, orchards of Mango, Citrus, exist near Section-II (b), need special provision for the compensation;
- Affectees will be involved in the valuation process at all stages of the Project i.e. soil investigations, Tower footings, Tower erection and stringing of conductors;
- Orchards of Guava and Citrus (except mangoes) with height less than 2.5 m can be grown. Similarly, cultivation of the crops can be carried out without any hindrance. In case of mango trees (such as Section-II and change in alignment should be made to avoid the cutting of mango trees or use of high Towers for mango trees; and
- Since the erection of Towers will involve very limited amount of land and the land under the Towers and conductors can be easily used for crops, so not much depreciation in the land value is foreseen. However, at certain locations where other T/Ls crossing land value may depreciate. This is a residual impact.

vi. Gender Issues

- As the Project route is passing through the rural areas of Okara, Pakpattan, Bahawalnagar, Bahawalpur, Rahim Yar Khan and all district of Sindh from Ghotki to Sanghar, Matiari, women activities in the field may become affected due to the construction activities;
- The rural women in these areas normally use the open field latrines and their privacy may suffer due to the Project activities;
- The induction of outside labour may create social and gender issues due to the unawareness of local customs and norms. It will also cause hindrance to the mobility of local women; and
- Disturbance to the privacy of the local women will be due to outside workers working on the erection of Towers and stringing of conductors.

This impact can be categorized as direct, moderate, local, medium term, temporary, high probability and reversible.

Mitigation

- The Contractor have to select the specific timings for the construction activities like Tower footings, erection and stringing of conductors so as to cause least disturbance to the local population particularly women considering their routine movement hours;
- The Contractor have to carry out the construction activities in such a way that the open field latrine usage timings by the local community particularly women, should not be affected. The normal timings to use the toilet facilities by the rural women are early in the morning and at evening so the Contractor will have to take care of these timings;
- Contractor should warn the staff strictly not to involve in any un-ethical activities such as theft, prostitution and to obey the local norms and cultural restrictions particularly with reference to the women;
- While working on the erection of Towers, if privacy of the nearby households is affected, the Contractor will inform the house owner to make some arrangements;

vii. Indigenous, Vulnerable and Women Headed Households

- During the social field survey of the Project, no indigenous group of people was identified, which comes under the definition of the "Indigenous People". So, no impact on the indigenous people is envisaged due to the implementation of the Project;
- During baseline survey it was identified that, T/L also crosses some houses of vulnerable people in few areas of SectionI (Sanghar, Ghotkik and Sukkur) and Section-II (Bahawalpur district, Bahawalnagar, Pakpattan and Okara districts). During the field visit it was also identified that the owners of the affected structures fall below the poverty line. Income of these vulnerable groups may be affected due to the implementation of the Project like crossing of T/L upon their infrastructure, affect of any assets such as houses, tubewells room etc. However, their livelihood will not be affected by the implementation of the Project;
- No women headed household was identified during the social survey of the Project, therefore, no special measures are recommended.

This impact can be categorized as direct, moderate, local, medium term, temporary, high probability and reversible.

Mitigation

- As referred earlier, no indigenous people have been identified in or along the Project corridor, so no mitigation is required;

- Assistance provisions for the vulnerable persons identified during baseline survey will be covered under LARP. The vulnerable persons shall be provided with all possible assistance and help for acquiring the skills and preference should be given to them for employment. The persons having no land or a person who is going to lose over 50 % of his land will be considered as vulnerable people and will be specially treated to provide the maximum benefits;
- As referred earlier, no women headed household has been identified during the social field survey. So no mitigation is proposed due to the implementation of the Project on women headed households; and
- At some location efforts are being made to avoid the houses by adjusting Towers locations.

viii. Safety Hazards

- Occurrence of accidents/incidents during the construction stage is a common phenomenon and workers as well as locals will be more prone to serious accidents; and
- The COI falls in Sindh and Punjab in which area is sensitive from the law and order point of view and the security of the Contractor and Consultant staff will be a major issue.

This impact can be categorized as direct, moderate, site-specific, medium term, temporary, medium probability and irreversible.

Mitigation

Following mitigation is given to avoid the accidental risks:

- Complying with the safety precautions for the construction workers as per International Labour Organization (ILO) Convention No. 62, as far as applicable to the Project Contract;
- Training of workers in construction safety procedures, environmental awareness, equipping all construction workers with safety boots, helmets, gloves and protective masks, goggles, shields and monitoring their proper and sustained usage.
- Contractor will ensure the provision of medicines, first aid kits, ambulance etc. at the camp site.
- Contractors should instruct their staff to use Personnel Protective Equipments (PPEs) (e.g., wire containment, displaying warning signs along the work site, communicating advance warnings to mats) to enhance the safety.
- Safety lookouts will be built to prevent people and vehicles from passing at the time of hot or cold work.
- In the security vulnerable areas, special measures should be adopted by the Contractor as well as the Consultant staff with the consultation of the local responsible agencies to control the law and order.

ix. Relocation of Private/Public Infrastructure

Removal of the infrastructure like buildings, huts, animal sheds, tubewells etc. will cause the loss of community shelters and sources of income.

Although the number of public infrastructure fall into the proposed T/L route, no relocation is expected as the Project has the flexibility to provide proper horizontal/vertical clearance for safe passage over the existing infrastructure. This impact can be categorized as direct, low, site-specific, long term, temporary, low probabilityand reversible. Detail of affected structures is given in Table 7-3.

Mitigation

- In order to mitigate or compensate the impact of land acquisition and resettlement LARP needs to be prepared;
- Utmost efforts will be made to minimize the relocation/damage to infrastructure especially houses. For this purpose, the route alignment will also be changed subject to the site conditions;
- No relocation of settlements (group of people) will be involved as the Project has flexibility to change the alignment;
- Compensation will be paid to the affectees for the built-up areas like buildings, huts, animal sheds, peter engines/electric motor sheds etc. on replacement cost basis and the land on existing agricultural land value;
- Payment of three (03) months house-rent will be made to the affectees while they will construct a new abode for their families;
- Full market price of any equipment (not shiftable) and cost of reconstruction including labour charges will be paid to the affectees;
- Affectees will be allowed the salvaging of the demolished materials; and
- All the provision of LARP should be followed.

x. Religious, Cultural and Historical Sites

There are no notified religious, cultural and historical sites exist in the proposed T/L COI and ROW. T/L passes close to a number of religious structures like shrines, mosques and graveyards, none of them is falling within the ROW limits except a katcha mosque (which is not in use). This impact can be categorized as negligible.

Mitigation

- During detail design, efforts will be made to avoid the crossing of mosque. Incase of relocation, NTDC will compensate the owner (community/imam/caretaker) on replacement value basis and will pay the land value on agricultural land basis;
- No other religious and cultural sites like mazars/shrines, graveyards, community center etc. will be affected due to the implementation of the proposed Project; and
- Similarly, no known archaeological site is located within the Project corridor; therefore, no impact on any archaeological site is envisaged. However, the Contractors will be required to train the construction crews and the site supervisors in archaeological site recognition, conservation procedures and temporary site protection. In case of a chance archaeological find during excavation, the Contractors must halt work at the site immediately and notify the Department of Archaeology and Museums through Project Director, NTDC.

7.4.3 Adverse Impacts during Operation Stage

7.4.3.1 Physical Environment

i. Air Quality

The air quality during operation phase is not expected to be different than at planning and design phase and will be better than the air quality during construction phase due to the absence of large vehicular movements etc. However, the use of machinery and vehicles for routine inspection may affect the air quality to some extent but it is expected to be insignificant. This impact can be categorized as direct, low, site-specific, short term, temporary, low probabilityand reversible.

Good engineering practices such as use of properly tuned vehicles, use of silencers, prohibition of pressure horns, scheduling of O&M at appropriate timing and compliance of NEQS applicable for vehicles and ambient air quality is recommended.

ii. Excessive Noise Problem

During the operational stage some people may have to tolerate a higher noise level due to the current flow in the conductors especially in the rainy season. Noise is generated during the ionization of the ambient air due to the electromagnetic field (EMF) around the T/L. Such a situation occurs with more severity in the rainy season when moisture in the air is relatively high. The community residing under or along the T/L may feel discomfort due to the noise generated through the passage of electric current. This impact can be categorized as direct, low, local, long term, permanent, highprobabilityand reversible.

Mitigation

To overcome this problem, the route has been selected to pass through the least populated areas. Construction of houses and building structure within the COI will be avoided and NTDC will make sure to check noise level should not cross the permissible limit near the sensitive receptor i.e. school, residential areas etc. in the COI. Recommended Monitoring Protocol provided in Chapter 9 for the monitoring of noise in the COI should also be followed.

iii. Electric Current

During the operational stage, electric current (induction) may travel into the Towers due to short circuiting and may become a hazard to the public and livestock. This impact can be categorized as indirect, low, site-specific, long term, permanent, low probabilityand reversible.

Mitigation

It is recommended that NTDC at the planning stage of the Project would plan necessary arrangements in the form of Earthling system of the Towers to avoid accidents. As exact location of Towers spotting is not yet finalized at this stage. However, it is recommended that at least two diagonal legs of the Towers should be properly grounded to avoid any such incident.

iv. Effect of Electro Magnetic Field (EMF)

The EMF may have significant adverse impacts on the health of locals. EMF due to extra high voltage (EHV) can cause the risk of *leukaemia,* which is a disease in which white blood cells mutate and become cancerous before maturity. These cells are important in fighting against infection in the body. Leukaemia also slows down the production of red blood cells that are needed to carry oxygen in the blood. Leukaemia is the second leading cause of death for children ages 2-15 years.

This impact can be categorized as indirect, low, local, long term, permanent, low probability and reversible.

Mitigation

Different studies were carried out in Britain to find out the effects of EMF due to EHV on children particularly with reference to leukaemia. British study suggested that children who live close to high voltage overhead Power lines may be at an increased risk of leukaemia. Although the researchers have made efforts to identify the effects of EHV related to leukaemia, but till now researchers cannot prove that the Power lines are the cause of leukaemia. They have admitted that their findings could be due to some chance or other factors.

Since the Project has been planned to pass through the least populated area and the T/L will be kept at least 100 m from the populated areas, effects due to EMF are envisaged will be minimal due to safe distance. Similarly a vertical clearance required as per international standards will also be maintained especially near the populated areas. During operation stage check will be kept by the NTDC that no construction will be allowed within 100 m of the proposed T/L.

v. Collapsing of Towers

Collapse of the Towers due to the high wind or earthquake will be dangerous for human as well as animal life and can cause loss to property. This impact can be categorized as direct, low, site-specific, long term, permanent, low probability and reversible.

Mitigation

The Towers are designed on the basis of proper subsoil investigations and climatic conditions of the area including maximum wind velocity and earthquakes which are normally based on last 50 years data. At the time of detailed survey for fixing the Tower positions proper soil investigations will be carried out to check the presence of collapsible soils and if detected, Engineer will be informed immediately for design change. It will be ensured that no accident due to collapsing of Towers would occur during the life of the Project.

vi. Breaking of Conductors

Breaking of conductors due to any mishap will cause a safety hazard due to the current flow in the fields and crossing over roads, canals, streams etc. This impact can be categorized as indirect, low, site-specific, long term, permanent, low probability and reversible.

Mitigation

The conductors are selected on the basis of local climatic conditions including maximum wind velocity, temperature and humidity conditions. So, there is almost no risk of breaking of conductors. However, due to some unavoidable circumstances, if such a situation occurs, NTDC has provided such an arrangement that the flow in the conductors will be automatically tripped instantaneously. So, no risk to human or animal life is envisaged due to the breaking of conductors.

vii. Working Failure of Electronic Devices/Equipment

The electronic devices/equipment class A, B, C and D may fail to work under the flux of EHV T/L. This impact can be categorized as indirect, low, local, long term, permanent, low probability and reversible.

Mitigation

The failure of electronic devices/equipment to work under the EHV T/L is a common phenomena. The severity of this impact can be minimized by providing proper requisite clearance, for which observations should be made in the field under the existing EHV T/L deliberately.

7.4.3.2 Ecological Environment

i. Danger to Bird Movements

The T/L may become a danger for the movement of indigenous birds and species and fatalities may occur if the birds sit on the conductors especially in the wet conditions. Since there is an EMF around the high voltage T/L and excessive noise, no birds sit over the conductors. However, even if the birds sit over the conductors particularly in the wetland areas, the danger will arise if two phases of the current meet, but as there is 4.75 m to 5.50 m distance between the two opposite phased conductors, no danger to the birds is envisaged.This impact can be categorized as indirect, low, local, long term, permanent, low probability and reversible.

Mitigation

Proper clearance between the two (02) conductors will be ensured.

ii. Danger to Aquatic Life

Passing of T/L from water bodies/wetland will be a continuous danger to the aquatic life due to the erosion and chances of flow of current into the water due to short circuiting. This impact can be categorized as indirect, low, local, long term, permanent, low probability and reversible.

Mitigation

- Buffer zones should be left on the banks to minimize erosion and habitat destruction; and
- Due to the provision of insulators at the junction of the conductors and Towers, no risk of flow of current from the conductors to the wetland/water bodies is expected. No such type of accident has been observed at the existing T/L passing through the rivers and wetlands.

7.4.3.3 Social Environment

i. Safety

The flow of electric current in the T/L will have an impact on the safety of the locals. The burning electrical equipment due to short circuiting can create a fire which can spread. This will become a safety hazard for the locals. This impact can be categorized as direct, low, local, long term, permanent, low probability and irreversible.

Mitigation

During the operational phase of the Project, a security plan should be employed and good engineering practices will be used for carrying out operation and maintenance activities. An effective communication system must be established so that the concerned authorities are notified in case a conductor wire falls loose.

7.5 Potential Adverse Impacts of Converter Stations

7.5.1 Adverse Impacts during Planning and Design Stage

7.5.1.1 Physical Environment

i. Permanent Land Acquisition

Following are the two (02) convertor stations for which NTDC will have to acquire land on permanent basis.

1. Matiari Convertor Station near N-5
2. Lahore Convertor Station

A total of approximately 215 acres of land will be permanently acquired for the construction of Matiari Convert Station and total land required by the Converter Station near Lahore is being finalized.

The land of Matiari Converter Station is privately and Governemnt owned. Land is highly fertile with agriculture fields and Orchards of furits such as Mango, Banana, Guava etc.

The land for Lahore Converter Station..

This impact can be categorized as direct, high, site-specific, long term, permanent, high probability and irreversible.

Mitigation

Permanent land will be acquired as per Land Acquisition Act (LAA), 1894 and local NTDC and concerned departmental policy requirements. Involuntary Resettlement requirments will also be fulfilled. It is recommended that existing market price of the land should be paid to the landowner. In this regard proper LARP should be prepared and implemented prior to the construction of the Converter Station.

ii. Temporary Acquisition of Land

As mention earlier, the Contractors will require temporary acquisition of land for Contractor camps, aggregate quarries and access roads for haulage etc. About 5000m^2 (1.2 acre)of land will be acquired for the construction of camp for each Coverter Station which may induce temporary as well as permanent changes in the existing landuse pattern.

This impact can be categorized as direct, low, site-specific, medium term, temporary, low probability and reversible.

Mitigation

Mitigations are already mentioned in the impact of Temporary Acquisition of Land for the proposed T/L (Section 7.4.1.1 (a-ii)).

7.5.1.2 Ecological Environment

i. Impact on Avifauna

Movement of vehicles will produce noise and vibration in the area during topographical, geotechnical and seismic studies which will scare away the birds, wildlife, rodents and reptiles etc.This impact can be categorized as indirect, low, site-specific, short term, temporary, low probability and reversible.

Mitigation

There will not be any major significant impact during this phase of the Project. Hence, no mitigation measures are suggested. However, impact can be minimized by use of good engineering practices.

7.5.1.3 Social Environment

No major impact on the social environment of the area is foreseen at this stage of Project. A few huts of the tenants were observed in the land selected for the Matiari Coverter Stations. These were contacted and it was confirmed that as the land will be acquired from the owners they will move to the new place with the owners. Hence no issues were identified.

7.5.2 Adverse Impacts during Construction Stage

7.5.2.1 Physical Environment

i. Soil Erosion

Construction activities such as clearing, excavation, filling, development of access roads, construction camps will cause the soil erosion in the Project Area and may have an adverse impact on the environment. This impact can be categorized as indirect, moderate, site-specific, long term, permanent, medium probability and irreversible.

Mitigation

All the disturbed areas need to be protected against severe erosion losses. The following good engineering practices will be adopted to control the soil erosion:

- Stripping and stockpiling of all the available topsoil for later re-vegetation;
- Use of Proper drainage system above the works for significant protection; and
- Planting of rapidly growing indigenous vegetation/grass in the Project Area to reduce the impact of soil erosion.

ii. Air Quality and Noise

During the construction stage, heavy equipment and machinery will be used which will generate noise and exhaust emissions. The anticipated equipment's to be used are:

- Concrete Batching plants;
- Concrete Paver;

- Concrete Mixer;
- Excavators;
- Dump trucks;
- Haul trucks; and
- Transport vehicles.

The possibility of noise generation and exhaust emissions increases when old vehicles/plants are utilized. Generally, construction activities will generate particulate matter (PM_{10}), smoke, dust, CO and NO_x in the ambient air which will deteriorate the air quality imparting adverse impacts on human health, flora and fauna. The movement of heavy machinery and vehicles on the dirt tracks will also be causing fugitive dust emissions. Due to the movement of trucks and other vehicles, noise and vibration will increase which will also create disturbance for the residents of the nearby settlements.

This impact can be categorized as direct, moderate, site-specific, medium term, temporary, medium probability and reversible.

Mitigation

The following effective measures need to be adopted for controlling the adverse impacts on the ambient air quality:

- Use of old vehicles should not be allowed during the construction phase of the Project
- Proper tuning of the construction vehicles at appropriate intervals should also be ensured;
- Haul truck carrying concrete, coarse and fine aggregate such as crush, sand and other fill materials should be kept covered with tarpaulin;
- Batching plant should be sited at least 500m away from the villages and settlements so that the dust generated by their operations does not have any adverse impact on the locals;
- Control of heavy machinery speed (dumpers, bulldozers, excavators etc.). Maximum speed of 30 km/hr. should be practiced;
- Concrete batching plant should be equipped with dust control equipment such as fabric filters or wet scrubbers to reduce the level of dust emissions or at least water should be used during crushing operations to avoid air pollution. This water should be recycled to avoid generation of wastewater;
- The existing quarries should be used to borrow the aggregate materials and each quarry site should have a proper quarry management plan;
- Where necessary, dust emissions will be reduced by regular sprinkling of water for keeping the dust settled, at least twice a day depending on the availability of water and nature of work;
- The NEQS applicable to the gaseous emissions generated by the construction vehicles, equipment, generators and machinery will be enforced during the construction works;
- Compliance monitoring of vehicles, generators and machines emissions (air and noise) should be regularly carried out;
- Construction activities shall be avoided during the night time and silencers should be provided in all the vehicles to minimize the emissions and noise. Noise complaints should be logged and kept onsite by the Contractor;
- Construction timings should be fixed after consultation with the residents of the nearby villages preferably during the day. This will minimize the disturbance to the local population; and

- If the proposed Project Area is near the school, college etc. the area where noise producing activity is to be undertaken should be screened with noise absorbing material or casing.

iii. Liquid and Solid Waste from Construction Camps

Approximate proposed strength of the labour in each camp for Converter Station will be about 25 persons which will generate about 1.9 m^3/day of wastewater and about 12.5 kg/day of solid waste. Improper wastewater and solid waste management activities can increase disease transmission, contaminate ground and surface water and ultimate damage to the ecosystem.

This impact can be categorized as direct, moderate, site-specific, short term, temporary, high probability and reversible.

Mitigation

Please refer the mitigation measures discussed in Section 7.4.2 (iii).

iv. Surface and Groundwater Quality

Surface water quality of the natural ponds/mullahs and the other water bodies may be impacted due to the construction activities and wastewater from labour camps. The movement of heavy vehicles on jeepable weathered (katcha) tracks, excavation activities; oil, lubricants, bitumen/coal tar and other liquid and chemical spills may deteriorate the quality of surface and groundwater resources. This impact can be categorized as direct, moderate, local, medium term, temporary, mediumprobability and reversible.

Mitigation

Mitigation regarding surface and groundwater quality as mentioned in impact of "Surface and Groundwater Quality" during construction stage of proposed T/L will be applicable for Converter Station.

7.5.2.2 Ecological Environment

Impact on Flora

During the construction stage, clearing and grubbing activities, construction of access road, installation of batching plants and worker's camps, natural vegetation and flora such as shrubs and herbs, including some species of medicinal plants, fuel wood plants and trees will be removed. This will be a potential adverse impact on the natural vegetation of the Study Area.This impact can be categorized as direct, low, site-specific, long term, permanent, high probability and irreversible.

Mitigation

The following measures will be carried out to mitigate the impacts on flora:

- While making paths for the carriage of construction materials, care will be taken that minimum land is utilized and minimum vegetation is disturbed;
- Plantation is required in the areas, where trees or bushes have been cut to make path for construction of new T/L;
- The camps and workshop facilities will be established on the barren land; however, if such type of land is not available, it will be ensured that minimum clearing of the vegetation occurs and minimum damage to the trees and undergrowth is ensured;
- The Contractor's staff and labour will be strictly directed not to damage any vegetation such as bushes; and
- Contractor will provide the fuel wood/gas cylinders at the camps for cooking purposes and cutting the trees/bushes for fuel will not be allowed.

Impact on Fauna

During construction activities lot of noise and noxious gases will be produced from the heavy vehicle, construction machinery and other activities which will scare away birds, wildlife, rodents and reptiles. Some of the avifauna may also get killed during construction works. This will be a potential adverse environmental impact and needs to be encountered on priority basis. This impact can be categorized as direct, low, site-specific, medium term, permanent, mediumprobability and reversible.

Mitigation

Please refer the mitigation for "Impact on Fauna" during construction stage of T/L.

7.5.2.3 Socio-Economic Environment

i. Mobility of Locals

During the construction phase, the general mobility of the locals and their livestock in and around the Project Area will be affected. The movement of the heavy equipment i.e. poles, transformers, conductors etc. from the storage area to the Convertor Stations will cause traffic problems on the road for the locals and affect their mobility. This impact can be categorized as direct, moderate, local, medium term, temporary, medium probability and reversible.

Mitigation

During the construction phase, mobility of the Contractor's staff through the nearby residential areas should also be strictly prohibited by the Contractor to avoid any inconvenience or any risk.

Temporarily and for short duration, the Contractor has to select specific timings for construction work so as to cause least disturbance to the local population considering their peak movement hours.

ii. Conflict over Resources

Local water supplies will be utilized to meet the camp site and construction requirements, bringing its use into competition with the local use. This may cause conflicts between the locals and the Contractors.This impact can be categorized as indirect, low, local, medium term, temporary, high probability and reversible.

Mitigation

Please refer to the mitigation for "Conflict over Resources" during construction stage of the proposed T/L.

iii. Cultural Issues

Induction of outside workers by the Contractor may cause conflicts with the local people on the cultural issues related to social and gender due to the unawareness of the local customs and norms. These issues may adversely affect the construction phase of the Project. This impact can be categorized as indirect, low, local, medium term, temporary, medium probability and reversible.

Mitigation

Following measures should be adopted in order to minimize the impacts related to the cultural issues.

- The Contractor will be required to maintain close liaison with the local communities to ensure that any potential conflicts related to the use of common resource utilization for the Project purposes are resolved quickly;
- Contractor will take care of the concerns of the local community and the sensitivity towards the local customs and traditions;

- Good relations with the local communities will be promoted by encouraging the Contractor to provide opportunities for skilled and unskilled employment to the locals on priority basis, as well as on-job training in construction for young people. Contractor should restrict the staff to mix with the locals to avoid any social problems; and
- Local vendors will be promoted for routine regular business by purchase of the camp site goods and services from them.

iv. Gender Issues

With the influx of labour force and other staff related to the construction activities, daily activities of the female population are likely to be affected. However, this impact will be of temporary nature.

Impact may also occur on the privacy of the local women during the construction activities as mostly the houses are without boundary walls. This impact can be categorized as indirect, low, local, medium term, temporary, medium probability and reversible.

Mitigation

Please refer the mitigation for "Gender Issues" during construction stage of proposed T/L which will be applicable to the Converter Station.

v. Health & Safety

Workers and the local community will be prone to accidents/incidents during the construction phase. They will be susceptible to accidents especially when the forklifts and cranes are being used for lifting the heavy equipments i.e. poles, transformers, conductors etc. Unmonitored construction activities, e.g. blasting may create an accident risk for the local residents particularly their children. This impact can be categorized as indirect, low, local, medium term, temporary, low probability and reversible.

Mitigation

Please refer to the mitigation for "Safety Hazardous" during construction stage of proposed T/L.

vi. Aesthetics

During the construction phase, excavation of land and drilling activities, storage of material and construction of workers camps at Project site, solid waste disposal by the workers and leakage and spillage of oil will have adverse impacts on the aesthetics of the area. Community have to face the noise and dust problems during the construction activities. This impact can be categorized as indirect, low, local, medium term, temporary, medium probability and reversible.

Mitigation

Proper disposal of excavated material and back filling of land after construction activities will minimize the impact on the aesthetics of the Project Area.

vii. Security Situation

Due to the vulnerable security situation in Section-I (AM # 41-49) Ghotki district there are potential risks for Contractor and other persons working during the construction stage. Therefore, these are potentially at risk. This impact can be categorized as indirect, low, local, medium term, temporary, low probability and reversible.

Mitigation

Due to the vulnerable security situations in the area special arrangements should be taken with the help of local heads for the Contractor staff to avoid any unpleasant incident.

Local heads should be involved in development works to gain confidence for local community.

7.5.3 Adverse Impacts during Operation Phase

7.5.3.1 Physical Environment

i. Air Quality

As mention earlier, the air quality during operation phase is not expected to be any different than that at planning and design phase and will be better than the air quality during construction phase due to the absence of large vehicular movements etc.

However, the heating of the oil in the transformers at Converter Stations and the heat generated due to current flowing through the supply lines will result in the emission of pollutants into the air, thus deteriorating air quality. These emissions can adversely affect human health. These emissions affect human life through the following process:

- Emission;
- Dispersion; and
- Reception.

Once these pollutants are dispersed into air they are inhaled by humans and intercepted by buildings. These emissions can be washed out of air through rain in the form of acid precipitation with significant adverse impacts on humans.

This impact can be categorized as direct, low, site-specific, short term, temporary, highprobability and reversible.

Mitigation

To mitigate the pollutants emissions, following measures should be adopted:

- Transformers should be equipped with silica gel; and
- Use of low sulfur oil should be ensured.

ii. Noise

Similarly, noise levels are expected to decrease at this phase due to the absence of construction workers and vehicles but it will be lower than the construction phase. However, during routine inspections, some noise may be generated during operational stage; however it will be of temporary in nature and insignificant.

This impact can be categorized as direct, low, site-specific, short term, temporary, medium probability and reversible.

Mitigation

Noise levels during operation phase will be negligible or insignificant during the operation stage. Therefore, no mitigation measures are suggested for the noise level.

iii. Soil

It is not expected that soil quality and texture will be adversely affected during the operation phase, however during routine inspection, if repair work is required involving oil leakage from the transformers and other electric equipments, the soil can be affected but this will be a minor impact and temporary in nature. This impact can be categorized as direct, low, site-specific, short term, temporary, low probability and reversible.

Mitigation

Impact on soil during operation phase will be insignificant. Good engineering practices will have to be adopted by the O&M staff of NTDC during the repair and replacement activities.

7.5.3.2 Ecological Environment

i. Flora

No major impact is foreseen on the flora during the operation phase of the Project.

ii. Fauna

During the operation phase of the Project no major impacts on the fauna are anticipated.

7.5.3.3 Socio-Economic Environment

i. Safety

The flow of electric current in the conductors will have an impact on the safety of the locals. The burning of the transformer or other electrical equipment due to short circuiting can create a fire which can spread. This will become a safety hazard for the locals. This impact can be categorized as direct, low, local, long term, permanent, low probability and irreversible.

Mitigation

During the operational phase of the Project, a security plan should be employed to ensure the safety of the employees working at the Converter Station. An effective communication system must be established so that the proper authorities are notified in case there is a fire in the Converter Station.

Table 7-3: Public Infrastructure within COI (Section I)

Sr. No.	Angle Marker	Length (KM)	Road		Type of Area	Canal	River	Shrine/ Graveyard	Tube Well	Residential Areas	Fish Pond/ Water Pond	Nullah	Railway Line	T/L	Forest	Airport	Orchard	Mosque	Brick Kiln	Reference Sheet #
			Katcha	Pacca																
1	Converter Station		Yes	Yes	Agriculture									Yes			Banana			Sheet # 1
2	1	0	Yes	Yes	Agriculture									Yes			Banana			Sheet # 1
3	2	1.71	Yes		Agriculture					Yes				Yes			Banana			Sheet # 1
4	3	3.13	Yes		Agriculture												Banana	Yes		Sheet # 1
5	4	4.97	Yes	Yes	Agriculture					Yes				Yes			Banana	Yes		Sheet # 1
6	4--5		Yes	Yes	Agriculture					Yes				Yes			Banana, Mango			Sheet # 1
7	5	6.9	Yes	Yes	Agriculture					Yes	Yes			Yes			Banana, Mango	Yes		Sheet # 1
8	5--6		Yes	Yes	Agriculture					Yes	Yes			Yes			Banana and Mango	Yes		Sheet # 1
9	6	10.29	Yes		Agriculture with some Barren land						Yes	Yes								Sheet # 1
10	6	10.29	Yes	Yes	Agriculture					Yes		Yes		Yes			Banana	Yes		Sheet # 1
11	7	16.55	Yes	Yes	Agriculture									Yes			Banana			Sheet # 1
12	7--8		Yes	Yes	Agriculture									Yes			Banana, Mango			Sheet # 2
13	8	19.5	Yes	Yes	Agriculture									Yes			Banana			Sheet # 2
14	8--9		Yes		Agriculture									Yes			Banana			Sheet # 2
15	8--9		Yes		Agriculture	Tando Adam Branch Canal								Yes						Sheet # 2
16	8--9		Yes		Agriculture	Tando Adam Branch Canal			Yes		Yes			Yes			Banana			Sheet # 2
17	9	26.97	Yes	Yes	Agriculture					Yes	Yes			Yes			Banana			Sheet # 2
18	9--10		Yes	Yes	Agriculture					Yes							Banana	Yes		Sheet # 2
19	10	29.46	Yes	Yes	Agriculture	Jam Branch					Yes							Yes		Sheet # 2

Sr. No.	Angle Marker	Length (KM)	Road		Type of Area	Canal	River	Shrine/ Graveyard	Tube Well	Residential Areas	Fish Pond/ Water Pond	Nullah	Railway Line	T/L	Forest	Airport	Orchard	Mosque	Brick Kiln	Reference Sheet #
			Katcha	Pacca																
						Canal														
20	10--11		Yes	Yes	Agriculture	Jam Branch Canal														Sheet # 2
21	11	33.91	Yes	Yes	Agriculture					Yes				Yes						Sheet # 2
22	12	36.15	Yes		Agriculture			DargahSay edMalok Shah Baba		Yes				Yes				Yes		Sheet # 2
23	13	42.01	Yes	Yes	Agriculture					Yes								Yes		Sheet # 3
24	14	46.37	Yes		Agriculture	Jamrao Canal			Yes	Yes				Yes						Sheet # 3
25	15	52.66	Yes	Yes	Agriculture					Yes										Sheet # 3
26	16	57.63	Yes	Yes	Agriculture					Yes				Yes						Sheet # 4
27	17	61.96	Yes		Agriculture	Dim Branch Canal			Yes	Yes				Yes						Sheet # 4
28	18	67.07	Yes		Agriculture	Dim Branch Canal				Yes				Yes						Sheet # 4
29	19	68.61	Yes		Barren Landsurround ed by Agriculture Area				Yes					Yes						Sheet # 4
30	20	72.04	Yes		Barren Land Most and LessAgricultur e					Yes	Yes							Yes		Sheet # 4
31	21	82.3	Yes		10 to 20 % Agriculture and 80 % Barren					Yes	Yes							Yes		Sheet # 5
32	21	82.3	Yes		50% Agriculture and 50% Barren					Yes				Yes			banana, Lemon, Mango, Oranges	Yes		Sheet # 5
33	22	87.78	Yes	Yes	Agriculture with less Barren					Yes	Yes			Yes				Yes		Sheet # 5
34	23	89.03	Yes	Yes	60 % Agriculture and 40 % Barren					Yes	Yes			Yes				Yes		Sheet # 5
35	24	90.51	Yes	Yes	Agriculture with less Barren					Yes	Yes			Yes				Yes		Sheet # 5

Sr. No.	Angle Marker	Length (KM)	Road		Type of Area	Canal	River	Shrine/ Graveyard	Tube Well	Residential Areas	Fish Pond/ Water Pond	Nullah	Railway Line	T/L	Forest	Airport	Orchard	Mosque	Brick Kiln	Reference Sheet #
			Katcha	Pacca																
36	25	96.52	Yes		Les Agriculture and more Barren						Yes			Yes				Yes		Sheet # 5
37	26	102.95	Yes		Barren and Desert type with less Agriculture						Yes			Yes						Sheet # 6
38	26-27		Yes		Barren and Desert type with less Agriculture													Yes		Sheet # 6
39	27	116.66	Yes		Barren Land					Yes	Yes			Yes						Sheet # 6
40	28	126.69	Yes		Barren more with less agriculture					Yes	Yes			Yes						Sheet # 7
41	29	153.19	Yes	Yes	Barren (Near Agriculture Area inside COI)					Yes										Sheet # 8
42	30	173.05	Yes	Yes	Sand Dunes					Yes				Yes						Sheet # 9
43	31	177.43	Yes	Yes	Agriculture					Yes				Yes			Dates			Sheet # 10
44	32	181.14	Yes		Agriculture					Yes				Yes			Dates			Sheet # 10
45	33	183.46	Yes		Barren Land With Less Agriculture Area					Yes										Sheet # 10
46	34	186.83	Yes	Yes	Agriculture with less Barren area					Yes				Yes			Mango			Sheet # 10
47	35	197.56	Yes	Yes	Mostly Barren / Desert area with less Agriculture area					Yes				Yes			Mango Dates	Yes		Sheet # 11
48	36	201.48	Yes		Mostly Barren / Desert area with less Agriculture area									Yes			Khumbri	Yes		Sheet # 11
49	37	210.71	Yes	Yes	Almost 60% Barren and 40% Agriculture						Yes			Yes			Dates	Yes		Sheet # 11
50	38	217.68	Yes		Mostly Barren / Desert area with less Agriculture					Yes				Ues			Khumbri	Yes		Sheet # 11

Sr. No.	Angle Marker	Length (KM)	Road		Type of Area	Canal	River	Shrine/ Graveyard	Tube Well	Residential Areas	Fish Pond/ Water Pond	Nullah	Railway Line	T/L	Forest	Airport	Orchard	Mosque	Brick Kiln	Reference Sheet #
			Katcha	Pacca																
					area															
51	Near A.M 38	217.68	Yes		Agriculture					Yes				Yes			Dates			Sheet # 12
52	Near A.M 38	217.68	Yes		Agriculture									Yes			Dates and Lemon			Sheet # 12
53	Near A.M 38	217.68	Yes		Agriculture															Sheet # 12
54	Near A.M 39	259.52	Yes		Agriculture									Yes				Yes		Sheet # 14
55	Near A.M 39	259.52	Yes		Agriculture						Yes			Yes				Yes		Sheet # 14
56	Near 40	262.16	Yes		Agriculture					Yes		Yes								Sheet # 14
57	Near 41	266.49	Yes		Agriculture with Few patches of Sand Dunes					Yes										Sheet # 14
58	Near 42	268.61	Yes		Agriculture															Sheet # 14
59	Near 43	273.78	Yes		Agriculture					Yes				Yes						Sheet # 15
60	44	279.67																		Sheet # 15
61	45	285.74																		Sheet # 15
62	46	290.75																		Sheet # 16
63	47	298.77																		Sheet # 16
64	48	301.38	Yes		Agriculture with less desert area					Yes	Yes			Yes			Lemon			Sheet # 16
65	49	313.37	Yes		Agriculture (mostly trees) with 70% desert area					Yes				Yes			Lemon			Sheet # 17

Table 7-3: Public Infrastructure within COI (Section II)

Sr. No.	Angle Marker	Length (KM)	Road		Type of Area	Canal	River	Shrine/ Graveyard	Tube Well	Residential Areas	Fish Pond/ Water Pond	Nullah	Railway Line	T/L	Forest	Airport	Orchard	Mosque	Brick Kiln	Reference Sheet #
			Katcha	Pacca																
1	50	342.08	Yes	Yes	Agriculture with less desert area					Yes				Yes			Lemon	Yes		Sheet # 17
2	51	340.75	Yes	Yes	Agriculture with less desert area					Yes				Yes				Yes		Sheet # 18
3	52	344.46	Yes		Agriculture with less desert area						Yes			Yes			Lemon			Sheet # 19
4	53	348.55	Yes		Agriculture Area				Yes	Yes				Yes			Mango (Few Trees)	Yes		Sheet # 19
5	54	354.84	Yes	Yes	Agriculture Area and surrounded by some Sand Dunes					Yes				Yes						Sheet # 19
6	55	356.55		Yes	Agriculture Area	Chaman Canal				Yes										Sheet # 19
7	56	364.5		Yes	Agriculture Area				Yes	Yes				Yes						Sheet # 20
8	57	369.59	Yes		Agriculture Area and surrounded by some Sand Dunes	Abe Hayat Canal					Yes			Yes				Yes		Sheet # 20
9	58	372.85		Yes	Agriculture Area and surrounded by some Sand Dunes	Abe Hayat Canal				Yes				Yes			Lemon and Orange			Sheet # 20
10	Near 59	386.99		Yes	Desert									Yes						Sheet # 21
11	60	399.48		Yes	Desert									Yes						Sheet # 22
12	60-61		Yes	Yes	Agriculture with less desert area						Yes			Yes				Yes		Sheet # 23
13	61	451.12	Yes	Yes	Agriculture with less desert area									Yes						Sheet # 24
14	62-63	481.9			Desert Area									Yes						Sheet # 25
15	Near 63	499.9		Yes	Agriculture Area and surrounded by Sand Dunes					Yes				Yes						Sheet # 27
16	64	519.59		Yes	Barren Area and surrounded			ChananPir			Yes			Yes				Yes		Sheet # 28

Sr. No.	Angle Marker	Length (KM)	Road		Type of Area	Canal	River	Shrine/ Graveyard	Tube Well	Residential Areas	Fish Pond/ Water Pond	Nullah	Railway Line	T/L	Forest	Airport	Orchard	Mosque	Brick Kiln	Reference Sheet #
			Katcha	Pacca																
					Area is Agriculture															
17	65	534.5	Yes	Yes	Agriculture with less desert area					Yes	Yes			Yes				Yes		Sheet # 29
18	66	540.4		Yes	More Desert and Less Agriculture					Yes				Yes				Yes		Sheet # 29
19	67	542.1		Yes	50% Agriculture and 50% Desert			Yes		Yes				Yes			Mango, Oranges , Dates	Yes		Sheet # 29
20	68-69	554..4	Yes		Desert						Yes			Yes						Sheet # 30
21	69-70	617.3	Yes		Desert						Yes			Yes						Sheet # 31
22	Near 70	614.2	Yes		Agriculture Area									Yes				Yes		Sheet # 33
23	71	626.8	Yes		Desert Area						Yes									Sheet # 34
24	72	633.1	Yes		Agriculture Area									Yes						Sheet # 34
25	73	637.5	Yes		Agriculture Area alongwith some barren patches									Yes			Mango	Yes		Sheet # 35
26	74	645.4		Yes	Agriculture Area alongwith some barren patches					Yes				Yes						Sheet # 35
27	75	650.6		Yes	Agriculture Area								Yes					Yes		Sheet # 35
28	75	650.6	Yes	Yes	Agriculture					Yes		Same Nullah	Yes	Yes (Large T/L)				Yes		Sheet # 35
29	76	654.3	Yes	Yes	Agriculture									Yes				Yes		Sheet # 36
30	77 - 78	661.5	Yes		Agriculture									Yes				Yes		Sheet # 36
31	Near 79	667.1	Yes		Agriculture			Yes		Yes				Yes				Yes	Yes	Sheet # 36
32	80	668.8	Yes	Yes	Agriculture					Yes				Yes				Yes	Yes	Sheet # 36
33	81	671.7	Yes	Yes	Agriculture			Yes		Yes				Yes				Yes	Yes	Sheet # 37
34	82	676.1	Yes	Yes	Agriculture					Yes				Yes				Yes		Sheet # 37

Sr. No.	Angle Marker	Length (KM)	Road		Type of Area	Canal	River	Shrine/ Graveyard	Tube Well	Residential Areas	Fish Pond/ Water Pond	Nullah	Railway Line	T/L	Forest	Airport	Orchard	Mosque	Brick Kiln	Reference Sheet #
			Katcha	Pacca																
35	83	678.4	Yes	Yes	Agriculture					Yes										Sheet # 37
36	84	681.9	Yes		Agriculture									Yes				Yes		Sheet # 37
37	85	685	Yes	Yes	Agriculture			Yes		Yes	Yes			Yes			Dates	Yes	Yes	Sheet # 37
38	86	689.2	Yes	Yes	Agriculture					Yes				Yes					Yes	Sheet # 37
39	87	691.6	Yes		Agriculture					Yes				Yes				Yes		Sheet # 38
40	88	697.8	Yes	Yes	Agriculture					Yes				Yes				Yes		Sheet # 38
41	88	697.8		Yes	Agriculture Area				Yes		Yes			Yes			Guava	Yes		Sheet # 38
42	89	700.6	Yes		Agriculture Area alongwith some barren patches					Yes	Yes			Yes				Yes		Sheet # 38
43	90	705.9	Yes		Agriculture Area	Sikanda rWah		Yes		Yes								Yes		Sheet # 38
44	91	708.7		Yes	Agriculture Area			Yes	Yes					Yes				Yes		Sheet # 39
45	92	709.6	Yes	Yes	Agriculture Area			Yes	Yes	Yes				Yes			Yes	Yes	Yes (Inside Village)	Sheet # 39
46	93	711.2	Yes		Agriculture Area		Yes			Yes										Sheet # 39
47	94	713.3	Yes		Agriculture Area		Yes			Yes										Sheet # 39
48	95	714.6	Yes		Agriculture Area		Yes			Yes										Sheet # 39
49	96	716.4	Yes		Agriculture Area alongwith some barren patches		Yes			Yes										Sheet # 39
50	97	718.1		Yes	Agriculture Area					Yes				Yes				Yes		Sheet # 39
51	98	719.9	Yes		Agriculture Area			Yes		Yes								Yes		Sheet # 39
52	99	721.3		Yes	Agriculture Area					Yes				Yes				Yes		Sheet # 39
53	100	722.1	Yes		Agriculture Area					Yes				Yes						Sheet # 40
54	101	723.5	Yes		Agriculture Area					Yes				Yes						Sheet # 40

Sr. No.	Angle Marker	Length (KM)	Road		Type of Area	Canal	River	Shrine/ Graveyard	Tube Well	Residential Areas	Fish Pond/ Water Pond	Nullah	Railway Line	T/L	Forest	Airport	Orchard	Mosque	Brick Kiln	Reference Sheet #
			Katcha	Pacca																
55	102	724.8	Yes		Agriculture Area	Khadir Branch			Yes	Yes				Yes				Yes		Sheet # 40
56	103	728.6		Yes	Agriculture Area					Yes				Yes						Sheet # 40
57	104	730.7		Yes	Agriculture Area					Yes				Yes						Sheet # 40
58	105	732.6	Yes		Agriculture Area					Yes				Yes						Sheet # 40
59	106-107	736.3	Yes		Agriculture					Yes				Yes						Sheet # 40
60	107	739.9	Yes	Yes	Agriculture					Yes				Yes						Sheet # 40
61	108	741.9	Yes	Yes	Agriculture			Yes		Yes				Yes				Yes		Sheet # 41
62	109	744.27	Yes	Yes	Agriculture					Yes			Yes	Yes				Yes		Sheet # 41
63	110	747.5	Yes	Yes	Agriculture					Yes				Yes						Sheet # 41
64	111	748.8	Yes	Yes	Agriculture					Yes				Yes				Yes	Yes	Sheet # 41
65	112	750.4	Yes	Yes	Agriculture					Yes	Yes			Yes				Yes	Yes	Sheet # 41
66	113	752.2	Yes	Yes	Agriculture					Yes				Yes				Yes		Sheet # 41
67	114	753.9	Yes		Agriculture					Yes				Yes (Large T/L)				Yes		Sheet # 41
68	115	755.3	Yes		Agriculture			Yes		Yes				Yes				Yes	Yes	Sheet # 41
69	116	760.9	Yes		Agriculture Area			Yes		Yes				Yes						Sheet # 41
70	117	763.2	Yes		Agriculture Area					Yes				Yes						Sheet # 42
71	118	765.02	Yes		Agriculture Area					Yes				Yes						Sheet # 42
72	119	767.7	Yes		Agriculture Area			Yes		Yes				Yes						Sheet # 42
73	120	770.2	Yes		Agriculture Area			Yes	Yes	Yes				Yes			Yes			Sheet # 42
74	121	773.5		Yes	Agriculture Area			Yes		Yes				Yes				Yes		Sheet # 42
75	122	774.6		Yes	Agriculture Area					Yes				Yes				Yes		Sheet # 42

Sr. No.	Angle Marker	Length (KM)	Road		Type of Area	Canal	River	Shrine/ Graveyard	Tube Well	Residential Areas	Fish Pond/ Water Pond	Nullah	Railway Line	T/L	Forest	Airport	Orchard	Mosque	Brick Kiln	Reference Sheet #
			Katcha	Pacca																
76	123	777.2	Yes		Agriculture Area					Yes				Yes			Guava			Sheet # 42
77	124	779.3	Yes		Agriculture Area			Yes		Yes				Yes				Yes		Sheet # 42
78	125	781.01		Yes	Agriculture Area					Yes				Yes			Dates	Yes		Sheet # 42
79	126	783.9	Yes		Forest									Yes	Yes					Sheet # 43
80	127	787.4	Yes	Yes	Agriculture					Yes				Yes				Yes		Sheet # 43
81	128	789.7	Yes	Yes	Agriculture			Yes		Yes				Yes				Yes		Sheet # 43
82	129	790.6	Yes	Yes	Agriculture					Yes				Yes				Yes		Sheet # 43
83	130	792.4	Yes		Agriculture					Yes				Yes				Yes		Sheet # 43
84	131	794.1	Yes	Yes	Agriculture									Yes				Yes		Sheet # 43
85	132	795.9	Yes	Yes	Agriculture					Yes				Yes				Yes		Sheet # 43
86	133	796.3	Yes	Yes	Agriculture	Gambeer Canal				Yes				Yes				Yes		Sheet # 43
87	134	798.6	Yes	Yes	Agriculture					Yes		Same Nullah		Yes				Yes		Sheet # 43
88	135	799.9	Yes	Yes	Agriculture			Yes		Yes				Yes (Large T/L)				Yes		Sheet # 43
89	136	800.7	Yes	Yes	Agriculture					Yes				Yes				Yes		Sheet # 43
90	137	801.4	Yes	Yes	Agriculture					Yes				Yes				Yes	Yes	Sheet # 44
91	138	803.9	Yes		Agriculture															Sheet # 44
92	139	806.2	Yes	Yes	Agriculture									Yes						Sheet # 44
93	140	808.2	Yes	Yes	Agriculture					Yes				Yes				Yes		Sheet # 44
94	141	814.7	Yes	Yes	Agriculture					Yes				Yes			Jambul	Yes	Yes	Sheet # 44
95	142	817.4	Yes	Yes	Agriculture					Yes				Yes (Large T/L)			Jambul	Yes		Sheet # 44
96	143	820.1	Yes		Agriculture					Yes				Yes (Large T/L)			Jambul	Yes		Sheet # 44

Sr. No.	Angle Marker	Length (KM)	Road		Type of Area	Canal	River	Shrine/ Graveyard	Tube Well	Residential Areas	Fish Pond/ Water Pond	Nullah	Railway Line	T/L	Forest	Airport	Orchard	Mosque	Brick Kiln	Reference Sheet #
			Katcha	Pacca																
97	144	821.05	Yes		Agriculture					Yes				Yes (Large T/L)			Jambul	Yes		Sheet # 44 & 45
98	145	822.8	Yes	Yes	Agriculture			Yes		Yes				Yes			Jambul	Yes		Sheet # 45
99	146	823.8	Yes		Agriculture					Yes				Yes			Jambul	Yes		Sheet # 45
100	147	824	Yes		Agriculture					Yes				Yes			Jambul	Yes		Sheet # 45
101	148	826.4	Yes	Yes	Agriculture								Yes	Yes (Large T/L)				Yes		Sheet # 45
102	149	827.4	Yes	Yes	Agriculture					Yes			Yes	Yes (Large T/L)			Janbul	Yes		Sheet # 45
103	150	835		Yes	Agriculture Area			Yes		Yes				Yes			Yes		Yes	Sheet # 45
104	151	836.8	Yes		Agriculture Area									Yes						Sheet # 45
105	152	837.6		Yes	Agriculture Area									Yes			Yes			Sheet # 45
106	153	837.8		Yes	Agriculture Area					Yes				Yes			Yes			Sheet # 45
107	154	840.6	Yes		Agriculture Area					Yes				Yes						Sheet # 45 & 46
108	155	842.7	Yes		Agriculture Area					Yes				Yes					Yes	Sheet # 46
109	156	844.1	Yes		Agriculture Area					Yes				Yes						Sheet # 46
110	157	845.5	Yes		Agriculture Area					Yes							Yes	Yes		Sheet # 46
111	158	846.6	Yes		Agriculture Area					Yes							Yes	Yes		Sheet # 46
112	159	848.5		Yes	Agriculture Area					Yes				Yes						Sheet # 46
113	160	849.4		Yes	Agriculture Area					Yes				Yes						Sheet # 46
114	161	851.1	Yes		Agriculture Area			Yes	Yes					Yes			Yes	Yes		Sheet # 46
115	162	853.03	Yes		Agriculture Area									Yes			Yes	Yes		Sheet # 46
116	163	853.9		Yes	Agriculture Area									Yes						Sheet # 46
117	164	854.9		Yes	Agriculture Area				Yes		Yes			Yes					Yes	Sheet # 46

Sr. No.	Angle Marker	Length (KM)	Road		Type of Area	Canal	River	Shrine/ Graveyard	Tube Well	Residential Areas	Fish Pond/ Water Pond	Nullah	Railway Line	T/L	Forest	Airport	Orchard	Mosque	Brick Kiln	Reference Sheet #
			Katcha	Pacca																
118	165	857.3		Yes	Agriculture Area			Yes						Yes				Yes	Yes	Sheet # 46 and 47
119	166	859.7	Yes	Yes	Agriculture	Baloki-Salman ki Link Canal				Yes	Yes	Yes		Yes						Sheet # 47
120	167	862.8	Yes		Agriculture		Ravi River							Yes						Sheet # 47
121	168	865.3	Yes	Yes	Agriculture					Yes	Yes			Yes (large T/L)				Yes		Sheet # 47
122	169	865.5	Yes	Yes	Agriculture									Yes (large T/L)			Guava Oranges	Yes		Sheet # 47
123	Converter Station Lahore		Yes	Yes	Agriculture					Yes		Yes		Yes (large T/L)			Guava	Yes		Sheet # 47

8 COMPENSATION POLICY FRAMEWORK

8.1 General

This section defines the compensation and rehabilitation framework for the proposed T/L. This framework is based on the laws of Pakistan and the requirements of the ADB Safeguard Policy Statement 2009 on Involuntary Resettlement and summarizes the main components of the policy framework prepared specifically for the proposed T/L Project to ensure that ADB's policy on involuntary resettlement is complied with. All the detailed surveys and other requirements related to the compensation, rehabilitation will be covered under LARP which is being prepared separately.

8.2 Identification of Project Affected Persons (PAPs)

As referred earlier, the Project is at the feasibility stage and detailed survey along with the spotting of the T/L Towers and their design are still to be finalized. Only demarcation of the T/L route and AMs has been marked on Google Imageries. In the absence of the demarcation of T/L in the field and spotting of Towers, it was very difficult to identify the PAPs within the ROW. However, efforts were made to identify the PAPs by the Consultants within the ROW which is a part of COI. The number of affectees will be identified within the ROW when the detailed LARP survey after the spotting of Towers at the site will be available. Occurrence of any public and religious structures such as mosque or graveyard will also be identified/verified at that stage, which may be affected due to the Project implementation.

The major effect of the Project is the loss of crops and few orchards during the implementation stage. As discussed earlier, the crops such as wheat, cotton, maize, and sugarcane and orchards of mangoes, plumb, guava and citrus are estimated to be affected during the field survey and the construction activities. However, at the present stage of the Project, it is hard to identify the actual loss and the list of the landowners to be affected.

8.3 Related Laws, Policies and Guidelines

Following paragraphs provide review of applicable laws and guidelines to be used for the compensation purpose:

8.3.1 Land Acquisition Act, 1894

The LAA 1894, with its successive amendments, is the main law regulating land acquisition for public purpose. The LAA has been interpreted by local governments and some province has augmented the LAA by issuing provincial legislations. The LAA and its Implementation rules require that following an impacts assessment/valuation effort, land and crops are compensated in cash at market rate to titled landowners and registered land tenants/users, respectively. The LAA mandates that land valuation is to be based on the latest 5-3 years average registered land sale rates, though, in several recent cases the median rate over the past year, or even the current rates, have been applied. Due to widespread land under-valuation by the Revenue Department, current market rates are now frequently used with an added 15 per cent Compulsory Acquisition Surcharge as provided in the LAA.

Based on the LAA, only legal owners and tenants registered with the Land Revenue Department or possessing formal lease agreements, are eligible for compensation. The rights of the non-titled, are however addressed under the 1986, Punjab Jinnah Abadis for Non-proprietors in Rural Areas Act which recognize squatters right to receive rehabilitation in form of a replacement plot. It is to be noted that this right has been sometimes extended in practice to include some form of rehabilitation in cash or in forms different from land. Projects such as Chotiari Dam, Ghazi Barotha HydroPower and National Highways Improvement, have awarded compensation and assistance to unregistered tenants and other forms of AH (sharecroppers/squatters).

It must also be noted here that the LAA does not automatically mandate for specific rehabilitation/assistance provisions benefiting the poor, vulnerable groups, or severely affected AHs, nor does it automatically provide for rehabilitation of income/livelihood losses or resettlement costs. This however is often done in many Projects in the form of adhoc arrangements based on negotiations for a specific Project.

As noted above, exceptions to the rule are intrinsic to the fact that the law is both elastic and broadly interpreted at provincial level depending on operational requirements, local needs and socio-economic circumstances. Recourse is often taken to adhoc arrangements, agreements and understandings for resettlement in difficult situations. The above is also influenced by the fact that an amendment of the LAA has been considered necessary by the Ministry of Environment now Ministry of Disaster Management. Accordingly, a National Resettlement Policy (NRP) and a Resettlement Ordinance have been drafted to broaden LAA provisions and current practices so as to widen the scope of eligibility and tightening up loopholes (i.e. regarding definitions of malpractices, cut-off dates, political influence on routing etc.). But both these documents are still awaiting government's approval for implementation.

8.3.2 ADB's Involuntary Resettlement Policy

The ADB Policy on Involuntary Resettlement is based on the following principles:

- Involuntary resettlement is to be avoided or at least minimized;
- Compensation must ensure the maintenance of the AHs' pre-Project living standards;
- Compensation is required for PAP's who as a result of a Project has their access to, or use of, land restricted;
- PAPs should be fully informed and consulted on Land Acquisition and Resettlement (LAR) compensation options;
- PAPs socio-cultural institutions should be supported/used as much as possible;
- Compensation will be carried out with equal consideration of women and men;
- Lack of formal legal land title should not be a hindrance to rehabilitation;
- Particular attention should be paid to households headed by women and other vulnerable groups, such as indigenous people and ethnic minorities and appropriate assistance should be provided to help them improve their status;
- LAR should be conceived and executed as a part of the Project and the full costs of compensation should be included in Project costs and benefits; and
- Compensation/rehabilitation assistance will be paid prior to ground levelling and demolition.

8.3.2.1 Comparison of Pakistan Land Acquisition Act & ADB Resettlement Policy

Table 8-1 below outlines the differences between Pakistani Law and ADB policy.

Table 8–1: Pakistan and ADB Land Acquisition Policies

Pakistan's Land Acquisition & Telegraph Acts	ADB Involuntary Resettlement Policy
Land compensation only for titled landowners or customary rights holders.	Lack of title should not be a bar to compensation and/or rehabilitation. Non-title-holders are to be rehabilitated also.
Crop losses compensation provided only to registered landowners and lease/sharecrop tenants (Non-registered are often deprived).	Crop compensation are provided to landowners and sharecrop/lease tenants according to their shares whether they are registered or not.
Tree losses are compensated on the basis of officially fixed rates by the Forest and	Tree losses are compensated according to actual worth of affected trees based on market

Pakistan's Land Acquisition & Telegraph Acts	ADB Involuntary Resettlement Policy
Horticulture departments.	rates.
Land valuation based on the median registered land transfer rate over the previous 3 years.	Land valuation is to be based on current replacement (open market) value.
Structures valuation based on official rates, with depreciation deducted from the structure gross value.	Valuation of built-up structures is based on current market value/cost of new construction of the structure.
Land Acquisition Collector (LAC) or District Judge (in case of the Telegraph act) are the final authorities to decide disputes and address complaints regarding quantification and assessment of compensation for the affected lands and other assets.	Complaints and grievances are resolved informally through community participation in the Grievance Redress Committees (GRC), local governments, NGO and/or local- level community based organizations.
The Telegraph Act (TA) provides that land for Tower construction or under a T/L is not to be acquired or compensated as long as the land's permanent productive potential is not affected. Under the TA therefore only temporary impacts on crops are compensated.	Based on ADB policy all land impacts are to be compensated. As urban/residential-commercial land is affected either if a Tower/pole provides clearance or not, the TA provisions have been modified for this project so as to address damages that a Tower/pole causes to plots with real estate value. For this project urban and commercial or residential plots weather urban or rural will be fully acquired and compensated at market rates. The same will happen in case of rural/agricultural land when the land under a Tower/pole is no longer usable or access of the APs is restricted.

Conclusions

In principle, Pakistan Law and ADB Policy adhere not only to the objective of PAPs compensation, but also to the objective of rehabilitation. However, LAA is unclear on how rehabilitation is to be achieved and in practice the provision of rehabilitation is left to ad hoc arrangements taken by local governments and specific Project Proponents. To clarify these issues and reconcile eventual gaps between Pakistan Law and ADB Policy, the LARF and LARP for the proposed T/L is being prepared as a separate document to ensure compensation at replacement cost of all items, the rehabilitation of informal settlers and the provision of subsidies or allowances for PAPs that may be relocated, suffer business losses, or may be severely affected.

8.3.3 Telegraph Act (TA), 1885

In case of impacts caused by Poles and Towers for public facilities and T/Ls, the land acquisition is not regulated by the LAA but instead by the Telegraph Act, 1885 (amended in 1975). The original provision of this law was that the land occupied by telegraph poles was not to be compensated (only crops destroyed during the erection of the pole were compensated). This was based on the logic that a pole, covering only a negligible land area, does not cause substantial impacts to landusers. This, however, is no longer the case once the same provision is extended to transmission Towers.

The Telegraph Act (Section 11) confers Powers on the DISCOs to enter private lands and (Section 10) construct/ maintain electric poles and lines without the need to acquire the land affected and paying compensation for it. However, the Sub-section 10 (d) provides that a DISCOs is required to avoid causing unnecessary damages to the affected land and associated assets. Finally, the Section 16 provides that if any such damage occurs (i.e. damages to crops, irrigation facilities, and land quality or land income). The Proponent has to provide compensation for the damages.

To accommodate the APs needs, under this program, the DISCOs have agreed to apply the Telegraphic Act liberally by i) compensating at market rates all land occupied by Towers in urban areas; ii) by avoiding land impacts in rural areas through the use of Towers with sufficient vertical clearance to allow the continuation of unrestricted farming and animal grazing; and iii) if the construction of such Towers is impossible, by compensating the land occupied by Tower bases land also in rural areas. In addition, the DISCOs will compensate by default all crops expected to be affected by the 3 major distribution lines construction phases, i.e. i) construction of Tower bases; ii) Tower erection; and iii) stringing.

8.3.4 Punjab Katchi Abadis Act, 1992

Punjab Katchi Abadis Act, 1992 (Amendment Ordinance No. XVIII of 2007), this ordinance updated the Punjab Katchi Abadis Act, 1986. It made provisions for the regularization of Katchi Abadis and outlined the provision for giving assistance. The ordinance stated that the Director General shall be appointed by the Government and will be responsible to implement the Act. Subject to the provisions of sub-sections (2), (3), (4) and (5) and the directions, if any, of the government the Director General can regularize any settlement of more than 40 dwelling units that was occupied before 23rd March 2010.

8.3.5 Sindh Katchi Abadis Act, 1987

The impact of urbanization and urban growth on land has been severe. The government is unable to provide land for the poor and migrants. This reality has led to a large scale proliferation of squatter settlements or Katchi Abadis. People get piece of land from the land grabbers at an affordable price. Mostly, the land belongs to the Board of Revenue. The Katchi Abadi is officially a temporary settlement where legal leases cannot be issued. However, the official temporary nature of these settlements may be perceived quite differently by the occupants as the defecto security level of the settlement is usually much higher. The security level has also been increased with periodic announcements by different governments for regularizing Katchi Abadis creating one cut-off date following by another. Under the policy, Katchi Abadis existing upto 23 March 1985 and comprising at least 40 houses will be identified for regularization.

Until the late seventies low-income housing policies in Karachi were based on clearance of Katchi abadis and resettlement of the residents. All the resettlement schemes failed to reach the target group due to variety of reasons. In the early seventies a change of policy came about. This policy was to legalize and improve these settlements rather than to demolish them. There were the following four basic features of the policy:

i). Security of tenure for the residents was provided through the issue of 99 years leases for which the resident had to pay a lump sum amount. The lease rate were differentiated as per landuse category (residential, commercial) and according to plot size (the larger the plot the higher the lease rate per square yards);

ii). Karachi Metropolitan Cooperation (KMC) carried out a program of environmental upgrading (water supply, drainage, sewerage and solid waste disposal systems and metalling of roads). Planning standards where flexible in relation to local circumstances, and incremental, no solution was fixed; rather the opportunity for future development was being guaranteed;

iii). The whole program was self-financing; improvement had to be financed out of revenues from lease and improvement charges;

iv). In the whole process, peoples participation was crucial, not only because the residents had to pay for the improvements; also, because planning (e.g. of standards) cannot be done properly without the residents involvement. Finally, on plot improvements were completely left upto the inhabitants;

Thus, the regularized Katchi Abadi is one, which has been approved by the government agencies for proper leasing and carrying out physical improvements to certain acceptable minimum standards. Its then forms an officially accepted part of the city master plan.

In 1978 Martial Law Order (MLO) No. 67 was issued called 'Regularization and Development of Katchi Abadis'. It was reconstituted in 1979 (MLO 110) and again in 1982 (MLO 183), and complemented by the Sindh Katchi Abadi Rules of 1982. This order further states refer page no. 2 article 7(1)(1)(a) that regularization scheme shall inter-alia provide for 'the rehabilitation of the unauthorized occupants of a Katchi Abadi in the same Katchi Abadi or, where it is not possible, in any other locality by allotting plots of prescribed size'.

In 1980 Chief Martial Law Administrator Zone 'C' promulgated an order MLO 130 to provide for measures for prevention and removal of encroachments. This order was called Removal of Encroachment Order, refer page 8. In 1983 Martial Law Administrator zone 'C' reconstituted MLO 130 by MLO 202. This order provides the encroacher a facility to appear before the officer issuing the notice for removal of encroachment refer Page 11 Article 8.

In March 1987, the Government of Sindh enacted a new law known as Sindh Katchi Abadis Act, 1987 refer page 52, whereby Sindh Katchi Abadis Authoirty was setup under the Act. Sindh Katchi Abadis Authority was authorized to declare any area or part thereof, which was partially or wholly occupied in an unauthorized manner, prior to March 23, 1985, as a Katchi Abadi.

In the year 1993, in suppression of all previous orders, directives and instructions formulated Sindh Katchi Abadis Authority (Regulations, improvement and development) Regulations, refer page no. 19, was notified. The article 8 of chapter IV of this regulation states "that the regularization scheme should dislocate minimum occupants, article 10 (ii) and (v) provides for an opportunity to the occupant to submit his objection regarding the scheme and when any building is required to be demolished according to the approved development scheme, the Authority shall compensate the owner in shape of allocating a minimum size open plot. Article 8 and 9 of chapter VII of the Sindh Katchi Abadi Act regulations 1993 further provides for the relocation and rehabilitation for the structures demolished from any reservations or amenity areas. Sufficient time will be given to the owner for removal of such structures'. and 'if affected by an approved scheme, original unauthorized occupant may be resettled by providing an open plot of not less than 80 sq. yd. in area, preferably within the same Katchi abadi depending on the availability of land on the rates as mentioned in schedule 'C' of Sindh Katchi Abadis Regulations 1993. No cash compensation shall be given except the provision of an open plot mentioned above'.

Present policy decisions announced by the Chief Executive of Pakistan for the Regularization and up-gradation of Katchi Abadis on 15th January 2001 refer Page No. 71 states that the process of the regularization and up-gradation of the before 1985 Katchi Abadis shall continue as per current policy.

8.4 Strategy for Compensation of Land Affected by Towers

Besides the amended LAA, the NTDC has adopted the Telegraph Act, 1885 (amended) for the construction and maintenance of T/L. The later Act was originally framed for the construction of telegraphic poles during the British Era and later inherited by Pakistan upon independence. This Act was subsequently adopted by WAPDA for electric poles and supply lines and eventually passed to NTDC. However, telegraphic or electric poles cover a much smaller area of land compared with transmission Towers which have the potential to affect crops, orchards and scattered wood and fruit trees. The NTDC makes utmost efforts to minimize resettlement impacts, alternatively the affected farmers are compensated for their crop and tree losses and built-up structures requiring relocation, based on prevalent market prices.

Based on current Pakistani Law and NTDC's practice, the land under the Towers is not acquired permanently and therefore, compensation is not required for land. However, it is suggested that the land under the Tower will not be acquired, but would only require compensation in the case where: (i) in rural areas, the Tower hinders access to the land under the Tower for cultivation; and/or, (ii) in urban/residential areas, the Tower restricts use of the land for housing development.

In the case of urban/residential areas, the land under Towers will be considered as being permanently affected and therefore it will be compensated in full. In the case of rural areas and agricultural land as long as the Towers provide sufficient clearance to allow the continuation of crop cultivation, the land will be considered to be temporarily affected (for the duration of Tower installation and stringing of the lines) and therefore will not be acquired nor compensated. However, for Towers with low-bars which would restrict the farmer's access for cultivation activities, the land will be considered as acquired permanently and compensated. However, the respective landowners can reuse such land for cultivation or similar purposes. But, as none of the Towers of this 500KV TL are located in an urban area nor they will hinder future cultivation of land in rural areas, no land compensation will be applicable for the land under Tower and only crop and tree compensation will be paid to the AHs.

The construction of Towers on agricultural land however will still require the provision of compensation for crops and loss of trees, for the area under the Tower plus a small perimeter surrounding it (an access and working area). The area included in the perimeter has been assessed at10,000m^2(1 ha) for a ±600KV Tower. Furthermore, as the construction of Towers involves a 3-tier process, namely: (i) preparation of the foundation; (ii) erection of the Tower; and (iii) stringing of the Power cables and this process has the potential to affect three crops and thus, compensation for three crops will be paid to the affected farmers. The outstanding payment of compensation for the affected crops and trees by the construction of Tower foundations in the past (1996-97) will be paid to the affected farmers (landowners and sharecroppers) at the current market rates of the year of payment.

8.5 Land Classification

Identification of the type of land affected is an important step in determining eligibility for compensation of land. Jurisdiction rather than use classifies land. Rural land includes irrigated land and un-irrigated land and is governed by the Land Revenue Act, 1967 which must be read in conjunction with the LAA and other legislation that may also apply, including for example the Punjab Alienation of Land Act, 1900, Colonization of Government Lands Act, 1912 and the various Land Reform Regulations. Rural land falls under the jurisdiction of revenue districts.

Land other than rural land is urban and including all permutations there-under such as residential, commercial, built upon and buildable and is governed by various regulations and ordinances including the People's Local Government Ordinance, 1972 for each province, Cantonments Act, 1924 and Land Control Act, 1952. Urban land falls under the jurisdiction of municipal and local government authorities.

While there are broad definitions of rural and urban land in the People's Local Government Ordinances, such classifications are not immutable and have been and are changed by the Collector of Revenues and provincial governments over time. In general, it is either the People's Local Government Ordinances or the Land Revenue Act that determines the classification of land however there are some cases where both applies and other cases where different legislation altogether can dictate jurisdiction and classification over land. Hence there is neither a universal classification nor legislation pertaining to the land that will be potentially affected under the program.

8.6 Eligibility

PAPs entitled for compensation or rehabilitation provisions under the program are:

- All PAPs affected by restricted access to or use of land whether they have legal title/traditional land rights or not;
- Tenants and sharecroppers whether registered or not;

- Owners of buildings, crops, plants, or other objects attached to the land; and
- PAPs losing business, income and salaries (livelihood).

Cut-off Date: Compensation eligibility will be limited by a cut-off date fixed by NTDC for this Project. PAPs that settle in the affected areas and/or make changes in the landuse patterns after this cut-off date will not be eligible for compensation. They will, however, be given sufficient advance notice requesting them to vacate premises/corridor and dismantle all affected structures and other establishments (if any) prior to Project implementation. They will be allowed to reuse their salvaged material for free and they will not be asked to pay any fine for making those change. Forced eviction will only be considered after all other efforts are exhausted.

8.7 Compensation Entitlements

Entitlement provisions for PAPs cover such impacts as land losses, house and buildings losses, crops and trees losses, a relocation subsidy, rehabilitation measures and a business losses allowance based on tax declarations and/or lump sums. These entitlements are detailed below:

Agricultural land impacts will be compensated based on whether a PAP's access to, or use of, their land is restricted. For PAPs whose access to and use of, agricultural land is not restricted i.e. they can continue to cultivate the land, compensation will be for removed or damaged crops and trees. For PAPs whose access to, or use of, agricultural land is restricted i.e. they cannot continue to cultivate the land compensation will be paid at replacement value in: (i) cash at current market rates plus a 15% compulsory acquisition surcharge (CAS), or (ii) through replacement land equal in value/productivity to the plot lost. When >10% of an PAP's income or agricultural land is affected, AHs (owners, leaseholders and sharecroppers) will get an additional allowance for severe impacts equal to the market value of a year's gross yield of the land lost (inclusive of winter and summer harvest). Eventual transaction taxes/fees will either be paid by NTDC or waived by local governments. Market rates will be assessed through a survey of prevalent land prices, carried out by local government and financing institutions along with involvement of community.

Residential/commercial land will be compensated at replacement value by either (i) land for land or (ii) cash at current market rates free of any deductions. Renters/leaseholders will receive an allowance corresponding to 3 months' rent. However, the land under Towers and line (100m wide ROW) can be used by the landowner or sharecropper for cultivation.

Houses, buildings, structures will be compensated in cash at replacement cost free of depreciation, salvaged materials and transaction cost deductions. The compensation for houses/buildings will also include the cost of lost water and electricity connections.

Crops: Cash compensation at current market rates for the net harvest actually lost as it may be the winter, the summer crop, or both. Crop compensation will be paid both to landowners and tenants based on their specific sharecropping agreements.

Trees: Cash compensation shall reflect income replacement based on market price.

Businesses: compensation for permanent business losses will be in cash for a 1-year income based on tax declaration or, if unavailable, based on the official minimum salary; compensation for temporary business will be in cash for the period of income interruption (1 to 3 months) based on tax declaration or, if unavailable, official minimum salary.

Business workers and employees: Indemnity for lost wages for the period of business interruption upto a maximum of 3 months.

Agricultural land leaseholders, sharecroppers and workers: Where the access to, or use of, the land is restricted; affected leaseholders will receive either a renewal of the lease in other plots or cash corresponding to the yearly yield of land lost for remaining years of the lease upto a maximum of (3) years. Sharecroppers will receive their share of harvest at market rates (if impact is temporary) or if the land is lost permanently additional compensation for one (1) crop. Agricultural workers, with contracts interrupted, will get an indemnity in cash corresponding to their salary in cash and kind for the remaining part of the agricultural year (inclusive of both winter and summer crops).

Community structures and public utilities: These will be fully compensated or replaced/rehabilitated so as to satisfy their pre-Project functions.

Relocation subsidy: PAPs forced to relocate will receive a relocation subsidy sufficient to cover transport costs and living expenses for 1 month.

8.8 NTDC Current Procedures for Payment of Compensation

The construction of the T/L and Converter Station will cause damage to the crops, trees and may be some built-up properties during:

- Soil Investigation at the Tower foundations;
- Excavation and concreting of the Tower foundations;
- Erection of Towers; and
- Stringing of conductors.

These impacts have been estimated based on the preliminary route alignment, field survey and similar Projects carried out in the past. At the time of detailed survey, the losses will be properly assessed and evaluated for compensation, in accordance with the prevailing rules and regulations of the Government. Cutting/trimming of the trees above 2.5 m height and built-up properties (if any) for public safety and integrity of the T/Ls within ROW of 100m, will be adequately compensated.

8.8.1 Compensation at the Time of Survey/Soil Investigations

The damages caused to the existing crops during the detailed survey and soil investigation work for the Tower foundations will be recorded and estimates of compensation will be prepared accordingly by the concerned revenue staff i.e. Patwari. For the identification of the crop owners, it is preferable that the "Dhal-Wash" document may be consulted. This document is prepared by the "Mal Patwari" and issued to the farmers by the Qanoongo. The estimates will be prepared in accordance with the approved rates of the concerned District Government. The record of the Patwari will be verified by the Assistant Land Acquisition Officer (ALAO) and NTDC's Sub-Divisional Officer (SDO), who will be the in-charge of the work. After verification, the record will be submitted to the Chief Engineer (EHV-II), NTDC through the Project Director, NTDC, the competent authority for approval. Accordingly, funds will be released for prompt payment to the affectees.

8.8.2 Compensation at the Time of Construction of Towers

Considerable vehicular movement for the transportation of the materials/water and steel formwork will be involved at the time of construction of the Tower foundations. This will be considered as temporary acquisition of land. This movement and storage of the materials and equipment will cause damage to the existing crops. In this case, the damage of the access road to the Tower locations will also be recorded. The procedure for recording verifications, approvals and payments to the affectees will be the same as discussed in the above paragraph.

As per NTDC's existing practices under the Telegraph Act, 1910, no permanent land is acquired for the Tower foundations as the landowners are allowed to use the land under the Towers for cultivation purposes. For the other existing EHV lines, farmers are using the land under the Tower footings for cultivation and even use tractors for the ploughing purposes.

The stringing of conductors involves the movement of equipment and vehicles along the corridor, which may involve the cutting of trees and cause considerable losses of the existing crops. The revenue staff including Patwari, Qanoongo and ALAO will be responsible for the estimation and valuation of the crops as per prescribed criteria of the District Government.

On completion of the estimates and their approval, the compensation amount will be disbursed promptly.

Stringing activities can affect the built-up properties and other structures due to the required clearance for the T/L. However, as per preliminary field observations, no such structure or built-up property have been identified, which may be affected, however, this matter will be checked during the detailed design stage.

8.9 NTDC Practice for Passing Transmission Lines over Existing Infrastructure

For crossing the T/L over or near the existing infrastructure or sensitive sites, NTDC approaches the concerned agencies and gets their approval. Any damages caused to the trees or other properties are paid to the concerned agency as per their rules.

This particularly implies to the forest areas, wetlands, railway tracks, highways, airports, archaeological sites, army garrisons etc. Normally, where the existing infrastructure like highways, railway tracks, telephone poles and other T/Ls are to be crossed, NTDC adjusts the Towers in a way that will requires minimum clearance.

In the following paragraphs, it is discussed as to whether or not for the proposed ±600KV T/L and ±600KV Grid Station; NTDC has to get "No Objection Certificate (NOC)" from the different agencies/departments.

8.9.1 National Highway Authority (NHA)

The proposed T/L will cross National Highway at various locations. NTDC will get NOC from NHA if deemed necessary as per NHA rules and regulations. However, NTDC has already taken care to provide the required horizontal as well as vertical clearances to pass the T/L over the highways and motorways.

8.9.2 Pakistan Railways

As the proposed T/L will pass near the railway track and crosses at some points, so NOC may be required from Pakistan Railway.

8.10 Compensation Eligibility and Entitlements for the Project

Land acquisition tasks for this T/L Project, will be implemented according to a compensation eligibility and entitlements framework in line with Pakistan's laws/ regulation and ADB Policy.

Entitlements matrix based on the available information and field surveys is provided in Table 8-2 below.

Table 8–2: Compensation and Entitlement Matrix

Sr. No.	Assets Lost/ Impact	Specification	Affected Persons	Compensation Entitlements
1.	Land permanently acquired for the construction of Grid/ Substation/ Converter Station	All land losses	Land owner/ Title holders/ Customary rights	• Cash compensation at replacement cost plus 15% CAS, free of taxes, of registration and transfer costs; or • Land for land compensation through provision of plots of equal value and productivity as that of lost. • If land is provided as a donation/ or on voluntarily basis, in such cases, ADB Policy is not triggered.
2.	Arable Land temporarily affected by the construction/ installation of Towers/ or T/L	Access is not restricted and existing or current landuse will remain unchanged by the construction of Towers and installation of T/L.	Land owner/ Titleholder/ Customary rights	• No land compensation provided that land is rehabilitated/restored to former quality following completion of works. • Compensation, in cash, for all damaged crops and trees.
			Leaseholder	• No land compensation provided that

Sr. No.	Assets Lost/ Impact	Specification	Affected Persons	Compensation Entitlements
			(registered or not)	land is rehabilitated/restored to former quality following completion of works. • Compensation, in cash, for all damaged crops and trees.
			Sharecroppers (registered or not)	• Compensation, in cash or kind, for all damaged crops/ trees.
			Squatters/ Encroacher	• Cash compensation, for all damaged crops/ trees.
3.	Arable land for Tower/T/L installation, construction restricts access or agricultural use	All adverse effects on landuse having the severity of impact).	Land owner/ Title holders/ Customary rights	• Land for land compensation with plots of equal value and productivity to the plots lost/or cash compensation for affected land at current market price plus 15% CAS and free of taxes, registration, and transfer costs.
			Leaseholder (registered or not)	• Renewal of lease in plots of equal value/or productivity of land lost, or Cash equivalent to market value of gross value of affected land for the remaining lease years (upto a maximum of 3 years).
			Sharecroppers (registered or not)	• Cash compensation equal to market value of lost harvest share once (temporary impact) or twice in case of permanent impacts.
			Agricultural workers	• Cash indemnity equal to salary (including portions in kind) for remaining part of agricultural year.
			Squatters/ Encroacher	• 1 rehabilitation allowance equal to market value of 1 gross harvest (additional to crop compensation) for the loss of landuse.
		Additional for severe impacts (>10% of land loss)	Land owner/ Title holder/ Customary rights	• 1 severe impact allowance equal to market value of gross harvest of affected land for 1 year (inclusive of winter and summer crop and additional to standard crop compensation).
			Leaseholder (registered or not)	• 1 severe impact allowance equal to market value of gross harvest of affected land for 1 year or renewal of lease in plots of equal value/ or productivity of land lost, or Cash equivalent to market value of gross value of affected land for the remaining lease years (upto a maximum of 3 years).
			Sharecroppers/ leaseholders (registered or not)	• 1 severe impact allowance equal to market value of harvest share (additional to standard crop compensation)
			Squatter/ Encroacher	• 1 severe impact allowance equal to market value of gross harvest of the

Sr. No.	Assets Lost/ Impact	Specification	Affected Persons	Compensation Entitlements
				affected land for 1 year (inclusive of winter and summer crops and additional to standard crop compensation).
4.	Residential/ Commercial land affected by Towers/ T/L	Future usage of the land will get restricted permanently	Titleholder	• Land for land through provision of plots comparable in value/ location to plot lost; or cash compensation for affected land at full replacement cost free of taxes, registration, transfer costs plus 15% CAS.
			Renter/ Leaseholder	• 1-3 months allowance based on current monthly rent
			Squatters	• Relocation in a public resettlement area or a self-relocation allowance
5.	Houses and Structures	Displaced houses/ structures will be demolished	Relevant AFs/ squatters/ Encroacher	• Cash compensation at replacement rate for affected structure/other fixed assets free of salvaged materials, depreciation transaction costs. For partial impacts full cash assistance to restore structure.
6.	Crops	Crops affected (damaged/ lost)	All APs/ squatters	• Tower installation (excavation, concrete and erection): Crop compensation in cash at full market rate equivalent to maximum 3 harvests depending upon the magnitude of impact on APs. • Line corridor stringing: Cash compensation at market rate equivalent to 1 harvest.
7.	Trees	Affected trees (trees removed)	All APs/ squatters	• For ornamental/timber/ wood trees, the compensation will be the market value of tree's wood content. • Fruit trees: compensation to reflect income replacement; trees grown and/or used.
8.	Business/ Employment	Loss of business/ or employment	All APs/ squatters	• Owner of business: (i) Cash compensation equal to 1 year income (if loss permanent); (ii) Cash compensation for the period of business interruption (if loss is temporary). • Worker/ employee: lost wages indemnity for the business interruption period upto 3 months.
9.	Relocation	Transport/ transition costs	All AFs	• Provision of sufficient allowance to cover the transport/ shifting expenses; and livelihood assistance for 1 month.
10.	Community Structures/ Assets	Affected community structures & installations	All affected communities	• Rehabilitation/substitutionof affected structures/utilities (i.e. mosques, roads, schools and other.

Sr. No.	Assets Lost/ Impact	Specification	Affected Persons	Compensation Entitlements
11.	Vulnerable affected families	Households below poverty line and female headed households	All affected vulnerable families	• Lump sum one time livelihood assistance allowance (Rs. 7,500) on account of livelihood restoration support. • Temporary or permanent employment during construction or operation, where feasible.
12.	Unidentified Losses	Unanticipated impacts	All APs	• Deal appropriately during proposed project implementation according to the ADB Safeguard Policy.

8.10.1 Assessment of Compensation Unit Values

The proposed methodology to be adopted during the LARP for assessing unit compensation values of different items is illustrated as follows:

- Land shall be valued at replacement cost based on actual land sale price survey in the year before the impact survey. No deductions for taxes/transaction costs will be applied;
- Houses/buildings will be valued at replacement value based on cost of materials, type of construction, labour, transport and other construction costs. No deductions will be applied for depreciation, salvaged materials and transaction costs;
- Annual crops will be valued at net market rates at the farm gate for the first year crop. In the eventuality that more than one-year compensation is due to the AHs the crops, after the first will be compensated at gross market value; and
- Fruit trees will be valued based on age category (a. seedling; b. not yet productive; c. productive). Productive trees will be valued at gross market value of 1 year income x the number of years needed to grow a new tree with the productive potential of the lost tree.

8.11 Mechanism for Redress of Grievances

The cost of properties likely to be damaged, removed or relocated will be assessed and evaluated with the consultation of affectees. Complete inventory of the properties will be maintained in the compensation registers. Where needed, the respective Revenue Record will also be consulted. All the payments will be made in the presence of the local representatives through cross-cheques.

Although due care will be taken for the assessment, valuation and compensation to the affectees, even then the affected persons may have some objections or observations such as:

- Dispute on ownership;
- Relocation of infrastructure;
- Inadequate compensation;
- Delays in the payment of compensation, resulting in court cases;
- Reluctance of the owners to allow the installation of the Towers before payment of compensation; and
- Type and number of trees to be removed and their compensation.

To address the grievances, a committee comprising the following members will be constituted by NTDC:

- Executive Engineer, Head of the committee;

- Sub-Division Officer, Member;
- Social Expert, Coordinator;
- Nazim/Naib Nazim of concerned tehsil, Member; and
- Representative of PAPs Member.

A Community Complaints Register (CCR) will be maintained by the committee. The affectees will register their complaints in the register with their particulars, such as name of the affectee, village, type of complaint etc. The committee will resolve the issue within two weeks to overcome the delay in the construction activities. In case the committee is unable to resolve the issue, the case will be forwarded to the Project Director (Superintending Engineer), who will resolve the issue with the consultation of Chief Engineer within a week. The social expert will act as a coordinator between NTDC and the community. The decision of the committee will be conveyed to the affectee in writing. As there will be very minor resettlement issues and no permanent land acquisition is involved, so it is expected that the grievances will be addressed adequately to the satisfaction of PAPs within the purview of the proposed committee. However, in case of any unresolved issue, court will be considered as last resort.

9 ENVIRONMENTAL MANAGEMENT AND MONITORING PLAN

9.1 General

This Chapter provides an overall approach for managing and monitoring the potential environmental and social impacts and describes the institutional framework and resource allocations to implement these measures. The main objectives of the EMMP are:

- Provide the details of the Project impacts along with the proposed mitigation measures and the corresponding implementation activities;
- Define the role and responsibilities of the Project Proponent, Contractor, Supervisory Consultants and other role players and effectively communicate environmental issues among them;
- Define a monitoring mechanism, reporting frequency and identify monitoring parameters to ensure that all the mitigation measures are completely and effectively implemented; and
- Identify the resources required to implement the EMMP and outline the corresponding financing arrangements.

9.2 Environmental Policy, Legislation and Framework

A brief about Environmental policy, legislation and framework is described below:

The Pakistan Environmental Protection Act, 1997

PEPA Act, 1997, provides for environmental assessment inClause 12, and various other clauses. The details description of PEPA Act, 1997 is given in Section 2.3.

Review of Initial Environmental Examination and Environmental Impact Assessment Regulations, 2000

This regulation has been notified vide S. R. O. No. 339 (1)/2000 dated 13th June, 2000. A detail of these regulations is given in Section 2.3.1.

EIA Guideline Package

The Federal EPA, in collaboration with other key stakeholders, including Provincial EPA's and Planning and Development Division from both the Federal Government and the provinces, other Agencies, NGO's representatives of Chambers of Commerce and Industry, and academics and consultants, prepared a package of comprehensive procedures and guidelines for environmental assessment in Pakistan. It is emphasized that the various guidelines may be read as a package; reliance on the sectoral guidelines alone will be inadequate. The principal documents are:

Policy and procedures for the filing, review and approval of environmental assessments, which setsout the key policy and procedural requirement contains a brief policy statement on the purpose of environmental assessment and the goal of sustainable development, required that environmental assessment be integrated with feasibility studies. Defines the jurisdiction of the Federal and Provincial EPA's and P&D's. Lists the responsibilities of Proponents, and lists the duties of Responsible Authorities. It provides schedules of proposals that require either an IEE or an EIA.

Guidelines for the preparation and review of Environmental Reports

It is a longer and more descriptivedocument, which covers:

- The Initial Environmental report (scoping, alternatives, site selection, format of IEE) ;
- Assessing impacts (identification, analysis and prediction, baseline data, significance);

- Mitigation and impact management (and preparing an environmental management plan);
- Reporting (drafting style, main features, shortcoming, other forms of presentation);
- Review and decision-making (role, steps, remedial options, checks and balances);
- Monitoring and auditing (systematic follow up, purpose, effective data management); and
- Project management (inter-disciplinary teams, programming & budgeting).

Guidelines for public consultation (in preparation)

This document covers:

- Consultation, involvement and participation;
- Stakeholders;
- Techniques for public consultation (principles, levels of involvement, tools, building trust);
- Effective public consultation (planning, stages of EIA where consultation is appropriate);
- Consensus building and dispute resolution; and
- Facilitating involvement (including the poor, women, building community and NGO capacity).

Guidelines for sensitive and critical areas (in preparation)

These guidelines will identify sensitive and criticalareas in Pakistan, in relation both to the natural environment and to cultural aspects. Detail of these guidelines is given in Section 2.5.

Pakistan environmental legislation and the National Environmental Quality Standards (NEQS)

It is a reference document listing key environmental laws and regulations, and a complete listing of the NEQS. Details of NEQS are given in Section 2.8.

ADB's Safeguard Policy Statement (2009)

Environmental safeguards requirements, including environmental impact assessment requirements, are defined in ADB's Safeguard Policy Statement (2009). All projects funded by ADB must comply with SPS 2009. The purpose of the SPS, 2009 is to establish an environmental review process to ensure that projects undertaken as part of programs funded under ADB loans are environmentally sound, are designed to operate in compliance with applicable regulatory requirements, and are not likely to cause significant environmental, health, or safety hazards. Detail of SPS 2009 is given in Section 2.11.1.

9.2.1 Interaction with Other Agencies

NTDC is responsible for ensuring that the Project complies with the laws and regulations controlling the environmental concerns of the construction and operation of HVDC T/L from Thar to Lahore and that all pre-construction requisites, such as permits and clearances are met. This section describes the nature of the relationship between the NTDC and the concerned line departments.

9.2.2 Federal Government Institutions

The Ministry of Disaster Management deals with the Environment and Wildlife issues at the federal level. Within the Ministry, the NCS Unit, established in 1992, is responsible for overseeing the implementation of the Strategy.

Pakistan Environmental Protection Council (PEPC) and the Pak-EPA are primarily responsible for administering the provisions of PEPA, 1997. The PEPC oversees the functioning of the Pak-EPA. Its members include representatives of the government, industry and NGOs. Pak-EPA is required to ensure compliance with the NEQS, establish monitoring and evaluation systems and identify the need as well as initiate legislation whenever necessary. It is thus the primary implementing agency in the hierarchy. The provincial EPAs are the provincial arms of the federal EPA. Pak-EPA has delegated Powers to its provincial counterparts. One of the functions delegated by the Pak-EPA to the provincial EPAs is the review and approval of environmental assessment reports and to issue NOCs. EPA, Sindh (SEPA) and EPA, Punjab are responsible for the approval of EIA and issuance of NOC for HVDC 1300Km Long T/L from Thar to Upcountry being a part of Sindh and Punjab provinces.

9.2.3 Federal and Provincial EPAs

As per PEPA 1997, each provincial government has its own Environmental Protection Agency/Department responsible for environmental protection and pollution control. The provincial EPAs are responsible for the approval of the EIA and IEE of new developments under their jurisdictions.

9.2.4 Provincial Departments of Wildlife, Forestand Archaeology

At the feasibility stage of the Project as per the requirement of EPA guidelines for the Sensitive and Critical Area, concerned provincial departments are informed through letters for the proposed T/L project.

During the construction stage, if the implementation of the proposed Project involves the clearing of vegetation and trees which belongs to the forest or wildlife department, the Project Contractor will be responsible for acquiring a NOC from the concerned provincial forest department. The application for an NOC will need to be endorsed by NTDC. Similarly, if any Archaeological monument or site is crossed by the proposed T/L concerned provincial department needs to be contacted for NOC.

Where construction is to be carried out in the close proximity of the protected forests and Wildlife and Archaeology sites, the NTDC is required to coordinate with the concerned departments to ensure that the impacts on vegetation and wildlife are minimized. The Contractor is also required to contact with concerned department before the start of the construction work.

9.2.5 Provincial Revenue Departments

Under the national law, matters relating to the landuse and ownership are provincial subjects and the revenue department of the concerned province is emPowered to carry out the acquisition of private land or built-up property for public purposes, including on behalf of other provincial or federal agency. For this purpose, the concerned department must lodge an application with the concerned provincial government to depute a LAC and other revenue staff, who will be responsible for handling the matters related to the acquisition and disbursement of compensation.

9.3 NOC and Other Approvals

Obtaining NOC from the SEPA and EPA, Punjab is the primary responsibility of the Client prior to the start of any construction activities. This process is discussed in Chapter 2.

This NOC will not relieve the Proponent from other legal obligations and hence Project Proponent and Project Contractors will obtain all other relevant clearances and necessary approvals required by the GOP prior to commencing their respective operations.

9.4 Project Proponent

NTDC was incorporated on the 6th November, 1998 and commenced commercial operation on 24thDecember, 1998. NTDC operates under WAPDA. It was organized to take over all the properties, rights and assets, obligations and liabilities of 220KV and 500KV Grid Stations and T/Ls/network owned by Pakistan Water and Power Development Authority (WAPDA).The NTDC operates and maintains nine 500KV Grid Stations, 4,160 km of 500KV T/Ls and 4,000 Km of 220KV T/Ls in Pakistan.

NTDC was granted Transmission License No. TL/01//2002 on 31stDecember 2002 by National Electric Power Regularity Authority (NEPRA) to engage in the exclusive transmission business for a term of thirty (30) years, pursuant to Section 17 of the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997.

Under the regime set out in the License, the NTDC is entrusted to act as:

- Central Power Purchasing Agency;
- System Operator;
- Transmission Network Operator; and
- Contract Registrar and Power Exchange Administrator.

The roles of NTDC listed above are briefly outlined below:

i. **Central Power Purchasing Agency (CPPA):** As the Central Power Purchasing Agency (CPPA), for procurement of Power from GENCOs, Hydel & IPPs on behalf of Distribution Companies (DISCOs), for delivery through 500 KV, 220KV & 132KV Network.

ii. **System Operator:** For secure, safe and reliable operation, control and dispatch of generation facilities.

iii. **Transmission Network Operator:** For O&M, Planning, Design and expansion of the 500 KV and 220 KV transmission network.

iv. **Contract Registrar and Power Exchange Administrator (CRPEA)**: As CRPEA, to record and monitor contracts relating to the bilateral trading system.

NTDC's headquarter is situated at WAPDA House, Lahore.

9.4.1 Roles and Responsibilities of NTDC

9.4.1.1 Design and Construction Stage

Design and construction of the Project is the core responsibility of Chief Engineer (EHV-I &II) and his staff. The major role and responsibilities related to the environmental and social tasks are as under:

Chief Engineer (EHV-I &II)

The Chief Engineer (EHV-I &II) 'Construction Projects' will be responsible for ensuring that the Project design and specifications adequately reflected in the EMMP along with the resettlement/compensation provisions documents. Other responsibilities will include:

- To ensure the Project compliance with the environmental regulations and donor requirements;
- Stakeholder participation in the Project design;
- To ensure that the TOR for the Supervisory Consultants adequately cover the environmental and social issues; and
- Approval of compensation budgets.

Project Director (PD)

The specific responsibilities are as follows:

- Setting up systems for environmental management;

- Ensuring that the Contractor(s) develop and carry out environmental implementation plans that are consistent with the EMMP;
- Change of alignment, if sensitive sites come into the proposed route;
- Coordination with the regulatory agencies including EPAs, local NGOs and CBOs that could assist NTDC in independent review of environmental and social compliance;
- Assistance in EIA approval from the EPAs concerned; and
- Liaising between the Project staff (essentially XENs, SDOs etc.) and the Supervisory Consultant's staff to monitor environmental compliance during construction.

Executive Engineer and Sub Divisional Officers (XENs and SDOs)

The specific responsibilities will be as under:

- Select the Tower spotting in such a way that it should not disrupt the community or if unavoidable, then disruption should be the minimum;
- To ensure the minimum disruption of shaded trees and no disruption of fruit trees;
- Project route should avoid the disruption of schools, hospitals, shrines, mazars, mosques and graveyards; and
- Proper soil investigations should be ensured and appropriate mitigations should be adopted at the design stage in water logged, wetland and wet soils.

Executive Engineer and Sub Divisional Officers (TLC)

The Executive Engineer and Sub-divisional officers (TLC) are the core persons to handle the field activities and report them to the PD. The main field activities related with the environmental management are as under:

- Preparing a joint on-site inventory and valuation of the affected assets and incomes of individual PAPs with Social Expert;
- Supervising and providing technical support to the Project supervision and monitoring staff to help ensure compliance with the EMMP;
- To recommend compensation for the loss of crops and cropping seasons;
- To recommend compensation for removal of trees having economic value and more than 2.5 m high from the ROW of 50 m (25 m on each side of the centerline of the T/L route);
- Compensation for the built-up properties to be removed from the COI as well as ROW;
- Compensation for the removal of infrastructure like houses, wells etc.;
- To make the site visits to manage the pollution of land and water resources including irrigation channels, nullahs, natural streams etc.;
- Clearance of 50 m wide strip during the stringing operations;
- To check the possibility of soil erosion during the excavation of Tower foundations as per EMMP;
- To deal with a surprise archaeological find in the area and report it to Archaeological Department;
- Visually check the fugitive dust, noise and vibration during the construction stage; and
- To ensure safety measures during construction.

Environment and Social Expert

The specific responsibilities of the social experts will include:

- Provide environmental and social review and technical support to the Project Director, NTDC;
- Coordination between NTDC management and the community including PAPs, NGOs, CBOs and other stakeholders;
- Identifying and verifying PAPs on the basis of LARP and revenue records etc.;
- Identifying alternative resettlement sites for PAPs (if applicable);
- Carrying out a consultation and dissemination campaign with regard to compensation procedures, entitlement packages and the proposed alternative resettlement sites;
- Identifying any problems due to the restricted access to the community during construction;
- Preparing individual entitlement files;
- Preparing compensation budgets;
- Providing shifting assistance to the displaced persons and to allow them to salvage their facilities;
- Full fill the responsibilities as specified during the LARP implementation; and
- Identifying major issues of conflict between PAPs and the NTDC/Contractors during the implementation of the Project activities.

NTDC Environment Cell

Environmental Cell is directly in-charge for the financial and technical matters and directly reports to the Project Director.

The general monitoring responsibilities of the Environmental Cell and NTDC Environment and Social Expert will consist of:

- Assessment of the crops, valuation of property and negotiation with the affectees for fixation of compensation to be paid for temporary acquisition of the land under the Towers.
- To estimate the crop compensation for the construction of foundations and erection of Towers and in the 10 m wide corridor during the stringing operations;
- Assist in valuation of the infrastructure, tubewells/peter engines, trees etc. and negotiation with the owners;
- Assist in checking genuine ownerships of the claimants, in consultation with the Revenue staff for prompt payment to the affectees;
- To ensure that the tenants get their rightful compensation as per prevailing law especially in case of loss of crops;
- Assist the Contractor for the timely payments of negotiated prices;
- Check that the Contractor backfills, compacts and leaves the ground in the original condition after excavation of pits for subsurface investigations and for the Tower footings;
- Keep checks and controls so that the pollution of land and water resources due to the spills of lubricants, fuel, chemicals and other wastes does not take place;

- Monitor, that pollution of wetlands is not avoided during the excavation for the Tower footings;
- To check that the Contractor keeps the damages to the minimum while making tracks for accessibility and that the damage is rectified properly;
- All the existing tracks, roads, water courses etc. are left in the original shape after completion of the construction activities;
- Monitor that the Contractor uses such working methodology so as not to cause disturbance to the communities by fugitive dust, noise, fumes etc.;
- Monitor that the Contractor adjusts his working hours during the stringing activities in such a manner that it causes the least inconvenience to the local population.
- To ensure that the Contractor keeps first aid kits, medicines, safety gadgets at the site for taking care of possible mishaps to the workers or other persons; and
- To keep the working site/camps tidy so as to avoid unhealthy impacts on the work force.

9.4.1.2 Operation Phase

The Chief Engineer (GSO)

Chief Engineer will take over the Project after completion of the construction activities on completion of the Project, a joint visit will be made by the staff of Chief Engineer (GSO) to ensure that the implementation of the Project is as per approved specifications. In the operation stage, Chief Engineer (GSO) is responsible for the overall operation and maintenance of the Converter Stations as well as T/Ls. He will coordinate with the staff to monitor the environmental compliance during the operation and maintenance of the T/L and the Grid Station.

The Superintending Engineer (SE)

Superintending Engineer, will be responsible for reporting on the progress of the environmental compliance to the concerned provincial EPAs. Similarly, he will plan for sustaining a working partnership among NTDC, EPAs, provincial agriculture, forest and Wildlife departments, NGOs/CBOs and other related public/private sector organizations.

Executive Engineer and Sub-divisional Officers (XEN and SDOs)

These officers will be responsible to check the stability of the Towers and the system on periodic basis and to assess the long-term environmental impacts of the T/L operation including EMF. For Sub Stations operation, a contingency plan will be prepared to overcome any emergency situation arising due to fire, disaster etc.

Environment and Social expert will assist and advise all the above key players in their respective responsibilities as and when required.

9.4.2 Role and Responsibilities of Supervisory Consultants (SC)

A Supervisory Consultant appointed by NTDC will be designated as the "Engineer/Project Manager". The Consultant will be responsible for:

- Supervising the Project's Contractors and ensuring that all the contractual obligations related to the design and construction, as well as environmental and social compliance are met;
- Ensuring that the day-to-day construction activities are carried out in an environmentally and socially sound and sustainable manner; Developing 'good practices' construction guidelines to assist the Contractors and NTDC staff in implementing the EMMP; and

- Assisting the Chief Engineer (EHV-I&II) in coordinating with the EPAs, provincial agriculture, forest and Wildlife departments, NGOs/CBOs and other public/private sector organizations.

9.4.3 Role and Responsibilities of Contractor

For the proposed Project, NTDC will appoint Contractor(s) for construction and other project activities. The Contractor(s) will be responsible for the physical execution / implementation of EMMP, or adherence to all the provisions of the EIA and EMMP and any environmental or other code of conduct required by EPA Punjab and SEPA. Overall responsibility for the Contractor's environmental performance will rest with the NTDC.

9.4.4 Environmental Protection Agency

SEPA and EPA, Punjab are the regulator authorities and mainly responsible to develop and implement national environmental policies and strategies in order to integrate the environmental issues and sustainable development approaches into the legal and regulatory frameworks. EPAs are also responsible to assess the effectiveness of the implementation of the environmental legislation and regulations to improve the sustainability of the use and management of natural resources and the effectiveness of the measures for conservation and rehabilitation of the environment. Similarly, PEPA, 1997 emPowers the EPAs to take legal action against the non-compliance of environmental legislation and regulations and penalties may be imposed from cancellation of license to six months imprisonment, or both.

Its main function is to develop and implement the national environmental policies and in the proposed Project will be as an independent monitoring agency. EPA will inspect the Project at its own convenience or on receipt of complaint about non-compliance of any environmental legislation or its part.

The proposed Project falls under the jurisdiction of SEPA as well as EPA, Punjab. For the implementation of the proposed Project as well as other anticipated developments, these EPAs have to play a proactive role apart from issuing NOC.

9.4.5 Local Government

Revenue department will be involved for the verification of land ownerships and disbursement of compensation for land, crops and other infrastructure. However, this aspect is being taken up in detail during the preparation of Land Acquisition and Resettlement Framework and Plan (LARF and LARP).

It is suggested that concerned staff of the Revenue Department should be nominated for the Project and properly trained.

9.4.6 NGO

A strategy is needed to outline the ways and means through which the NGOs and Community Based Organizations (CBOs) can play their part in the sustainable development of this Project. NGOs mostly provide support to the locals, in the form of small grants and installation of tubewells. Still the works are required to focus on social welfare problems with attention to environmental and development issues. That will increase their role in networking and public decision-making. This aspect is being taken up in detail during the LARF and LARP studies.

9.5 Environmental Mitigation and Management Matrix

The environmental protection and enhancement are achieved in various ways. These approaches should begin right at the embryonic stage, i.e. i) Project location; ii) design, specifications and tender/contract documents; iii) construction activities; and iv) post completion activities i.e. operation and maintenance stage. Appropriate environmental management measures are required to be exercised in a cascade manner by NTDC at each stage of the Project in Pakistan.

It is envisaged that the Project will achieve maximum on-going cost-effective, environmental sustainability and social soundness, far beyond the end of implementation of the Project. All the stages of the Project have to be managed by adopting the proposed environmental mitigation measures, where, besides engineering aspects, due importance is to be accorded to the mitigation measures which make a perfect blend with the surrounding ecosystem. The key environmental and social issues have already been discussed in Chapter-7.

An Environmental Mitigation & Management Matrix (MMM) for the T/L and Converter Stations is given in Table 9-1 (a&b). This table is attached at the end of this Chapter, which establishes the linkages between the environmental and social impacts, mitigation strategy and the agencies responsible for execution.

9.6 Environmental Monitoring Plan

This section provides a monitoring plan that identifies the roles and responsibilities of the staff involved in environmental monitoring under the proposed Project and lists the parameters that will be used in the monitoring process.

9.6.1 Objectives

The main objectives of the pre-construction and construction phase monitoring plans will be:

- To monitor compensation for the loss of assets during the pre-construction activities and payment of compensation for the loss of crops as per latest rates announced by the government as every year rates have to be revised by the government;
- Monitor the actual impacts of the construction activities in the COI related to physical, ecological and socio-economic receptors. This will indicate the adequacy of the EIA;
- Recommend mitigation measures for any unexpected impact or where the impact level exceeds the anticipated levels;
- Ensure compliance with legal and community obligations including safety at the construction sites; and
- Monitor the impacts on land water resources, air quality, noise level and cutting of trees in the corridor of T/L and vegetation clearing at campsites as described in the EMMP.

The main objectives of environmental monitoring during the operation phase will be to:

- Appraise the adequacy of the EIA with respect to the Project's predicted long-term impact on the corridor's physical, ecological and socio-economic environment;
- Evaluate the effectiveness of the mitigation measures proposed in the EMMP and recommend improvements, if necessary; and
- Compile periodic non-conformance report to support the analyses that will help to minimize the future risks.

9.6.2 NTDC Proposed Setup

The existing institutional setup of NTDC for the implementation and operation of the Project for design and construction stage is illustrated in Figure 9-1. Theproposed Project will be administrated by NTDC during the implementation stage as described in detail below:

9.6.2.1 Design and Construction Stage

The NTDC head offices at Hyderabad and Lahore are responsible for managing the Project at the policy level. At the highest level, General Manager (GSC) along with Chief Engineer (EHV-I and II) will be responsible for the day-to-day Project management at the Project implementation stage. He will report directly to the General Manager, who will have the ultimate responsibility for planning and managing the implementation of the T/L Project.

The Chief Engineer (EHV-I and II) will be assisted by the Project Directors who will have the overall responsibility for ensuring the Project compliance with the EMMP. The Project Director (PD) will be supported by two Executive Engineers i.e. Survey and Soil Investigations (SI) and Transmission Line Construction (T/LC), who will further be assisted by the concerned Sub-Divisional Officers (SDOs) and their teams. To ensure community participation and to provide socially viable conditions, NTDC will also hire the services of Environmental and Social Experts from their Environmental Cell, who will support the field team and also work as the coordinator between the community and Client i.e. NTDC and the Stakeholders. If the staff from the Environmental Cell is not available then it is proposed that Environment and Social Experts should at least having Degree in Environmental Engineering and Sociology/Social Sciences with 5 years experience in handling environmental and social issues of development Projects should be hired for the proposed Project.

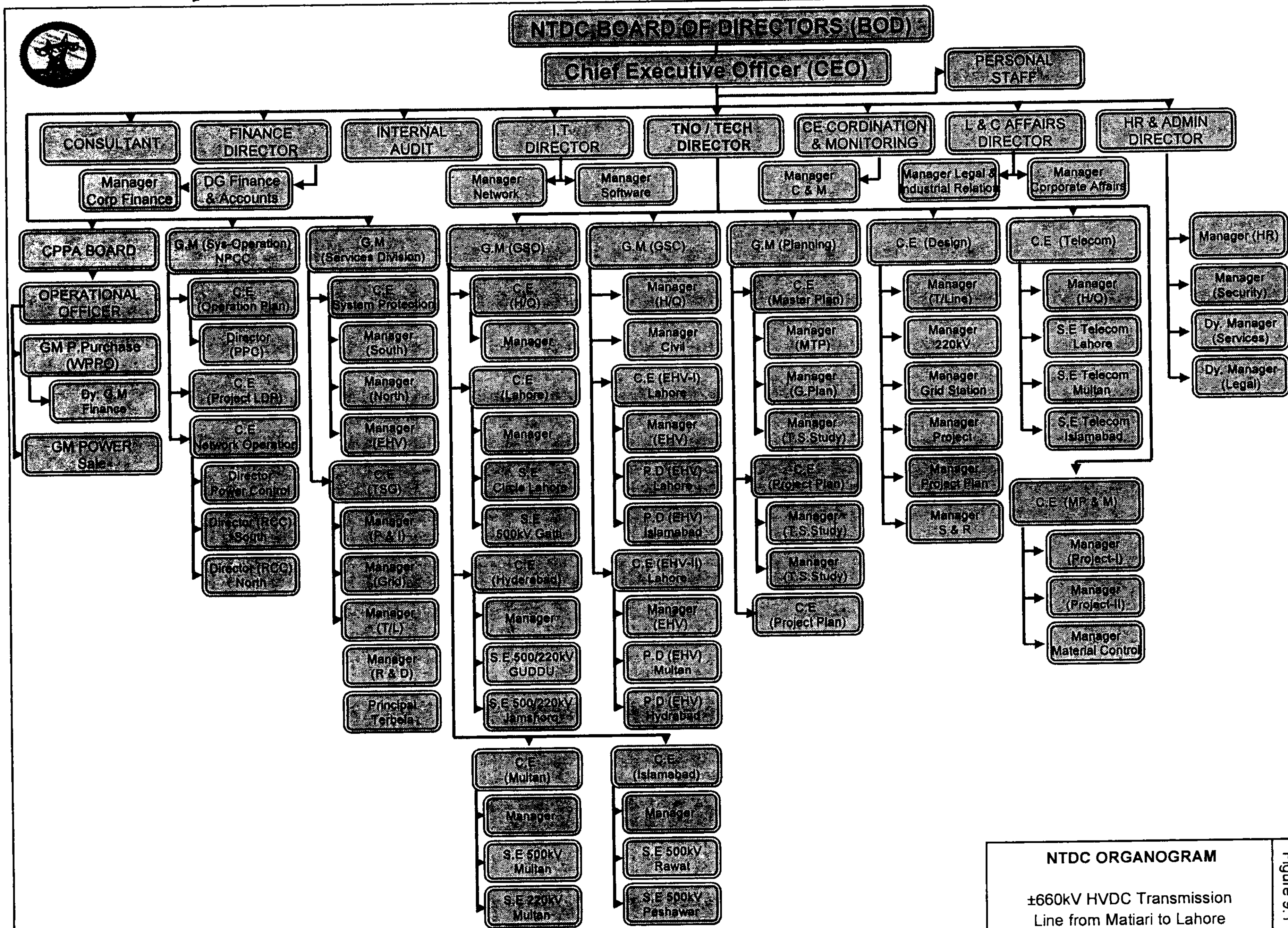
9.6.2.2 Operational and Maintenance Stage

After completion of the Project, It will be handed over to the GSO Division of NTDC, which is working under the General Manager and Chief Engineers (GSO). Chief Engineers (GSO) reports to the General Manager, GSO for operation and maintenance of the T/Ls and Grid Stations. The Chief Engineer GSO will be supported by the Superintending Engineer (SE) for the proposed Project, who will also be assisted by Executive Engineer, SDO and his field team. The hired environmental and social staff will be transferred to the GSO office for their duties related to O & M stage.

9.7 Site Restoration Plan

The main areas to be considered for the site restoration include the construction area, camp sites area, temporary tracks; landused for vehicle and material stores and material excavation pits etc. These areas should be restored to their original condition with the maximum possible effort. The following procedures will be adopted for the restoration of the site:

- All temporary construction built for the site development will be removed;
- Site for construction camps will be restored to its original (pre-construction) condition as much as possible;
- All the toxic and hazardous chemicals/materials will be completely removed from the site. Efforts will be made to completely remove the oils and chemical spills during the construction;
- Any debris from the construction site will be removed properly;
- All fencing and gates will be removed and pits will be backfilled; and
- Whole of the site will be covered with the original soil and plantation will be done, wherever required.



NTDC ORGANOGRAM

±660kV HVDC Transmission Line from Matiari to Lahore

Figure 9.1

Contractor will prepare a Site Restoration Plan well before the completion of the construction activities and submit to NTDC through SC for approval. Finally, after the completion of the restoration process, NTDC, through Environmental and Social Staff and other community members will inspect the site and give restoration clearance to the Contractor.

9.8 Management of Solid and Hazardous Waste

Management of solid and hazardous waste is one of the most important issues during construction stage of the Project. Development of solid and hazardous waste management plan is beyond the scope of this EIA study and EMMP. However, a criterion is given below for the development of a solid and hazardous waste management plan.

The criterion is as follows:

- All the anticipated solid wastes should be collected through a properly designed solid waste management system. Enough number of containers should be placed inside the camps and within the construction area for the collection of various types of waste;
- These containers will help the component separation of various type of waste at source. Classification will be based on organic waste, recyclable waste, reusable waste (for resource and recovery) and waste for sanitary land fill. Based on the conditions of the region, organic waste should be frequently collected to avoid odour problems; and
- Recyclable, reusable and waste for sanitary land fill should be collected twice a week and on alternate days and should be transferred to a properly designed sanitary landfill site. All these waste should be stored and compacted to increase their density. These wastes should be transferred twice a month from the transfer station to final disposal for recycling, reuse and landfill purpose. It is recommended that the solid waste management system should have a stationary container system to collect such waste and transport them to the transfer station.

Many of the materials found at the construction site may be hazardous to the environment or to personnel. It is always important to read the MSDS of the materials or products that are located onsite; they may contain warning information that will indicate a potential problem. As a minimum, any products in the categories listed below are considered to be hazardous:

- Paints;
- Acids for cleaning masonry surfaces;
- Cleaning solvents;
- Asphalt products;
- Chemical additives used for soil stabilization (e.g. palliative such as calcium chloride); and
- Concrete curing compounds and additives etc.

The Criterion given above should be followed for selection of an effective solid waste management system.

9.9 Archaeological Chance Find Procedure

The purpose of these guidelines is to address the possibility of archaeological deposits, finds and features becoming exposed during earth removing and ground altering activities associated with the Tower construction and to provide procedures to follow in the event of a chance archaeological find.

The objective of these procedures is to identify and promote the preservation and recording of any archaeological material that may be discovered at the construction site.

Procedure

During the Project induction meeting, all Contractors will be made aware of the presence of an on Site In-Charge who will monitor earthmoving and excavation activities. The following procedure is to be executed in the event that archaeological material is discovered:

- All construction activity in the vicinity of the find/feature/site will cease immediately;
- The discovered find/feature/site will be delineated;
- Record the find location and all remains are to be left in place;
- Secure the area to prevent any damage or loss of removable objects;
- The on-site HSE In-charge will assess record and photograph the find/feature/site;
- The on-site HSE In-charge will undertake the inspection process in accordance with all Project health and safety protocols;
- The Project Manager will inform the concerned provisional department i.e. Culture Department, Sindh and Youth Affairs, Sports, Archaeology and Tourism Department Punjab;
- In consultation with the statutory authorities, the on-site in-charge and Archaeologist will determine the appropriate course of action to take;
- Finds retrieval strategy: All investigation of archaeological soils will be undertaken by hand all finds, osteological remains and samples will be kept and submitted to the National Museum as required. In the event that any artefacts need to be conserved, the relevant licence (Licence to Alter) will be sought from the concerned authorities;
- An on-site office and finds storage area will be provided, allowing storage of any artefacts or other archaeological material recovered during the monitoring process;
- In the case of human remains, in addition to the above, the concerned authorities will be contacted and the guidelines for the treatment of human remains will be adhered to. If skeletal remains are identified, an osteo archaeologist will be made available to examine the remains;
- Conservation: A conservator will be made available to the Project, if required;
- The on-site archaeologist will complete a report on the findings; and
- Once authorisation has been given by the responsible statutory authorities, the client will be informed when works can resume.

9.10 Monitoring Strategy

The monitoring of environmental and social activities will be carried out by NTDC through Environmental and Social Experts from their Environmental Cell or hired staff by NTDC as already mentioned above as Internal Monitoring agency. The Environment and Social Expert working under the NTDC field staff will supervise all the activities in the field and will provide assistance to the NTDC staff in this regard. He will also ensure public participation.

9.11 Environmental and Social Monitoring

9.11.1 Objectives

The objective of environmental monitoring during the construction and operation will be as follows:

- To check compliance with the requirements of the EMMP by monitoring activities of the Project Contractors on daily basis. This will be called Activity Monitoring;

- To monitor the actual impacts of the Project activities on the physical, ecological and socio-economic receptors of the COI so that any impacts not anticipated in the EIA or impacts which exceed the levels anticipated in the EIA can be identified and appropriate mitigation measures can be adopted in time. This objective will be achieved through the effects monitoring; and
- To ascertain residual impacts of the operation. This will be achieved by post-Project monitoring.

The Contractors will report compliance with the MMM to NTDC for verification. Table 9-2 shows the Recommended Monitoring Protocol for the proposed Project.

Table 9–2: Recommended Monitoring Protocol

Receptor	Monitoring Parameters	Location	Monitoring Mechanism	Monitoring and Reporting Frequency
Water Resources/ Water Quality	pH, Temperature, Colour, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Taste and Odour, Total Hardness, Aluminium, Antimony, Barium, Boron, Cadmium, Copper, Cyanide, Lead, Manganese, Mercury, Nickel, Nitrate as NO_3, Selenium, Residual Chlorine, Pesticides, Phenolic compounds, Poly-nuclear aromatic hydrocarbons, Alpha emitters, Beta emitters Ammonia, Arsenic, Turbidity, Chlorides as Cl-, Fluoride as F-, Sulphate as SO_4^{2-}, Iron as Fe^{3+}, Sodium, Iodine, Zinc as Zn^{2+}, Total Coliform and E-Coli as per NEQS 2010 for Drinking Water. pH, Temperature, Biochemical Oxygen Demand	Converter Station near Lahore. – Three (03) points within the boundary of Converter Station. Converter Station at Matiari. – Three (03) points within the boundary of Converter Station. Proposed T/L Route. – Major receptor i.e. rivers, canals, residential areas etc. within the ROW of the Proposed T/L. However, estimated sampling points are sixty (60) which will be verified at construction stage. Other proposed effluent discharge points are: – Contractors camps – Concrete preparation plants – Fuel (Petrol. Oil and Grease) products storages. – Vehicle and machines repairing and servicing yards.	Discrete grab sampling and laboratory testing of water samples by EPA approved Labouratory for monitoring.	Once before the start of construction by activity monitors and reported on a monthly basis during the construction and bi-annually during operation.

Receptor	Monitoring Parameters	Location	Monitoring Mechanism	Monitoring and Reporting Frequency
	(BOD_5), Chemical Oxygen Demand (COD), TSS, TDS, Grease & Oil, Phenolic Compound as Phenols, Chloride as Cl-, Fluoride as F-, Cyanide total as CN-, An-Ionic Detergents as MBAs, Sulphate as SO_4^{2-}, Sulphide as S^{2-}, Ammonia Pesticides, Cadmium, Chromium trivalent and hexavalent, Copper, Lead, Mercury, Selenium, Nickel, Sliver, Total toxic metals, Zinc, Arsenic, Barium, Iron, Manganese, Boron and Chlorine as per NEQS 2000 for wastewater.			
Soil Contamination	Visual observations. Soil testing of contaminated sites.	Converter Station near Lahore. – Three (03) points within the boundary of Converter Station. Converter Station at Matiari. – Three (03) points within the boundary of Converter Station. Proposed T/L Route. – Tower sites with severe contamination. Other proposed sampling sites are: – Construction Camp. – Equipment washing yards. – Spillage points of	Discrete grab sampling and laboratory testing for soil and water samples.	Once before the start of construction by EPA approved Labouratory. Sampling and laboratory testing should be done on fortnightly basis during the construction stage and reported on a monthly basis. Bi-annual monitoring and reporting during the operational stage.

Receptor	Monitoring Parameters	Location	Monitoring Mechanism	Monitoring and Reporting Frequency
		fuel, chemicals and lubricants.		
Land Resources	Random visits and visual observations of landuse change from agriculture to residential and commercial.	Surrounding areas of Converter Station near Lahore. Surrounding areas of Converter Station at Thar. Proposed T/L Route. – Towers Sites with significant landuse change.	Visual checks.	Once about a fortnight before the construction starts by activity monitors and reported on a monthly basis during the construction period.
Dust Emissions	PM_{10}	Converter Station near Lahore. – Four (04) points within and outside the boundary of Converter Station. Converter Station at Matiari. – Four (04) points within and outside the boundary of Converter Station. Proposed T/L Route. – Sensitive receptors within the ROW of the proposed T/L close to the access roads. Estimated sampling points are thirty (30) which will be verified during construction stage.	Visual checks.	Once prior to the construction Weekly during the construction period reported on monthly basis.
Noise Pollution	dBA Leq. as per NEQS 2010	Converter Station near Lahore. – Four (04) points within and outside the boundary of Converter Station. Converter Station at Matiari. – Four (04) points within and outside the boundary of Converter Station. Proposed T/L Route – Sensitive receptors within the ROW of the proposed T/L close to the access roads. Estimated sampling points	Noise level meter	Once prior to the start of construction. As and when necessary or as instructed by Supervisory Consultants. Sampling should be done on regular basis during the construction of Project specifically during the blasting period and reported on a monthly

Receptor	Monitoring Parameters	Location	Monitoring Mechanism	Monitoring and Reporting Frequency
		are thirty (30) which will be verified during construction stage. Other proposed sampling sites are: – Construction camps. – Equipment yards.		
Fumes and gases	SO_x, NO_x, HC and PM_{10} as per NEQS 2010 for ambient air and NEQS 2009 for vehicular emission.	Converter Station near Lahore. – Four (04) points within and outside the boundary of Converter Station. Converter Station at Matiari. – Four (04) points within and outside the boundary of Converter Station. Proposed T/L Route – Major receptors within the ROW of the proposed T/L close to the access roads. Estimated sampling points are thirty (30) which will be verified during construction stage. Emissions from the silencers of heavy machinery, trucks and other vehicles.	Onsite monitoring of ambient air quality in ppb will be preferred, however if onsite monitoring facility is not available than onsite sampling and testing in laboratory can be performed.	During the baseline and once prior to construction Monitoring and reporting of air pollution parameters including NO_X, SO_X, CO_X, Lead and HC after every three (03) months during the construction period. Monitoring and reporting on bi-annual basis during the operation.
Ecological Resources	Random visual checks of natural habitat.	Converter Station near Lahore. – Ten (10) points within and outside the boundary of Converter Station. – Converter Station at Matiari. – Ten (10) points within and outside the boundary of Converter Station. – Proposed T/L Route – Natural habitats along the ROW of the proposed T/L (i.e. Deserts and	Visual checks and counting to ensure that only marked trees are cut. During operation to check that no tree should be above 2.5 m height in 15 m of Project corridor on either side. Monitoring of Wildlife/birds hunting.	Monitoring and reporting on monthly basis during the construction stage. Bi-annual monitoring and reporting during the operation stage.

Receptor	Monitoring Parameters	Location	Monitoring Mechanism	Monitoring and Reporting Frequency
		Xeric Shrublands and North-western Thorn Scrub Forests).		
Houses and Animal Sheds	Visual checks and consultation with community. Removal of houses, animal sheds etc. which are within the Project corridor.	Lahore Converter Station site. MatiariConverter Station site. Proposed T/L Route – Houses, animal sheds within the ROW of the proposed T/L. These structures will be verified prior to the start of construction.	Random visits and consultations with PAP's.	Prior to the start of construction. Reporting will be done on the basis of LARP.
Public infrastructure	Visual checks and by community consultations Removal of tubewells, peter pumps, rooms, open wells etc. within the ROW and Project Area for Converter Stations.	Lahore Converter Station site. MatiariConverter Station site. Proposed T/L Route – Public infrastructures within the ROW of proposed T/L. These structures will be verified prior to the start of construction.	Random visits and consultations with PAP's.	Prior to the start of construction. Reporting will be done on the basis of LARP.
Community around the Project corridor	Use of common resources. Hindrance to mobility.	- Communities around the Lahore Converter Station site. - Communities around the Thar Converter Station site. - Communities within the ROW of the proposed T/L	By community consultations.	Prior to the start of construction and during the construction stage. Reporting will be done on the basis of LARP.

9.12 Environmental and Social Training

To strengthen the environmental and social monitoring capacity of NTDC field staff, short training courses supplemented through on job training will be conducted, which will also provide awareness about the environmental issues, ADB safeguards and guidelines and monitoring strategies. The short term training programmes will also be conducted for the unskilled workers hired from the local community. Training Consultants will be engaged to impart these trainings. The remunerations for the training Consultant and training materials are included in the cost.

9.12.1 Reporting Mechanism

The Supervisory Consultant will be responsible for submitting a monthly environmental/social report for the Project, with copies to the Chief Engineer (EHV-I &II) and PD who can submit these to EPAs and the donor agencies. The Supervisory Consultant's monthly progress report will include the following environmental and social information:

- Breakdown of environmental non-compliances and rectification by the Contractors;
- The results of monitoring of environmental and social parameters carried out by the Environmental Staff; and
- Grievances that arise during the month and their rectification to the satisfaction of PAPs.

The Environmental Cell will provide the report depicting the monitoring results to the Supervisory Consultants with a copy to the PD. The overall progress reporting of the compensation for the losses of crops, structures, infrastructure and other community issues is the responsibility of the Environmental and Social Expert of NTDC and field Staff, who will provide these reports to the Supervisory Consultant. The Consultant will compile the report on monthly basis and submit to the Chief Engineer (EHV-I &II) who will submit it to ADB. The Consultant will also submit a comprehensive report reflecting the environmental and social aspects based on the reports of Environmental Cell, Environmental and Social Experts and their own observations on quarterly basis.

9.13 Community Consultation

There will be different stages of the Project such as design, pre-construction, construction, operation and maintenance. To make the Project sustainable and environmentally viable, it is essential to consult the community in the various activities to be carried out at the different stages of the Project. Therefore, following mechanism is suggested to ensure participatory consultations.

Pre-construction Stage

During pre-construction stage NTDC will depute a consultant who will full fill all the environmental and social requirements of the local as well as the ADB Safeguards. In this regard, IPSA, EIA and the preparation of LARP will ensure the participatory consultation of all the stakeholders including PAPs.

Construction Stage

NTDC will ensure that the construction contractor is legally bound to full fill all the arrangements, measures and documentation as per the EIA, EMMP etc. This will be ensuring through Supervisory Consultant deputed by the NTDC. SC will ensure that active participatory consultation with the locals and concerned NGOs and other groups is being carried out.

Operation and Maintenance

During the O & M stage, NTDC Environmental Cell staff will ensure the consultation with the locals. In this regards, Environmental Cell will generate annual reports covering the consultations records with photographic evidence.

Based on the potential impacts of the proposed T/L following Table 9-3 shows the major activities which will require participatory consultation along with stage and major issues to be discussed.

Table 9–3: Community Consultations in Various Project Activities

Sr. No.	Activities	Project Stage	Consultation Mechanism
•	Compensation of Losses (crops	Pre-	To consult the community in order to evaluate the

Sr. No.	Activities	Project Stage	Consultation Mechanism
	&trees)	Construction	losses and compensation paid to them.
•	Relocation of Structures	Pre-Construction	Relocation of structures (houses etc.) will be done with the community participation.
•	Relocation of Infrastructure	Pre-Construction	Relocation of infrastructure (tube well, well etc.) will be done with the community consultation.
•	Installation of Contractors & Workforce Camps	Construction	For the placement of camps at appropriate locations, locals will be taken into confidence through discussing the needs with them.
•	Installation of Towers	Construction	Social mobilization will be done before installation of Towers to get the consent/willingness of the community.
•	Camp/ Labour force activities (hunting, fishing etc.)	Construction	In the local consultations, the Contractor will make sure his presence.
•	Installation of Water Pumps by the Contractors	Construction	Suitable location (s) for the installation of water pumps must be shared with the locals. The community must be assured that after completing the Project, the Contractor will leave the installed assets (like water pumps etc.) with the community.
•	Noise Effects of the Project	Operation	During the periodic inspection for the proper operation and maintenance of the Project, the concerned community will be consulted to identify the Project effects. Accordingly remedial/mitigation measures will be adopted/implemented.
•	Electromagnetic Field Effects of the Project	Operation	Periodic consultations with the locals will be carried out to examine the EMF effects and suggested measures to mitigate such effects will be forwarded to the concerned authorities.
•	Others	Operation	In the periodic inspection visits, the community concerns will be examined and analyzed in the operational stage of the Project.

9.14 Monitoring and Evaluation

Monitoring and evaluation (M&E) are critical activities in the social impacts assessment and involuntary resettlement. Monitoring involves periodic checking to ascertain whether the activities are progressing as per schedule while the evaluation is essentially a summing up, at the end of the Project, of the assessment of actual achievements in comparison to those aimed at during the implementation and to assess the benefits provided by the Project to uplift the socio-economic conditions of the community particularly PAPs.

The monitoring and evaluation is carried out in two stages i.e. during implementation of the Project and at operation stage. During the implementation of the Project, as referred in previous paragraphs Environmental and Social Expert will be responsible for the environmental and social monitoring. During the operation and maintenance stage, same staff will monitor the environmental and social aspects. The parameters to be monitored at each Project stage have been discussed in previous sections.

As there are temporary impacts on the PAPs during the implementation stage like crop and tree losses, houses and infrastructure relocation and they will be compensated properly, so it is expected that they will return to their normal routine life soon after implementation of the Project. Due to the above reasons, it is not necessary to evaluate the social impacts during the operation stage of the Project by an independent agency. However, the NTDC operation staff will monitor and evaluate the social impacts like EMF effects etc.

9.15 Change Management Plan

The present EIA has been carried out on the basis of the Project information available at this stage. It is however possible that the changes are made in some components of the Project during the design and construction phases. In order to address the environmental and social implications of these changes, a simple framework has been devised, which is described in this section. The change management framework recognizes the three broad categories (A, B & C) of the changes in the Project as detailed below:

9.15.1 Category 'A' Change

The 'Category A' change is one that will lead to a significant departure from the Project described in the EIA and consequently requires a reassessment of the environmental and socioeconomic impacts associated with the change. In such an instance, NTDC will be required to conduct a fresh EIA of the changed aspect of the Project design and send the updated report to the relevant agencies for approval. Some of the examples of category "A" changes are briefed below:

- Change in the T/L route by more than 10 km of the original alignment or a change in the route by less than 10 km, but the changed route has environmental and/or social sensitivity more than the original route. Increase in the T/L length exceeding 20 % of the original design, or increase in the length by less than 20% but involving areas which are more sensitive – environmentally and/or socially – than the original route. Change in the Converter Station site by more than 1 km of the location studied during the EIA, or change in the site by less than 1 km but the new location has a higher environmental and/or social sensitivity. Increase in the number of Converter or Grid Station to be established.

9.15.2 Category 'B' Change

The category 'B' change is one that will entail Project activities not significantly different from those described in the EIA, which may result in the Project effects with overall magnitude to be similar to the assessment made in this report. In case of such changes, the EIA will be required to reassess the environmental and socio-economic impacts of the activity, specify additional mitigation measures, if necessary and report the changes to the relevant agencies (Contractors, EPAs). Examples of such changes are provided below.

- Changes in the T/L route by more than 500 m but less than 2 Km of the original alignment or increase in the T/L length exceeding 10 % of the original design, but not exceeding 20%, provided that the extended route does not have environmental or social sensitivity. Change in the Grid Station site by more than 500 m of the location studied during the ESA, but not exceeding 1 km, provided that the new location does not have such changes, which will necessitate site surveys for the T/L routes or Grid Station sites, by the environmental and socioeconomic experts. A site specific assessment for any additional environmental as well as socioeconomic issues will need to be carried out.

9.15.3 Category 'C' Change

A Category-C change is one that is of little consequence to the EIA findings such as change in alignment less than 500 m. This type of change does not result in effects beyond those already assessed in the EIA; rather it may be made onsite to minimize the impact of an activity, such as re-aligning a particular section of the T/Ls to avoid cutting a tree, or relocating construction campsites to minimize clearing vegetation. The only actions required for such changes are informing all the key personnel and document the change.

9.16 Public Disclosure

NTDC will disclose this EIA to all the stakeholders prior to the start of the construction. This report will be made available to the stakeholders at places as designated by the EPAs in accordance with the PEPA, 1997. In addition, executive summary of the Report will be translated into Urdu language and made available to the affected communities and locals. The copies will also be kept at construction site for ease in accessibility of the locals. This will ensure the locals to be aware of the Project impacts, its mitigation, responsible staff and mode of implementation. In addition, the executive summary will also be published on NTDC website.

9.17 Plantation Plan

Plantation plans for the oneConverter Station at Matiari and one sub-station near Nankana Sahib are described in the following paragraphs.

9.17.1 Converter Station at Matiari

The Converter Station has a total peripheral area of 5.0 Km and if two (02) rows of plants are proposed to be raised, one along the outer periphery and one along the inner side of the boundary wall, keeping the distance as 3 meters from plant to plant, nearly 3500 plants (or say, 4000 plants) shall be raised along the boundary. Therefore, about 2000 large size plants shall be planted along the outer side of the boundary wall, whereas medium size plants (2000 Nos.) are recommended for inner side.

Approximately, another 2000 plants of medium size height can be grown along the inner roads of the Converter Station, while 2000 ornamental and flowery shrubs are to be raised in the open spaces of the Converter Station and in the grassy lawns. The following number and kinds of plants, therefore, will be required for the Converter Station as given in Table 9-4.

Table 9-4: Number and Types of Plants

Sr.No.	Kind of Plants	Number of Plants
1	Large Size Plants	2,000
2	Medium Size Plants	4,000
3	Ornamental / Flowery Shrubs	2,000
Total Plants		**8,000**

i) Large Trees to be planted along outer side of Main Boundary

Trees suggested to be planted along the outer side of Main Boundary are given in Table 9-5 below:

Table 9-5: Large sized Trees for Outer Boundary

Sr. No.	Local Name	Scientific Name
1.	Pipal	*Ficus religiosa*
2.	Simal	*Bombax ceiba*
3	Arjan	*Terminalia arjuna*
4.	Shisham	*Dalbergia sissoo*
5.	Neem	*Azadirachta indica*
6.	Kikar	*Acacia nilotica*
7.	Gule-Nishtar	*Erythorina suberosa*
8	Conocarpus	*Conocarpus lancifolius*
9.	Siris	*Albizzia lebbek*

ii) Medium Sized Trees to be planted along the inner side of the main boundary and Inner Roads

Table 9-6 shows the trees suggested to be planted along the inner roads on both sides.

Table 9-6: Medium Sized Trees for Inner Boundary and Roads

Sr. No.	Local Name	Scientific Name
1.	Bakain	*Melia azadarach*
2.	Amaltas	*Cassia fistula*
3.	Gul Mohar	*Poinciana regia*
4.	Jacaranda	*Jacaranda moniosifolia*
5.	Robinia	*Robinia pseudoacacia*
6.	Alstonia	*Alstonia scholaris*
7.	Silver Oak	*Grevillea robusta*
8.	Bottle Brush	*Collistemon lanceolatos*
9.	Sukhchain	*Pongamia glabra*
10.	Kachnar	*Bauhinia variegata*

iii) Shrubs to be Raised in the Grassy Lawns and Open Areas

- Duranta *Golden (Duranta sp)*;
- Boganvilla (*Bougain villea sp*);
- Tecoma (*Tecoma stans*);
- Peeli booti (*Cassia glauca*);
- Habiscus (*Hibiscus sp*);
- Erythrina sp; and
- largestomia (*Lagerstroemia alba*).

9.17.2 Converter Station near Lahore

Length of the boundary, covering all the four sides of this Converter Station comes to 4.2 Km and as in case of Converter Station at Matiari, two rows of plants shall be raised along the periphery, one row of large size plants on the outer side of the boundary and one row of medium size plants along the inner side of the boundary wall keeping plant to plant distance as 3 meters. In this way nearly 3000 plants will be required for boundary planting with 1500 large size plants for the outer side of the boundary and 1500 plants of medium size for the inner row of the boundary wall. Likewise, another 1500 plants of medium size shall be required for raising plants along the inner roads, while 1500 ornamental/flowery shrubs will be required for the grassy and open land. Detail of plants required is in the Table 9-7 given below.

Table 9-7: Number and Types of Plants

Sr.No.	Kind of Plants	Number of Plants
1	Large Size Plants	1,500
2	Medium Size Plants	3,000
3	Ornamental / Flowery Shrubs	1,500
Total Plants		**6,000**

Trees recommended for raising along the outer and inner side of the main boundary

i) Large Trees to be planted along outer side of Main Boundary:

Trees suggested to be planted along the outer side of Main Boundary are given in the Table 9-8.

Table 9-8: Large Trees to be Planted

Sr. No.	Local Name	Scientific Name
1.	Pipal	*Ficus religiosa*
2.	Shisham	*Dalbergia sissoo*
3.	Neem	*Azadirachta indica*
4.	Simal	*Bombar cilba*
5.	Arjan	*Terminalia arjuna*
6.	Siris	*Albizzia lebbek*
7.	Kikar	*Acacia nilotica*
8.	Chinar	*Platanus orientalis*
9.	Alstonia	*Alstonia scholaris*
10.	Gule-Nishtar	*Erythorina suberosa*
11.	Pilkan	*Ficus infectoris*
12.	Kachnar	*Bauhinia variegata*

ii) Medium Sized Trees to be planted along the inner side of the main boundary and Inner Roads

Table 9-9 indicates the tree species suggested for planting along the inner roads on both sides.

Table 9-9: Medium Sized Trees to be Planted

Sr. No.	Local Name	Scientific Name
1.	Amaltas	*Cassia fistula*
2.	Mulberry	*Morus alba*
3.	Gul Mohar	*Poinciana regia*
4.	Jacaranda	*Jacaranda moniosifolia*
5.	Robinia	*Robinia pseudo acacia*
6.	Bakain	*Melia azadarach*
7.	Silver Oak	*Grevillea robusta*
8.	Bottle Brush	*Collistemon lanceolatos*
9.	Sukhchain	*Pongamia glabra*

iii) Shrubs to be Raised in the Grassy Lawns and Open Areas

- Jasmine (*Jasminum humile*);
- Peeli booti (*Cassia glauca*);
- Habiscus (*Hibiscus sp*);
- Erythrina sp;

- Marva (*Murraya exotica*);
- largestomia (*Lagerstroemia alba*);
- Largestomia (*Lagerstroemia rosa*);
- Largestomia (*Lagerstroemia purpurea*).
- Tecoma (*Tecoma stans*); and
- Bouganvilla (*Bougain villea sp*).

9.17.3 Plantation Cost

The cost of plantation includes the cost of initial planting (including restocking during first 2 years), and maintenance cost for first four years of plantation on the basis of Rs. 500/- daily labour rate for first two years and Rs. 600/- for the 3rd and 4th year. The cost break-up of planting and maintenance for a period of four years is given in the Tables 9-10 to 9-13.

Table 9-10: Estimated Cost of Plantation of 500 Plants for First Year

Sr. No.	Particulars of Work	Quantity	Rate (Rupees)	Amount (Rs.)
1	Clearance of site	500 plants (2 MD)	500/MD	1,000
2	Layout	500 plants (2 MD)	500/MD	1,000
3	Digging of Pits 2.65 x 500 = 1325 cft. (465.075 m^3)	500 pits (20 MD)	500/MD	10,000
4	Average cost of plants	500 plants	Rs.50/-	25,000
5	Carriage of plants 500 Nos. from Nursery to Site including loading/unloading	500 plants	Rs.10/- per plant	5,000
6	Planting of plants with ball of earth	500 plants (10 MD)	500/MD	5,000
7	Replacement of earth with silt 1 cft. per pit	500 cft.	LS	15,000
8	Hand watering with bowser (one driver+one coolie) 60 times x 500 plants @ 5 MD per 1000 plants	30,000plants (150 MD)	500/MD	75,000
9	Weeding 4 times 500x4	2000 plants (4 MD)	500/MD	2,000
10	Miscellaneous/ Contigencies		LS	15,000
			Sub-total	**154,000**

Table 9-11: Estimated Cost of Restocking of 20% Plants and Maintenance for 2nd Year

Sr. No.	Particulars of Work	Quantity	Rate (Rupees)	Amount (Rs.)
1	Restocking of 20% plants	100 plants	Rs 50/-	5,000
2	Carriage of plants from Nursery to site including loading/unloading	100 plants	Rs. 10/- per plant	1,000
3	Re-digging of pits 20% (100 No)	100 No. (4 MD)	500/MD	2,000
4	Planting of plants with ball of earth – 100 No.	100 No. (2 MD)	500/MD	1,000
5	Hand watering with bowser (one driver+one coolie) 60 times x 500 plants @ 5 MD per 1000 plants	30,000 plants (150 MD)	500/MD	75,000
6	Reopening of pits twice 1 cft per pit (400+500) = 900 cft	900 cft (4.5 MD)	500/MD	2,250
7	Weeding 500x2	1000 Nos. of plants (4 MD)	500/MD	2,000
8	Miscellaneous		LS	15,000
			Sub-total	**103,250**

Table 9-12: Estimated Cost of Restocking of 20% Plants and Maintenance for 3rd Year

Sr.No.	Particulars of Work	Quantity	Rate (Rupees)	Amount (Rs.)
1	Restocking of 20% plants	100 No.	Rs 60/-	6,000
2	Carriage of plants from Nursery to site including loading/ unloading	100 No.	Rs. 15/- per plant	1,500
3	Re-digging of pits 20% 60 No.	100 No. (4 MD)	600/MD	2,400
4	Planting of plants with ball of earth (100 No.)	100 No. (2 MD)	600/MD	1,200
5	Hand watering with bowser (one driver+one coolie) 48 times x 500 plants @ 5 MD per 1000 plants	24,000 plants (120 MD)	600/MD	72,000
6	Reopening of pits twice 1 cft per pit (400+500) = 900 cft	900 cft	600/MD	2,700

Sr.No.	Particulars of Work	Quantity	Rate (Rupees)	Amount (Rs.)
		(4.5 MD)		
7	Weeding twice 500x2	1000 Nos. (4 MD)	600/MD	2,400
8	Miscellaneous			20,000
			Sub-total	**108,200**

Table 9-13: Estimated Cost for Maintaining 500 Plants for 4th Year

Sr.No.	Particulars of Work	Quantity	Rate (Rupees)	Amount (Rs.)
1	Hand watering with bowser (one driver+one coolie) 48 times x 500 plants @ 5 MD per 1000 plants	24,000 plants (120 MD)	600/MD	72,000
2	Weeding 500x2	1,000 Nos. (4 MD)	600/MD	2,400
3	Trimming/pruning of plants	500 No. (5 MD)	600/MD	3,000
4	Miscellaneous			20,000
			Sub-total	**97,400**
			Grand Total	**462,850**
			(or say) Rs.	**465,000**

Cost of raising 500 plants has been estimated as Rs. 465,000/- including price of plants, earthwork, procurement of manures, supply of water to young plants throughout the year and maintenance of plantation for four years. Therefore, cost of raising one plant and its maintenance for 4 years comes to be Rs. 930/-.

i) Cost for raising 14,000 plants @ Rs. 930/- per plant alongwith maintenance for 4 years = Rs. 13,020,000

ii) Cost of development of Grassy Lawns on 5 acres in different patches at both Converter Stations (LS) = Rs. 1,000,000

Total Cost: = Rs. 14.02 million

9.18 Estimated Environmental Management, Monitoring and Auditing Costs

Table 9-14 provides the estimated costs for the resettlement/compensation, environmental monitoring and training to NTDC field staff.

The resettlement/compensation costs relate to the compensations for temporary acquisition of land under the Towers, crops, cropping season, trees, structures, infrastructure etc. to be removed from the 100 m corridor. It should be noted that as referred earlier that the Project is at a preliminary stage and the detailed survey is to be carried out for the Project showing the actual position of the Towers, so at this stage only tentative and lump sum amount has been allocated for the relocation of the infrastructure and the compensation for land acquisition and resettlement is based on the environmental and social field surveys. The cost of land was calculated based on the discussions with stakeholders, PAPs and market rates of the area.

To assess the replacement cost of the structures, similar newly constructed structures will be visited and the cost assessed by consultation with the owners of these structures. The loss of crops will be estimated during the soil investigations and construction of the Tower foundations and erection. A 20 m x 20 m space will be required for the aforesaid activities and during stringing action a 10 m wide strip will be required. To reach the working sites, the existing tracks and roads will be used. However, a minor loss due to the accessibility to the site has also been included in the crop loss estimation. The loss of crops will be based on the considerations that the loss will be for a whole year i.e. two cropping seasons i.e. winter harvest and summer harvest. During the valuation of crops and trees, in addition to the social surveys, the concerned agriculture and forest departments needs to be visited along with discussion with the PAPs.

The crop rates vary on yearly basis as these are dependent upon the market rates. Govt. announces new rates every year for rice, wheat and cotton crops in Pakistan. The cost for environmental monitoring is based on the sampling, transportation and analysis of the samples by EPA approved private laboratory. However, cost for the purchase of any equipment has also been included in the estimate.

Cost for training is based on one week training workshops both on environmental and social issues and the hiring of services of two Environmental and Social Consultants and developing reading materials required for distribution amongst the participants of the workshop.

Cost for auditing is based on the fact that on each trip two experts i.e. environmentalist and social expert will visit the site for one week. This also includes cost for their travelling and lodging, report writing at home etc.

Table 9-14 shows the estimated Environmental and Social Management, Monitoring and Auditing Cost for the proposed T/L Project. The total estimated cost for the environmental and social management, monitoring and auditing comes to about Rs. 60.4 Million.

Table 9–14: Estimated Environmental and Social Management, Monitoring and Auditing Cost

Sr. No.	Description	Unit	Quantity	Unit Rate (Rs.)	Total Cost (Rs.)	Remarks
A. Land Acquisition, Compensation and Resettlement						
1.	Loss of crops	Acre		Rates of various crops are provided in Table 9-15.		For two crop seasons loss (i.e. winter harvest and summer harvest). Cost worked out for each crops and finally weighted average considered. Loss will be about four (04) times i.e. at the time of the excavations of tower foundations, concreting/pouring, tower installation and stringing of

Sr. No.	Description	Unit	Quantity	Unit Rate (Rs.)	Total Cost (Rs.)	Remarks
						conductors
2.	Loss of Trees					--
a.	Loss of Trees (Ornamental)			Rs. 2,500/tree (Average rate)		Based on past experiences of such Projects and general perception of the Punjab and Sindh areas compensation for each tree has been evaluated as an average of Rs. 2,500/tree.
b.	Loss of Trees (Fruit)			Rs. 10,000/tree		Based on past experiences of such Projects and general perception of the Punjab and Sindh areas compensation for each tree has been evaluated as an average of Rs. 10,000/tree.
3.	Plantation Cost					
a.	Reforestation Works for Converter Stations.	Lump sum			14,020,000	Cost includes four (04) years maintenance (refer Section 9.17)
b.	Reforestation works during installation of towers					Refer section 9.17 for cost of raising per plant @ Rs. 540/-
4.	Compensation of house structures			An average of Rs. 100,000 /- per house structure		Cost will be worked out once the ROW is marked on site
5.	Shifting Assistance			Rs. 14,000/- per house		Once Only
6.	Assistance for three months rent			Rs. 9,000/- per house		--
7.	Relocation of Infrastructure	Lump sum			3,000,000	On the basis of assumption that a few no. tubewells, wells, boundary wall etc. may be affected during the final design
	Sub-Total (A)				**17,200,000**	
B. Environmental and Social Monitoring and Evaluation						
1	Monitoring of Social Parameters by Social Expert	Month	24	Rs. 75,000/- per month	1,800,000	Social Expert is to be employed by NTDC Environmental Cell
2	Environmental Monitoring by NTDC Environmental Cell	Lump sum (Annualy)			12,000,000	Cost worked out based on market rates of monitoring and the frequency as mentioned in the report (Refer Section 9.11 and Table 9-2).

Sr. No.	Description	Unit	Quantity	Unit Rate (Rs.)	Total Cost (Rs.)	Remarks
3	Training on environmental and Social issues with the breakup as follows:					
a.	Training Design (training module environmental and social)	Lump sum		500,000/- per year	500,000	This cost includes cost of Trainer.
b.	Training Material (reading material for participants, training aids etc.)	Lump sum		500,000/- per year	500,000	Initially for one (01) years This Cost includes cost of literature preparation, cost of printed material such as posters, pamphlets etc.
c.	Miscellaneous	Lump sum			400,000	Training expert will be hired by NTDC for one (01) week.
4. Auditing Cost						
a.	Hiring of Auditing Agency	Trip	6 trips/- (two (02) trips per year)	Rs. 375,000/- per trip	2,250,000	One (01) week input at site and three (03) days input at office for report preparation by two (02) experts. Total trips will be six (06) upto the completion of construction period. The cost for local travelling at site will be bome by the NTDC.
	Sub-Total (B)				**17,450,000**	
C. Management Cost						
a.	HSE	Month	12	Rs. 313,400	3,760,800	One (01) HSE Engineer will be deputed for one (01) year.
b.	Solid Waste Management	Month	24	Rs. 313,400	7,521,600	One (01) Solid Waste Management Expert will be deputed for the two years (construction stage).
c.	Social Welfare Cost	Lump sum			7,500,000	Different social welfare Projects i.e. easy loans for affectees, rehabilitation of schools, roads, irrigation channels etc.
	Sub-Total (C)				**18,782,400**	
D. Miscellaneous						
a.	Miscellaneous	Lump sum			1,500,000	
	Sub-Total (D)				**1,500,000**	
	Total Cost (A+B+C+D)				**54,932,400**	

Sr. No.	Description	Unit	Quantity	Unit Rate (Rs.)	Total Cost (Rs.)	Remarks
	Contingency @ 10 %				549,3240	
	Grand Total				**60,425,640**	

Table 9–15: Average Crops Prices in the COI in 2014 to 2015*

Sr.No.	Crops	Average Yield Kg/ha	Market Price Rs/40 kg	Crops Price Rs/ha	Crops Price Rs/acre
1	Maize	5,434	1,100	149,435	60,500
2	Sugarcane	74,100	155	287,135	166,248
3	Wheat	3,458	1,150	99,415	40,248
4	Oil seed	1,200	1,000	1,200,000	485,000
5	Cotton	3,952	2,500	247,000	100,000
6	Rice	5,434	800	108,680	44,000
7	Pulses	800	1,200	960,000	388,000

*Based on the baseline survey carried out for the EIA study.

Table 9-1 (a): Environmental Mitigation Management Matrix for Transmission Line

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
1.	Land Resources	Construction of T/L					
a.			Temporary acquisition of land for Tower Construction, Contractors Camps, access roads, aggregate quarries etc.	- Land would be acquired through short term lease agreement between the Landowners and Contractors. Rental terms should be negotiated up to the satisfaction of the concerned landowner. - Compensation for loss of crops, cropping seasons, and trees to be removed from the Tower locations in the 100 m wide ROW. - The other general guidelines to minimize the impacts on land use are: i. Project facilities should be located at a minimum distance of 500m from the major receptors i.e. built-up areas, wildlife habitats, archaeological, cultural monuments etc. ii. Prior to the commencement of the	Environment & Social Expert, NTDC	- To make fair assessment of the compensation cost and affectees approval to be sought. One window operation for quick payment to the affectees.	Before Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
				construction activities, the Contractor should submit a development plan to the Engineer-incharge and the concerned EPA (if required) for its scrutiny and approval. iii. Waste/barren land and natural areas located at high elevation should be used for setting up the Project campsite.			
b.			Excavation of pits during the subsurface investigations for Tower foundations.	- Backfilling, compaction and leveling to original state will avoid the accidental mishaps to people and cattle as well as check the potential land erosion.	- Contractor, Supervisory Consultants and NTDC.	Contractor adheres to the restoration clause.	During Construction
c.			Air Pollution due to the use of construction machinery and heavy vehicle during construction phase.	- Concrete batching plant should be equipped with dust control equipments i.e. fabric filters, wet scrubber etc. - NEQS should be enforced - Proper tuning of vehicles should be ensured. - Haul trucks should be covered with tarpaulin.	Contractor, Supervisory Consultants and NTDC.	Contractor to implement and regular monitoring by Supervisory Consultants.	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
				- NTDC should setup air quality monitoring system along Project corridor.			
d.			Noise Pollution due to the use of construction machinery and heavy vehicle during construction phase.	- Provide the casing to the noise generating machinery as use of noise absorbing material. - Proper tuning of vehicle and oiling of equipments moving parts. - NTDC should setup noise level monitoring system along the COI near construction activities.	Contractor, Supervisory Consultants and NTDC.	Contractor to implement and regular monitoring by Supervisory Consultants.	During Construction
e.			Soil erosion due to the construction activities such as clearing and grabbing, excavation, filling, laying down concrete foundation for Towers and setting up construction camp.	- All disturbed areas should be protected against severe soil erosion by stripping and stockpiling of the available topsoil for later re-vegetation. - Special slop protection in the sensitive areas i.e. desert or semi desert areas.	Contractor, Supervisory Consultants and NTDC.	- Contractor to implement - Regular Monitoring	During Construction
f.			Soil contamination	- Contractors will train their workers in the handling	Contractors, Supervisory	- Regular	During

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
			due to the spillage of fuel, chemicals and lubricants during the construction of T/L.	and storage of the chemicals that can cause soil contamination. - Soil contamination due to concrete transportation will be minimized by placing all containers in casings. - Solid waste generated at the camp sites will be properly treated and safely disposed of only in the demarcated waste disposal sites.	Consultants and NTDC to monitor.	Monitoring - Contractor to implement.	Construction
g.			Impacts on Public infrastructure i.e. roads, canals, existing power lines etc. during construction stage.	- For road crossings NTDC will provide adequate line clearance from road. Proper traffic management plan will be prepared and construction work will be carried out at off peak hours. - Canal crossing will not have any significant impact during the stringing action stage. - For Power lines crossing temporary shutdown of the existing T/Ls will be carried out and proactive coordination will be made between the	Contractor, Supervisory Consultants and NTDC.	- Regular Monitoring - Contractor to implement.	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
				construction staff and concerned grid station operation staff.			
h.			During the operational stage local people have to tolerate an excessive noise level due to the current flow in the conductors especially in the rainy season.	- To overcome this problem, the route has been selected to pass through the least populated areas. - Construction of houses and building structure within the COI will be avoided and NTDC will make sure to check such type of construction during the operation stage.	NTDC to monitor.	Regular Monitoring.	During Operation
i.			During the operational stage, electric current (induction) may travel into the Towers due to short circuiting and may become a hazard to the public /animals.	- Earthing system of the Towers to avoid accidents and at least two diagonal legs of the Towers should be properly grounded.	NTDC to monitor	Regular Monitoring.	During Operation.
j.			Collapse of the Towers due to the high wind or earthquake will be dangerous for human as well as	- The Towers are designed on the basis of proper subsoil investigations and climatic conditions of the area including maximum wind	Contractor, Supervisory Consultants and NTDC	Contractor will implement during construction and NTDC to monitor during operation.	During construction and operation

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
			animal life and can cause loss to property.	velocity and earthquakes which are normally based on last 50 years data. - At the time of detailed survey for fixing the Tower positions proper soil investigations will be carried out to check the presence of collapsible soils and if detected, Engineer will be informed immediately for design change. It will be ensured that no accident due to collapsing of Towers would occur during the life of the Project.			
k.			Limited use of agricultural land under the Towers during operation phase.	After construction of Towers, the land can mostly be used for agriculture, as observed along the existing 66/132/220/500kV T/Ls in Pakistan.	NTDC	Fair compensation at the start of work and job opportunities should be provided to the affectees to off-set the loss of income due to the acquisition of their land.	During Operation
l.			The electromagnetic field (EMF) due to current flow in	- The Project has been planned to pass through the least populated area and the T/L will be kept at least	NTDC to monitor	Regular Monitoring	During Operation

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
			proposed T/L can cause the risk of *leukemia* during operational stage.	100 m from the populated areas even if some effects due to EMF are envisaged will be minimal due to safe distance. - A vertical clearance required as per international standards will be maintained especially near the populated areas. - Check will be kept by the NTDC that no construction will be allowed within 100 m of the proposed T/L.			
m.			Breaking of conductors due to any mishap will cause a safety hazard due to the current flow in the fields and crossing over roads, canals, streams etc.	- The conductors are selected on the basis of local climatic conditions including maximum wind velocity, temperature and humidity conditions. So, there is almost no risk of breaking of conductors. However, due to some unavoidable circumstances, if such a situation occurs, NTDC has provided such an arrangement that the flow in the conductors will be automatically tripped instantaneously.	NTDC	Regular Monitoring	During Operation

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
n.			The electronic devices / equipment may fail to work under the flux EHV T/L.	The severity of this impact can be minimized by providing proper requisite clearance, for which observations should be made in the field under the existing EHV T/L deliberately.	NTDC	Regular Monitoring	During Operation
2.	Water Resources	Construction of T/L.					
a.			Contamination of surface and ground water resources from fuel and lubricants generated from the Contractors' camps, equipment wash yards, etc.	- The work will be carried out in such a manner that pollution of water resources is avoided. Fuel storage will be in proper bounded areas. Above surface storage tanks with polythene separators shall be used. All the spills and collected, waste products will be collected, stored and taken to the approved disposal sites as directed by the Supervisory Consultants. - Construction camps should be established in areas with adequate natural drainage channels in order to facilitate the flow of the	Contractors, Supervisory Consultants and NTDC.	- Regular Monitoring - Contractor to implement.	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
				treated effluents. - For wastewater effluent according to the NEQS, the BOD5 concentration in sewage must be brought down to less than 80 mg/l and COD of less than 150 mg/l should also be checked. - Similarly, if the sewage after treatment is to be discharged on to the land, it should meet the requirements of the NEQS for disposal of wastewater.			
b.			Siltation of Natural Streams and Irrigation Channels	- The excavated material will be managed by ensuring proper storage areas at location should be far away from the water bodies - At sand dunes, proper slope protection should be provided to reduce the erosion of the slopes, which may cause the siltation of natural streams.	Contractors, Supervisory Consultants and NTDC.	- Regular Monitoring - Contractor to implement.	During Construction
3.	Ecological Resources	Construction of T/L.					

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
a.			Trees and shrubs clearing at the Tower locations for foundations, stacking of materials and assembly.	Land holders should be paid reasonable compensation for the loss of their standing trees, in accordance with the prevailing market rates.	NTDC	Fair and prompt payment of compensation.	Before Construction
b.			Clearing of vegetation at location of camp facilities.	Areas for construction camps should be kept to the minimum required. The camp sites should be located in plain areas, with minimum vegetation cover.	NTDC	Fair and prompt payment of compensation.	Before Construction
c.			Use of ecological resources for fuel purposes at camps.	Staff and labour should be strictly directed not to damage any vegetation such as trees or bushes.	Contractor, Supervisory Consultants and NTDC.	Contractor will get approval from Engineer for location of camp facilities.	During Construction
d.			Adverse impact on agriculture in COI.	- Land holders will be paid compensation for the loss of their standing agricultural crops in accordance with the prevailing market rates as per LAA, Telegraph Act, NTDC practices, LARF and LARP specific to the Project.	Contractor, Supervisory Consultants and NTDC.	Contractor to implement, Supervisory Consultants and NTDC to check.	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
				- The landholders will also be allowed to salvage the agricultural crops and other vegetation from the affected fields.			
e.			Wild animals like wild boar, jackal etc. will move away from the construction areas and may get hunted by labour. Some reptiles may get killed during digging and dragging operation	- Hunting and harassing of wild animals will be strictly prohibited. - Activities such as construction of Towers, stretching of conductors and carriage of materials will not be allowed during the night in the wildlife sensitive areas. - Lights used in the camps during the construction will be kept to the minimum required. In the wildlife sensitive areas, upward scattering lights will preferably be used. - Vehicle speed should be controlled to avoid incidental mortality of small mammals and reptiles.	Contractor, Supervisory Consultants and NTDC.	Contractor to implement, Supervisory Consultants and NTDC to check	During Construction
f.			Birds will try to find shelter and food somewhere	- Trees having habitat of birds should not be allowed to cut.	Contractor, Supervisory Consultants	Contractor to implement, Supervisory	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
			else and will tend to move away from the route of T/L due to the construction activities and fear of being hunted/ trapped or killed.	- Special mitigation measures needs to be adopted to minimize impacts on the birds, such as avoiding construction activities during the critical periods of breeding and feeding. - Staff working on the Project should be given clear orders not to shoot, snare or trap any bird.	and NTDC.	Consultants and NTDC to check.	
g.			During operation the T/L may become a danger to the movement of indigenous birds and species and fatalities may occur if the birds sit on the conductors especially in the wet conditions.	- Since there is an EMF around the high voltage T/L and excessive noise, no birds sit over the conductors. - However, even if the birds sit over the conductors particularly in the wetland areas, the danger will arise if two phases of the current meet, but as there is 4.75 m to 5.50 m distance between the two opposite phased conductors, no danger to the birds is envisaged.	NTDC	Regular Monitoring.	During Operation
4.	Social and Cultural Resources	Construction of proposed T/L.					

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
a.			Loss of crops.	- Compensation for the loss of crops to the land owners as per prevailing market prices. - The whole process of the payment should be transparent, judicious and without any discrimination or favour. - Minimum possible area should be disturbed for the construction of new paths or roads for carriage of machinery and materials. - Barren land without any crop should be selected for the camp sites.	NTDC	Fair and prompt payment of compensation.	Before Construction
b.			Due to the construction of the Tower foundations, erection and stringing of conductor, people will suffer loss in their annual income due to the loss of crops, trees, etc.	- Compensation for the crops and trees on private land will be provided to the affectees.	NTDC	- Fair, prompt and negotiated payment. - One window operation to ensure prompt payment of negotiated value. NTDC will pay the compensation.	Before construction
c.			Removal of the	- Utmost efforts will be	NTDC to	Contractor to	Before

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
			infrastructure like buildings, huts, animal sheds, tube-wells, etc.	made to minimize the relocation/damage of infrastructure especially houses. - Compensation will be paid to the affectees for the built-up areas like buildings, huts, animal sheds, peter engines/electric motor sheds, etc. on replacement cost basis and the land on existing agricultural land value. - Payment of three (03) months house-rent will be made to the affectees while they will construct a new abode for their families. - Full market price of any equipment (not shiftable) and cost of reconstruction including labor charges will be paid to the affectees. - Affectees will be allowed the salvaging of the demolished materials.	Monitor	Implement	Construction
d.			Relocation of cultural and religious structures like mosques,	- Contractors will follow the realigned route of the T/L to avoid the relocation of cultural and religious structures.	NTDC to Monitor	Contractor to Implement	Before Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
			shrines, graveyards, etc.	- Where unavoidable, proper compensation will be paid with the consultation of the community.			
e.			Impact on the houses, school animal sheds, etc. due to crossing of proposed T/L.	Efforts are being made to avoid the school and houses by avoiding.	NTDC	Fair, prompt and negotiated payment in case of relocation.	Before Construction
f.			Income of the vulnerable people may be affected due crossing of T/L upon their infrastructure, affect of any asserts such as houses, tube wells room etc.	The vulnerable persons shall be provided with all possible assistance and help for acquiring the skills and preference should be given to them for employment. The persons having no land or a person who is going to lose over 50 % of his land will be considered as vulnerable people and will be specially treated to provide the maximum benefits.	NTDC	Contractor to Implement	Before Construction
g.			Conflict over the use of local water resources between locals and Contractor to meet the camp and construction	- In areas of concern where the potable water is in short supply; the availability of water will be assessed to evaluate the impacts on the community	Contractor, Supervisory Consultants and NTDC.	Contractor to implement. Regular Monitoring.	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
			requirements.	resources. - Camps should be located at least 500 m away from the nearest local settlements. - Approval from the local administration and representatives of the concerned irrigation departments will be obtained before using the local surface water resources. - The Contractors will be required to maintain close liaison with the local communities to ensure that any potential conflicts relating to the common resource utilization are resolved quickly. - Guidelines will be established to minimize the wastage of water during the construction activities and at campsites.			
h.			The general mobility of the locals and their livestock in and around the COI	- The contractor will select specific timings for stringing so as to cause least disturbance to the local population and their	Contractor, Supervisory Consultants and NTDC.	Contractor to implement. Regular Monitoring.	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
			will be affected temporarily on specific locations during the construction of proposed T/L.	livestock considering their peak movement hours.			
i.			Induction of outside workers by the contractor may cause conflicts with the locals on the cultural issues related to social and gender due to the unawareness of the local customs and norms. Theft problems to the community by the Contractor's workers and vice versa may also create social issues if outside labour is used by the contractor.	- Contractor will take care of the concerns of the local community and the sensitivity towards the local customs. - Good relations with the local communities will be promoted by encouraging the contractor to provide opportunities for skilled and unskilled employment to the locals, as well as on-job training for workers. Contractor will restrict his permanent staff to mix with the locals to avoid any social issues. - Local vendors will be provided with regular business by purchase of the camp site goods and services from them. - The Contractor will warn the workers not to indulge in any theft	Contractor, Supervisory Consultants and NTDC.	Contractor to implement. Regular Monitoring.	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
				activities. The Contractor camp should be fenced properly and main gate will be locked at night with a security guard to avoid any theft incidence.			
j.			Construction of proposed T/L can cause the gender issues in the area during construction stage.	- The Contractors have to select the specific timings for the construction activities so as to cause least disturbance to women considering their routine movement hours. - The Contractor have to carry out the construction activities in such a way that the open field latrine usage timings by the local community particularly women, should not be affected. - Contractor should warn the staff strictly not to involve in any un-ethical activities with reference to the women. - While working on the erection of Towers, if privacy of the nearby households is affected, the Contractor will inform the	Contractor, Supervisory Consultants and NTDC.	- Contractor to will implement. - Regular Monitoring.	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
				house owner to make some arrangements.			
k.			Construction activities will create health and safety issues for workers as well as locals will be more prone to serious accidents.	- Complying with the safety precautions for the construction workers as per ILO Convention No. 62, as far as applicable to the Project contract. - Training of workers in construction safety procedures, environmental awareness, equipping all construction workers with safety boots, helmets, gloves, and protective masks, goggles, shields and monitoring their proper and sustained usage. - Ensure the provision of medicines, first aid kits, ambulance, etc. at the camp site. - Contractors should be warned to their staff about using Personnel Protective Equipments (PPEs) (e.g., wire containment, displaying warning signs along the work site, communicating advance warnings to mats) to	Contractor, Supervisory Consultants and NTDC.	- Contractor to will implement. - Regular Monitoring.	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
				enhance the blasting safety. - Safety lookouts will be built to prevent people and vehicles from passing at the time of blasting. - In the security vulnerable areas, special measures should be adopted by the Contractor as well as the Consultant staff with the consultation of the local responsible agencies to control the law and order.			
l.			The land under the Towers during the operation stage may restrict the current land use for agriculture purposes.	Affectees will be involved in the valuation process at all stages of the Project i.e. soil investigations, Tower footings, Tower erection and stringing of conductors.	NTDC	Regular Monitoring.	During Operation
m.			The restriction of plantation of trees above 2.5 m height during the operation stage may also cause the inconvenience to the locals.	Orchards of Guava and Citrus (except mangoes) with height less than 2.5 m can be grown. Similarly, cultivation of the crops can be carried out without any let or hindrance.	NTDC	Regular Monitoring.	During Operation

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
n.			Due to the erection of Towers and the passing of T/L, the value of land may decrease in the long term basis.	Since the erection of Towers will involve very limited amount of land and the land under the Towers and conductors can be easily used for crops, so not much depreciation in land value is foreseen.	NTDC	NTDC Monitor.	During Operation

Table 9-1 (b): Environmental Mitigation Management Matrix for Converter Stations

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
1.	Land Resources	Construction of Converter Stations					
a.			Permanent acquisition of land for the construction of Converter Stations.	- Permanent land should be acquired as per Land Acquisition Act (LAA), 1894. - Existing market price of the land should be paid to the landowner.	Environment & Social Expert, NTDC	- To make fair assessment of the compensation cost and affectees approval to be sought. - One window operation for quick payment to the affectees.	Before Construction
b.			Temporary acquisition of land for Contractors Camps, access roads, aggregate quarries etc.	Pease refer the mitigation as mentioned in the T/L section.	NTDC	Fair compensation at the start of work and job opportunities should be provided to the affectees to off-set the loss of income due to the acquisition of their land.	Before Construction
c.			Soil erosion due to the construction activities such as clearing, excavation, filling, development of access roads, construction camps etc.	All the disturbed areas need to be protected against severe erosion losses by adopting following measures: - Stripping and stockpiling of all the available topsoil for later re-vegetation - Use of Proper	Contractors, Supervisory Consultants and NTDC to monitor.	- Contractor to implement. - Regular Monitoring by Supervisory Consultants and NTDC.	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
				drainage system above the works for significant protection - Planting of rapidly growing indigenous vegetation / grass in the Project Area to reduce the impact of soil erosion.			
d.			Air and noise pollution due to the use of construction machinery i.e. concrete batching plants, concrete paver, concrete mixer, excavators, dump trucks, road rollers, graders and heavy vehicle during construction phase.	- Use of old tuned vehicles should not be allowed. - Proper tuning of the construction vehicles at appropriate intervals. - Haul-trucks should be kept covered with tarpaulin. - Batching plant should be sited at least 500 m away from the villages and settlements. - Control of heavy machinery speeds. Maximum speed of 30 km/hr should be practiced. - Concrete batching plant should be equipped with dust control equipment such as fabric filters or wet scrubbers to reduce the level of dust emissions or at least water	Contractors, Supervisory Consultants and NTDC to monitor.	- Contractor to implement. - Regular Monitoring by Supervisory Consultants and NTDC.	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
				should be used during crushing operations to avoid air pollution. This water should be recycled to avoid generation of waste water. - The existing quarries should be used to borrow the aggregate materials and each quarry site should have a quarry management plan. - Where necessary, dust emissions should be reduced by regular sprinkling of water. - The NEQS applicable to the gaseous emissions should be enforced during the construction works. - Compliance monitoring of vehicles, generators and machines emissions (air and noise) to be regularly carried out. - Construction activities shall be avoided during the night time and mufflers should be provided in all the vehicles to minimize the emissions and noise. Noise complaints should be logged and kept onsite			

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
				by the Contractor. - Construction timings should be fixed after consultation with the residents of the nearby villages preferably during the day. This will minimize the disturbance to the local population. - If the proposed Project Area is near the hospital and college, the area where noise producing activity is to be undertaken should be screened with noise absorbing material or casing.			
e.			The heating of the oil in the transformers at Converter Stations and the heat generated due to current flowing through the supply lines will result in the emission of pollutants into the air, thus deteriorating air quality and affect human health.	To mitigate the pollutants emissions following measures should be adopted: - Transformers should be equipped with silica gel. - Use of low sulfur oil.	NTDC	NTDC to monitor.	During Operation.
f.			Routine inspection and repair work	- Impact on soil during operation phase will be	NTDC	NTDC to monitor.	During Operation.

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
			involving oil leakage from the transformers and other electric equipments can contaminate the soil.	insignificant. Good engineering practices should be adopted by the operation and maintenance (O&M) staff of NTDC during the repair and replacement activities.			
2.	Water Resources	Construction of Converter Station.					
a.			Disposal of wastewater without treatment will pollute the soil and ground water.	- Domestic and chemical effluents from the construction camp should be disposed of by the development of on-site sanitation systems i.e. septic tanks along with soakage pits. Proper monitoring to check the compliance of NEQS should be carried out. - Sewage from construction camps should be disposed of after proper pre-treatment and processes such as soakage pit. - The Contractor should also develop guidelines for the clean up of small spills on site. Proper PPE should be worn when	Contractors, Supervisory Consultants and NTDC to monitor.	- Contractor to implement. - Regular Monitoring by Supervisory Consultants and NTDC.	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
				cleaning the spills. Techniques for the spill cleaning should ensure that the spill is absorbed, neutralized and collected.			
b.			Improper waste management activities can increase disease transmission, contaminate ground and surface water and ultimate damage to the ecosystem.	- All the solid waste from the camps should be properly collected and disposed of through proper solid waste management system. - The Contractor should coordinate with local representatives and administration concerned department for the disposal of solid waste. - The concerned department must develop a plan of action for transporting the waste to the disposal site for final disposal. It is the responsibility of the concerned department to ensure that the disposal site is properly lined to prevent the leachate from contaminating the ground water. - Secondly, the disposal site must be located as far as practical from	Contractors, Supervisory Consultants and NTDC to monitor.	- Contractor to implement. - Regular Monitoring by Supervisory Consultants and NTDC.	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
				populated areas and regions that have a high density of wildlife. - Toxic waste should be handled, stored, transported and disposed of separately. - The waste should be properly sealed in containers with proper labels indicating the nature of the waste. - Solid waste should be segregated at source so that it can be re-used or recycled.			
c.			Surface water quality of the natural ponds/nullahs and the other water bodies may be impacted due to the construction activities and wastewater from labour camps.	Pease refer the mitigation strategy for T/L.	Contractors, Supervisory Consultants and NTDC to monitor.	- Contractor to implement. - Regular Monitoring by Supervisory Consultants and NTDC.	During Construction
3.	Ecological Resources	Construction of Converter Stations.				-	
a.			Movement of transport or vehicles produces noise and vibration in the area	This will not be a significant impact. However, this impact can be minimized by use of	NTDC	NTDC to monitor.	Before Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
			during topographical, geotechnical and seismic studies which will scare away the birds, wildlife, rodents and reptiles etc.	good engineering practices.			
b.			During the construction, clearing and grubbing activities, construction of access road, installation of batching plants and worker's camps, the natural vegetation and flora such as shrubs and herbs, including some species of medicinal plants, fuel wood plants and trees will be removed which will have a significant adverse impact on the natural vegetation of the Study Area.	- While making paths for carriage of construction materials minimum land should be utilized and minimum vegetation should be disturbed. - Plantation is required in the area, where trees or bushes have been cut to make path. - The camps and workshop facilities should be established on the barren land; however, if such type of land is not available, it should be ensured that minimum clearing of the vegetation occurs and minimum damage to the trees and undergrowth is ensured. - The Contractor's staff and labor will be strictly directed not to damage any vegetation such as bushes.	Contractors, Supervisory Consultants and NTDC to monitor.	- Contractor to implement. - Regular Monitoring by Supervisory Consultants and NTDC.	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
				local customs and traditions. - Good relations with the local communities will be promoted by encouraging the Contractor to provide opportunities for skilled and unskilled employment to the locals, as well as on -job training in construction for young people. - Contractor should restrict the staff to mix with the locals to avoid any social problems. - Local vendors will be promoted for routine regular business by purchase of the camp site goods and services from them.			
d.			With the influx of labor force and other staff related to the construction activities, daily activities of the women are likely to be affected.	Pease refer the mitigation strategy for "impact gender issues during construction phase" provided in T/L table.	Contractors, Supervisory Consultants and NTDC to monitor.	- Contractor to implement. - Regular Monitoring by Supervisory Consultants and NTDC.	During Construction
e.			Construction activities will create health and safety issue for the workers and the local	Pease refer the mitigation strategy for "Health and Safety issues during construction phase"	Contractors, Supervisory Consultants and NTDC to	- Contractor to implement. - Regular Monitoring by Supervisory	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
				Contractor has to select specific timings for construction work so as to cause least disturbance to the local population considering their peak movement hours.			
b.			Local water supplies utilization to meet the camp site and construction requirements may cause conflicts between the locals and the Contractors.	Pease refer the mitigation strategy for "impact of conflict over the use of local water resources during construction phase" provided in T/L table.	Contractors, Supervisory Consultants and NTDC to monitor.	- Contractor to implement. - Regular Monitoring by Supervisory Consultants and NTDC.	During Construction
c.			Induction of outside workers by the Contractor may cause conflicts with the local people on the cultural issues related to social and gender due to the unawareness of the local customs and norms.	Following measures should be adopted in order to minimize the impacts. - The Contractor will be required to maintain close liaison with the local communities to ensure that any potential conflicts related to the use of common resource utilization for the Project purposes are resolved quickly. - Contractor will take care of the concerns of the local community and the sensitivity towards the	Contractors, Supervisory Consultants and NTDC to monitor.	- Contractor to implement. - Regular Monitoring by Supervisory Consultants and NTDC.	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
				- Contractor will provide the fuel wood/gas cylinders at the camps for cooking purposes and cutting the trees/bushes for fuel will not be allowed.			
c.			Noise and noxious gases will be produced from the heavy vehicle, construction machinery and other activities during construction activities will scare away birds, wildlife, rodents and reptiles. Some of the avifauna may also get killed during construction works.	- Pease refer the mitigation strategy for "impact on wild animals and reptiles during construction provided in T/L section.	Contractors, Supervisory Consultants and NTDC to monitor.	- Contractor to implement. - Regular Monitoring by Supervisory Consultants and NTDC.	During Construction
4.	Social and Cultural Resources	Construction of Converter Stations.				-	
a.			The general mobility of the locals and their livestock in and around the Project Area will be affected during the construction phase.	- Mobility of the Contractor's staff through the nearby residential areas should also be strictly prohibited by the Contractor to avoid any inconvenience or any risk. - Temporarily and for short duration, the	Contractors, Supervisory Consultants and NTDC to monitor.	- Contractor to implement. - Regular Monitoring by Supervisory Consultants and NTDC.	During Construction

Sr. No.	Resource	Project Components	Envisaged Impacts	Mitigation Strategy	Responsibility	Action	Timing
			community and they will be prone to accidents / incidents.	provided in T/L table.	monitor.	Consultants and NTDC.	
f.			Excavation of land and drilling activities, storage of material and construction of workers camps, solid waste disposal by the workers and leakage and spillage of oil will affect the aesthetics of the area.	Proper disposal of excavated material and back filling of land after construction activities will minimize the impact on the aesthetics of the Project Area.	Contractors, Supervisory Consultants and NTDC to monitor.	- Contractor to implement. - Regular Monitoring by Supervisory Consultants and NTDC.	During Construction
g.			Due to the poor security situation in some areas of Punjab and Sindh there are security risks for the Contractor people.	Special arrangements should be taken with the help of local heads for the Contractor staff to avoid any unpleasant incident. Local heads should be involved in development works to gain confidence for local community.	NTDC	NTDC to monitor.	During Operation.

10 CONCLUSION AND RECOMMENDATIONS

The implementation of the proposed Project will have many positive impacts for the Country and on the population residing within the COI. Major positive impacts of the proposed Project are:

- Construction of new T/L and Converter Stations will improve transmission of electricity and increase its supply in the national grid. This electricity will help to reduce the load shedding and will reduce the load on the nearby grid thereby improving the overall electricity efficiency. Proposed T/L will add flexibility and reliability to NTDC grid.
- During construction and operation phases, unskilled and skilled jobs will be created. Locals will be employed in the Project to fulfill skilled and unskilled labour requirements.
- The construction of the Converter Stations will help towards the development of infrastructure, business and improved quality of life of the locals;
- Construction of new T/L and Converter Stations is expected to increase the land value, especially in villages where little or no road infrastructure is present due to the increase in infrastructure and improved accessibility;
- Development of business to fulfill the daily needs of staff working during the construction stage will cause socio-economic uplift of the locals along the COI; and

Indirect positive impacts of the proposed Project on environment and social settings of the COI are as under:

- Due to the implementation of the Project, availability of electricity will increase as per the demand of the area hence the issue of low voltage will be resolved;
- Opportunities will also be available to develop a large area of barren land into agriculture land by installation of electricity operated tubewells if electricity is made available to the areas in the COI;
- Expansion of the industrial base is expected due to the increase in the availability of electricity in the national grid; and

Apart from the positive impacts of the Project, the proposed T/L will also have potential adverse environmental and social impacts during the construction and operational stages. Most of these adverse impacts during construction are of a temporary nature. These potential impacts can be avoided or mitigated by adopting suitable mitigation or remedial measures as mentioned in this Report. Following are some of the potential adverse environmental and social impacts and their suggested mitigation measures:

- The proposed T/L Project will not involve the permanent land acquisition as per NTDC practice in the light of LAA and Telegraph Act, 1910; however, land needs to be acquired on permanent basis for the proposed Converter Stations near Nankana Sahib and at Matiari.
  - Permanent land will be acquired as per LAA, 1894 and ADB policy requirements for Involuntary Resettlement. It is recommended that existing market price of the land should be paid to the landowners. In this regard proper LARP should be prepared and implemented prior as soon as the locations of the Converter Stations are being finalized.
- The Contractors will also require temporary land acquisition for the development of Contractors' camps and facilities i.e. storage, workshop, equipment parking and washing areas, aggregate quarries and access roads/tracks for haulage, transportation etc. as per Telegraphy Act and NTDC practices.

  - The land for above mentioned facilities should be selected and leased prior to the start of construction phase. Land for above mentioned facilities will be directly rented from the private landowners by the Contractors.

- Based on the Google images and field surveys, the total cultivated area, which will be affected due to this Project, is nearly 16,500 hectares, which forms about 38.8% of the total area coming in the COI. The agriculture of the tract in Sindh and Punjab will receive significant adverse impact due to various operations such as movement of heavy machinery, erection of Towers, dragging, stretching and stringing etc.
  - Compensation for the loss of crops to the land owners and cultivators as the case may be will be paid, in accordance with the prevailing market prices and uniformity in rates will be ensured within the local areas.
  - The whole process of the payment to the farmers should be made transparent, judicious and without any discrimination or favour.
- Air quality will be affected by the fugitive dust and emissions from the construction machinery and vehicular traffic during the construction phase.
  - Use of good engineering practices such as water sprinkling, encasement and provision of silencer and mini stacks of generators etc. should be adopted to avoid inconvenience to the locals due to noise, smoke and fugitive dust.
- Construction activities such as clearing and grabbing, excavation, filling, laying down concrete foundation for Towers and setting up construction camp will affect the existing soil condition in the COI.
  - All the disturbed areas need to be protected against soil erosion by stripping and stockpiling of all the available topsoil for later re-vegetation. Special slope protection measures should be adopted in the sensitive areas i.e. desert or semi-desert areas of Sanghar, Ghotki, Rahim Yar Khan and Bahawalpur districts in Section-I and Section-II. Site restoration plan for the Project should be strictly followed.
- Land may get contaminated due to the spillage of chemicals, fuels, solvents, oils, paints, concrete, solid waste generated at campsites etc. This normally happens when these materials are transported in open or loosely capped containers.
  - Domestic and chemical effluents from the construction camp should be disposed by the development of on-site sanitation systems i.e. septic tanks along with soakage pits. Proper monitoring to check the compliance of NEQS will be carried out.
  - Sewage from construction camps will be disposed of after proper pre-treatment and processes such as soakage pit.
- At the time of stringing of conductors for the proposed T/L after the installation of Towers, interference to the traffic movement is expected. This can be a potential significant adverse physical and social impact during the construction stage but will be of temporary nature;
  - During the detailed design stage, NTDC will coordinate with NHA and local road department/authorities for the installation of the Towers and during stringing of the conductors where the line is crossing the existing roads for the provision of alternate traffic route and management.
- The selected route of the proposed T/L involves the crossings of the existing Power lines of i.e. 220 KV and 132 KV near Kasur and Nankana Sahib in Section II. This will be a great hazard during the installation of Towers, stringing of conductors and O & M stage.

- Special care is required during the construction of Towers as well as stringing of conductors. During the stringing of conductors, temporary shutdown of the existing T/Ls will be ensured to safeguard the workers and the surroundings. A proactive coordination is required between the construction staff and relevant Grid Station operation staff to ensure the shutdown schedule.

- Trees also exist along the highways and canals, which have been grown by the Government Departments. Sporadic growth of trees, coming within the ROW have to be removed if these are located within the Tower foundations during construction.
  - If cutting of trees along the COI is involved permission will be taken from the relevant department. As these are small in number, their removal will cause no significant adverse environmental impact. With the erection of T/L Towers, tree need to rise away from the location of Towers.
- It is anticipated that local water resources will be utilized to meet the camp and construction requirements, bringing its use into competition with the local use especially in Section I and II where the water availability is limited.
  - Approval from the local administration and representatives of the concerned irrigation departments or other relevant authorities will be obtained before using the local surface water resources.
  - The Contractors will be required to maintain close liaison with the local communities to ensure that any potential conflicts relating to the common resource utilization are resolved quickly.
  - Guidelines will be established to minimize the wastage of water during the construction activities and at camp sites.
- During the construction phase, the general mobility of the locals and their livestock in and around the COI will be affected temporarily on specific locations mostly in areas near to the villages. The movement of the Towers and conductors from the stocking area to the construction site may cause traffic problems on the road for the locals. This may affect their mobility at times. During the stringing operations, interference to the traffic movement is also expected. This will have low adverse impact on the locals on temporary basis.
  - The Contractor should select specific timings for stringing so as to cause least disturbance to the local population considering their peak movement hours; and proper traffic management plan should be developed to avoid such issues.
- Induction of outside workers by the Contractor may cause conflicts with the locals on the cultural issues related to social and gender due to the unawareness of the local customs and norms especially in Section-I falling in Sindh province. These issues may adversely affect the construction phase of the Project. This is a medium adverse social impact of temporary nature.
  - Good relations with the local communities will be promoted by encouraging the Contractor to provide opportunities for skilled and unskilled employment to the locals, as well as on-job training for workers. Contractor will restrict his permanent staff to mix with the locals to avoid any social issues.
  - During the construction phase, mobility of the workers in the nearby areas should be strictly restricted by the Contractor to avoid any inconvenience to the local communities.

- The Contractor have to select the specific timings for the construction activities like Tower footings, erection and stringing of conductors so as to cause least disturbance to the local population particularly women considering their routine movement hours.

- The land under the Towers during the operation stage may restrict the current landuse for agriculture purposes.
  - Towers are desinged to allow the paasage of vehicle such as tracters. Hence during the operation stage of project farmers can use their land under the Towers for agriculture purposes.
- Due to the erection of Towers and the passing of T/L, the value of land may decrease in areas where existing T/Ls are also crossing in Section II Kasur and Nankana Sahib districts;
  - Since the erection of Towers will involve very limited amount of land and the land under the Towers and conductors can be easily used for crops, so not much depreciation in the land value is foreseen.
- As the Project route is passing through the rural areas of Section-I and Section-II, women activities in the field may be affected due to the construction activities.
  - The Contractor have to select the specific timings for the construction activities like Tower footings, erection and stringing of conductors so as to cause least disturbance to the local population particularly women considering their routine movement hours.
- The rural women in few areas use the open field latrines and their privacy may suffer due to the Project activities.
  - The Contractor have to carry out the construction activities in such a way that the open field latrine usage timings by the local community particularly women, should not be affected. The normal timings to use the toilet facilities by the rural women are early in the morning and at evening so the Contractor will have to take care of these timings.
- Disturbance to the privacy of the local women will be due to outside workers working on the erection of Towers and stringing of conductors;
  - Contractor should warn the staff strictly not to involve in any un-ethical activities such as theft, etc. and to obey the local norms and cultural restrictions particularly with reference to the women.
- During the social field survey of the Project, no indigenous group of people was identified, which comes under the definition of the "Indigenous People". So, no impact on the indigenous people is envisaged due to the implementation of the Project.
- Income of the vulnerable people may be affected due to the implementation of the Project like crossing of T/L upon their infrastructure; affect on any assets such as houses, tubewells, room etc. In few areas, T/L also crosses some of the houses in Bahawalpur, Bahawalnagar, Pakpattan and Okara. The owners of the affected structures identified during the field visits also fall below the poverty line.
  - The vulnerable persons shall be provided with all possible assistance and help for acquiring the skills and preference should be given to them for employment. The persons having no land or a person who is going to lose over 50 % of his land will be considered as vulnerable people and will be specially treated to provide the maximum benefits.
- Occurrence of accidents/incidents during the construction stage is a common phenomenon and workers as well as locals will be more prone to serious accidents;

  - Complying with the safety precautions for the construction workers as per ILO Convention No. 62, as far as applicable to the Project Contract.
  - Training of workers in construction safety procedures, environmental awareness, equipping all construction workers with PPEs such as safety boots, helmets, gloves and protective masks, goggles, shields and monitoring their proper and sustained usage.
- During the operation stage, people assume that they will be prone to danger due to collapse of towers, the electric flux on conductors, Towers, breaking of conductors etc.
  - At the time of detailed survey for fixing the Tower positions proper soil investigations will be carried out to check the presence of collapsible soils and if detected, Engineer will be informed immediately for design change. It will be ensured that no accident due to collapsing of Towers would occur during the life of the Project.
  - The conductors are selected on the basis of local climatic conditions including maximum wind velocity, temperature and humidity conditions. So, there is almost no risk of breaking of conductors. However, due to some unavoidable circumstances, if such a situation occurs, NTDC has provided such an arrangement that the flow in the conductors will be automatically tripped instantaneously. So, no risk to human or animal life is envisaged due to the breaking of conductors.
- The COI falls in areas which is sensitive from the law and order point of view and the security of the Contractor and Consultant staff will be a major issue especially Section I Ghotki Area.
  - For the security in vulnerable areas, special measures should be adopted by the Contractor as well as the Consultant staff with the consultation of the local responsible agencies to control the law and order.
- Removal of the infrastructure like buildings, huts, animal sheds, tubewells etc. will cause the loss of community shelters and sources of income.
  - No relocation of settlements (group of people) will be involved as the Project has flexibility to change the alignment.
  - Compensation will be paid to the affectees for the built-up areas like buildings, huts, animal sheds, peter engines/electric motor sheds etc. on replacement cost basis and the land on existing agricultural land value.
  - Payment of three (03) months house-rent will be made to the affectees while they will construct a new abode for their families.
  - Full market price of any equipment (not shiftable) and cost of reconstruction including labour charges will be paid to the affectees.
  - Affectees will be allowed the salvaging of the demolished materials.

In order to minimize, avoid or reduce the potential adverse impact appropriate mitigation and remedial measures have been suggested against each identified impact. Efforts are made to propose economical and sustainable mitigation and remedial measures which can be easily implemented.

In order to provide compensation for losses, a framework has been suggested as per local laws as well as ADB polices. Moreover, detailed study for the mitigation of these major impacts i.e., the preparation of LARP, has been initiated.

Permanent acquisition of land will only be required for the construction of Converter Stations near Nankana Sahib and at Matiari. It will be ensured that no resettlement issue arises due the acquisition of land for these stations. Proper market price as per Land Acquisition Act and NTDC practices will be provided to the land owners. Moreover, as per PEPA, 1997 a separate Environmental Assessment Study should be carried out for each Converter Station.

In the end, EMMP has been developed to provide proper framework for the implementation of the suggested mitigation measures. This includes the identification of the major stakeholders, roles and responsibilities along with the resource requirements.

EMMP includes the monitoring mechanism which will ensure that proper results are being achieved by the implementation of the suggested mitigation measures from concerned entities. Change management plan has been suggested to incorporate the affects due to change in any design on route of the proposed T/L. An estimated cost for environmental management, monitoring and training has also been provided for inclusion in the PC-I or overall Project Cost.

As a conclusion of the study, the proposed T/L and Converter Stations will not cause potentially significant environmental and social adverse impacts on the local environment after the implementation of mitigation measures. Considering the current electricity situation and the efforts being made by the Government to generate electricity in Thar, T/L to dispatch the generated Power to the upcountry is a prerequisite. It is suggested that the proposed T/L should be implemented as soon as possible after all necessary approvals, design provisions and the implementation of EMMP and LARP.

±660 kV HVDC Matiari-Lahore approximately
878 km Transmission Project

System Studies

Pak Matiari-Lahore Transmission Company
(Private) Limited

April 2017

STATE GRID
CORPORATION OF CHINA

Ref. No.: CET-NTDC-16-036 Dated: May 10, 2016

General Manager (GSC)
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Project: Matiari - Lahore HVDC Transmission Line Project

Subject: System Studies for Matiari – Lahore HVDC Project

Dear Sir,

Upon the request of NTDC, CET had performed the system studies on the power grid of Pakistan jointly with NTDC Planning Department for feasibility phase of Matiari-Lahore HVDC Project.

Please find out attached:

1- Power Flow Contingency Analysis of the Year 2018 (WA00191K-SS-01)

2- Security and Stability Study (WA00191K-SS-02B)

(Submitted the versions of 02 & 02A in August, 2015 and March, 2016)

3- Access System Design of Matiari Converter Station (WA00191K-SS-03A)

(Submitted the versions of 03 in March, 2016)

4- Access System Design of Lahore Converter Station (WA00191K-SS-04A)

(Submitted the versions of 04 in March, 2016)

5- Study of System Short Circuit Characteristics (WA00191K-SS-05)

6- Study of Reactive Power Compensation of Converter Station (WA00191K-SS-06A)

(Submitted the versions of 06 in April, 2016)

These reports are still under translation; however, the major contents will not be changed.

We look forward to your consideration and early reply.

Sincerely Yours,

Transmission Co. Pak Matiari Lahore Pvt. Ltd.

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ATT 1- Power Flow Contingency Analysis of the Year 2018 (WA00191K-SS-01)

ATT 2- Security and Stability Study (WA00191K-SS-02B)

ATT 3- Access System Design of Matiari Converter Station (WA00191K-SS-03A)

ATT 4- Access System Design of Lahore Converter Station (WA00191K-SS-04A)

ATT 5- Study of System Short Circuit Characteristics (WA00191K-SS-05)

ATT 6- Study of Reactive Power Compensation of Converter Station (WA00191K-SS-06A)

Lahore Transmission Co. (Pvt) Ltd

国家电网公司
STATE GRID
CORPORATION OF CHINA

报告编号：
Report No.:WA00191K-SS-01

巴基斯坦默蒂亚里—拉合尔±660kV 直流输电工程

±660kV HVDC Project from Matiari to Lahore in Pakistan

可行性研究

Feasibility Study

电力系统一次

Power System Primary Part

潮流计算与 2018 年 N-1 安全检查分析

Load Flow Calculations and Contingency Analysis of The Year 2018

中国电力技术装备有限公司
CHINA ELECTRIC POWER EQUIPMENT AND TECHNOLOGY CO., LTD.

南京南瑞继保电气有限公司
NR ELECTRICAL CO., LTD.

2016 年 4 月
April 2016

Pak Matiari Lahore Transmission Co. (Pvt) Ltd.

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Pak Matiari Lahore Transmission Co. (Pvt) Ltd.

摘要

报告主要依据 NTDC 提供的巴基斯坦 2018-2022 水平年数据，计算基本潮流方式(全接线)以及分析 2018 年各方式下，母线电压越线及线路功率过载现象。

对 2018 水平年，校验了换流站 500kV 交流进出线路 N-1、与±660kV HVDC 并联运行的 500kV 交流通道线路 N-1 以及直流 N-1、N-2 时的系统静态安全。

Abstract

Basic load flow calculation with the scenarios ranging from 2018-2022 is conducted and the buses' voltage and load of lines with the scenarios 2018 are evaluated in this report. All the scenarios are provided by NTDC.

For the year 2018, the contingencies checked are converter station in and out AC 500kV lines N-1, AC 500kV parallel lines with ±660kV HVDC N-1, ±660kV HVDC N-1, N-2.

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Lahore Transmission Co. (Pvt) Ltd. Pak Matiari

1. 前言 Introduction

目前，巴基斯坦输电网最高电压等级为交流 500 千伏，已形成覆盖全国主要地区的主网架结构，形成南部、北部向伊斯兰堡、旁遮普省负荷中心供电的 2-4 回交流 500 千伏输电通道，在负荷中心建成环网。

At present, Pakistan has transmission grids with the ceiling voltage of AC 500kV, and its main grid structure covers the main areas of the country with 2-4 circuit AC 500kV transmission channels from the south and north to the load centers with loop networks in Islamabad and Punjab.

巴基斯坦国家输电公司（NTDC）主网架电压等级为交流 500 千伏及 220 千伏，地方配电公司电压等级为交流 132 千伏及 66 千伏，其中 66 千伏电压等级正初步向 132 千伏过渡。用电结构中，以居民生活用电比重最大，约 45%左右；工业用电比重其次，约 29%；农业、商业及其它大用户用电比重分别在 11%、8%和 7%左右。

NTDC has main grid structure with voltages of AC 500kV and 220kV, and local power distribution companies have grids of AC 132kV and 66kV, of which the 66kV is being transited to 132kV. As for the power consumption structure, residential electricity accounts for a largest proportion of about 45%; the proportion of industrial electricity takes second place with about 29%; and power consumption proportions for agriculture, business and other large users are about 11%, 8% and 7% respectively.

根据巴方提供最新的负荷预测数据，巴基斯坦电网 2017 年、2018 年、2020 年、2023 年最大负荷将分别达到 26680MW、28020MW、30820MW、38250MW，2015～2020 年年均增长率 4.9%，2020～2023 年年均增长率 7.5%。

According to the latest load forecast data provided by NTDC, the maximum loads of the power grid of Pakistan in 2017, 2018, 2020 and 2023 will reach 26680 MW, 28020 MW, 30820 MW and 38250 MW respectively; the average annual growth rates in 2015-2020 and 2020-2023 are 4.9% and 7.5% respectively.

为推进中巴经济走廊建设，促进巴基斯坦社会经济发展，2014 年国家能源局牵头开展了中巴经济走廊能源规划，双方政府于 2014 年 11 月签署了“中巴经济走廊能源项目合作的协议”。按照协议巴基斯坦 2023 年前投产的规划电源共 21 项，总规模为 1770.5 万千瓦。在对比了多种方案后，确定将南部电力送至北部的最合适传输方案为直流输电方案（双极±660 kV，4000 MW）。图 1.1 是 2018 年巴基斯坦电网规划图，在该规划图中，该直流输电线路一侧换流站在默蒂亚里，另一侧在拉合尔。

In order to meet the requirement of social and economic development in Pakistan, the National Energy Administration implemented energy planning for CPEC in 2014, and the bilateral governments signed “Cooperation Agreement for the Energy Project of CPEC” in November 2014. 21 planned power projects will be put into operation before 2023 as per the agreement with total scale of 17705 MW. After analyzing various alternatives, it was identified that the alternative of direct current transmission (Bipole of ± 660 kV, 4000 MW) as the most suitable plan for power transmission from the plant in the south to the north. Figure 1.1 shows a schematic diagram of the

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500 kV grid in Pakistan of the year 2018 including the DC link. One side of the DC link is located in MATIARI and the other side is located in LAHORE.

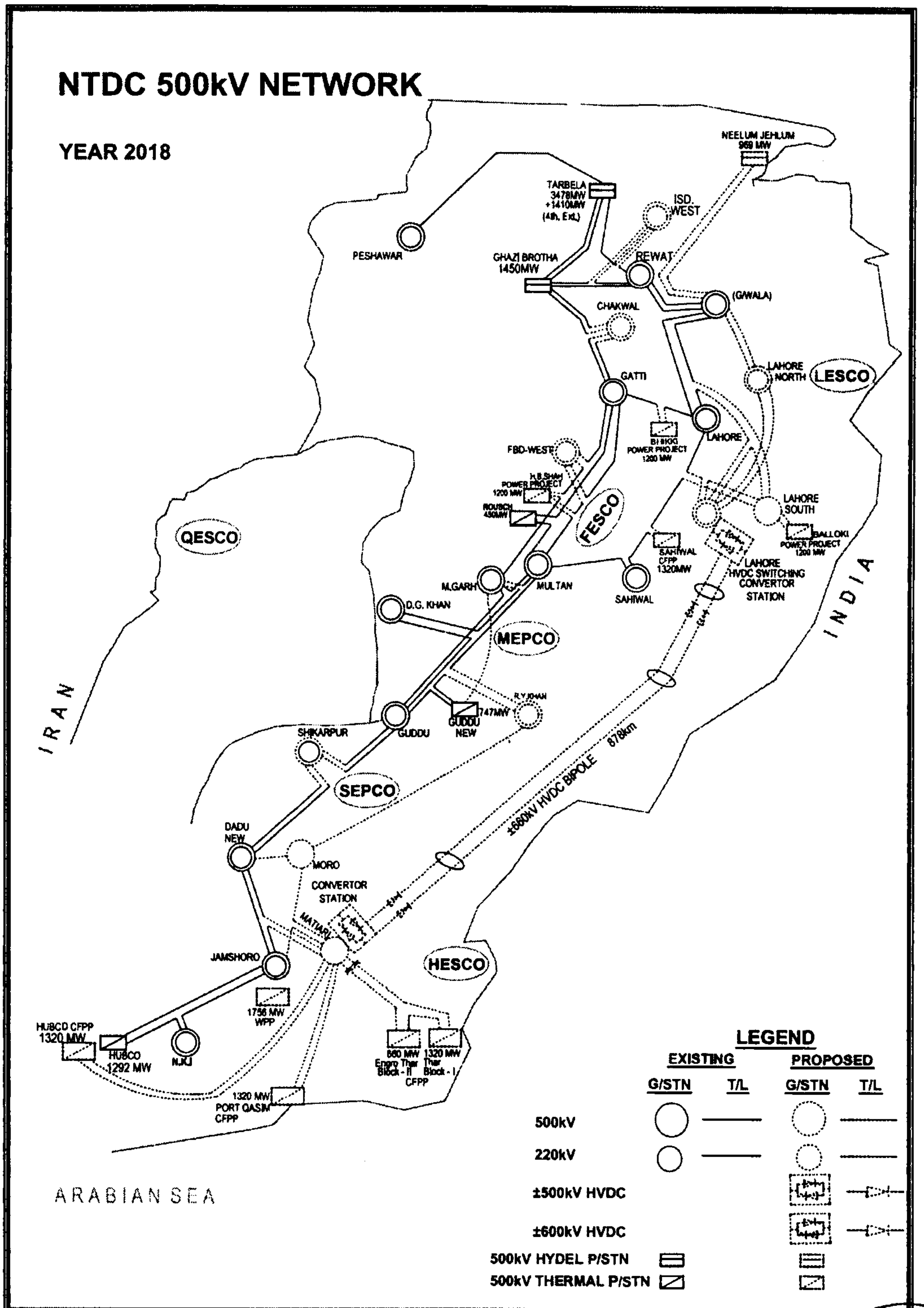

图 1.1 NTDC 2018 年 500 kV 网架

Figure 1.1 NTDC 500 kV network in 2018

2. 目标 Objective

本报告主要是分析评估默蒂亚里-拉合尔直流接入巴基斯坦电网之后，2018 年电网的静态安全水平，包括 2018 水平年的大小方式。

This report describes and evaluates the performance of the interconnected system with the entry into operation of the Matiari-Lahore DC link in steady state for the horizon year of 2018-2022.

考虑到不同的运行方式以及电网条件，直流输电线路接入电网之后的运行效果也需要核查。电网数据全部由 NTDC 提供。

In this study more unfavorable conditions were investigated considering different scenarios and settings in order to confirm the performance of the DC link. These conditions were provided by NTDC.

2018 年静态安全分析的内容包括：
Power flow contingencies analysis includes:

部分 500 kV 母线及线路需要根据母线运行电压范围(1.1-0.9 pu)及线路负载极限(Rate A)来校核，主要针对以下两个方式：
Some 500 kV buses and line flows will need to be reported and listed against line loading limits (Rate A) and bus operating voltages limits (1.1 to 0.9 pu) forthe following modes:

- 2018 年丰大方式——直流与并联交流通道断面上潮流为 5400MW，Moro-R.Y.Khan 无串补，无 R.Y.Khan-Sahiwal 线路；
  2018 peak load conditions – 5400 MW in total on both HVDC and AC channels, with no Moro-R.Y.Khan series compensation and R.Y.Khan- Saihwal line.
- 2018 年丰小方式——直流与并联交流通道断面上潮流为 5400MW，Moro-R.Y.Khan 无串补，无 R.Y.Khan-Sahiwal 线路，南部机组开机量最大，北部机组开机水平低。
  2018 off peak load conditions – 5400 MW in total on both HVDC and AC channels, withno Moro-R.Y.Khan series compensation and R.Y.Khan- Saihwal line.Maximum generation in the south and low genertation in the north.

需要校核的故障有：
And Conintngcies:

- a) 直流线路两端换流站交流进出线 N-1，并联交流通道 N-1；
  AC N-1 contingencies for the ac lines out from both converter stations and for the parallel AC channels;
- b) 直流闭锁故障，包括单极闭锁和双极闭锁。
  DC blocking faults, monopole or bipole.

以下母线的电压及线路的潮流必须在报告中体现：
The following bus voltages and line flows must be reported:

- 1) 南部地区的 500 kV 母线；
  500 kV buses in the southern region；
- 2) 拉合尔向北三层的母线（直到 Rewat）；
  Three buses away from Lahore in the north (up to Rewat)；
- 3) 从南到北并联交流母线上所有的 500 kV 母线及线路；
  All 500 kV buses and lines for the parallel AC lines from south to north.

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3. 计算边界条件及标准 Assumption and Criteria

3.1 直流接入系统方案

HVDC access scheme

送端换流站接入系统如图 3-1 所示。直流送端换流站 π 入贾姆沙罗（Jamshoro）-摩洛（Moro）500kV 线路，新建线路长度约 2×20km；π 入贾姆沙罗-新大都（Dadu New）500kV 线路，新建线路长度约 2×30km。直流配套火电机组以 500kV 电压等级接入换流站。送端换流站形成 10 回出线，2 回至贾姆沙罗，1 回至摩洛，1 回至新大都，6 回至配套电源。

The access system of sending-end converter station is shown as Figure 3.1.

At the HVAC side of HVDC Matiari converter station, connect (π connection) to Jamshoro - Moro 500kV lines, with the new lines being about 2×20km long, and connect (π connection) to Jamshoro - Dadu New 500kV lines, with the new lines being about 2×30km long. The HVDC thermal power generating unit is connected to the converter station at a voltage of 500kV. The Matiari converter station will have 10-circuit outgoing lines, with 2 to Jamshoro, 1 to Moro, 1 to Dadu New and 6 to the matching power supply..

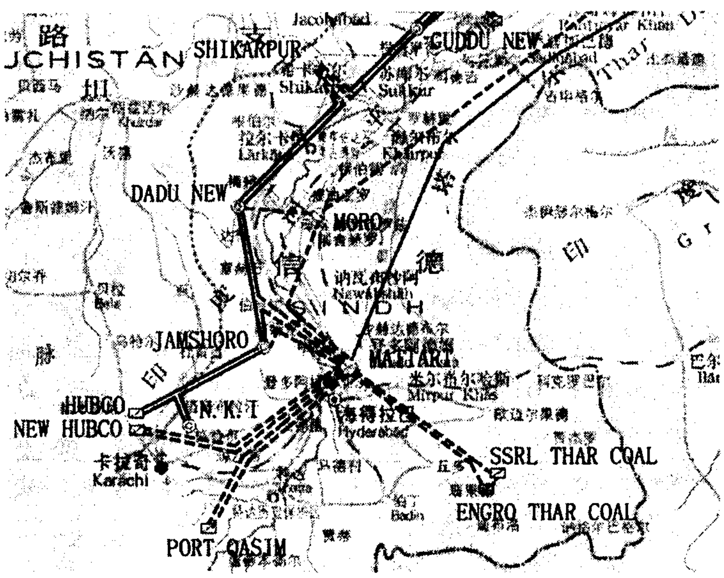

图 3.1 送端换流站接入系统示意图

Figure 3.1 Schematic diagram of access system of sending-end converter station

受端换流站接入系统如图 3-2 所示。直流受端换流站交流侧电压采用 500kV，分别 π 入拉合尔（Lahore）-拉合尔南（Lahore South）双回 500kV 线路，新建线路长度分别为 2×2km 和 2×12.5km；建设受端换流站-拉合尔北（Lahore North）双回 500kV 线路，线路长度约 2×100km。受端换流站形成 6 回出线，2 回至拉合尔，2 回至拉合尔南，2 回至拉合尔北。

The access system of receiving-end converter station is shown as Figure 3.2.

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Adopt 500kV voltage at the HVAC side of HVDC Lahore converter station and connect (π connection) the converter station to the Lahore-Lahore South double-circuit 500kV lines, with the new lines being 2×2km and 2×12.5km long respectively; build the receiving-end converter station-Lahore North double-circuit 500kV lines with a length of about 2×100km. The Lahore converter station will have 6-circuit outgoing lines, with 2 to Lahore, 2 to Lahore South and 2 to Lahore North.

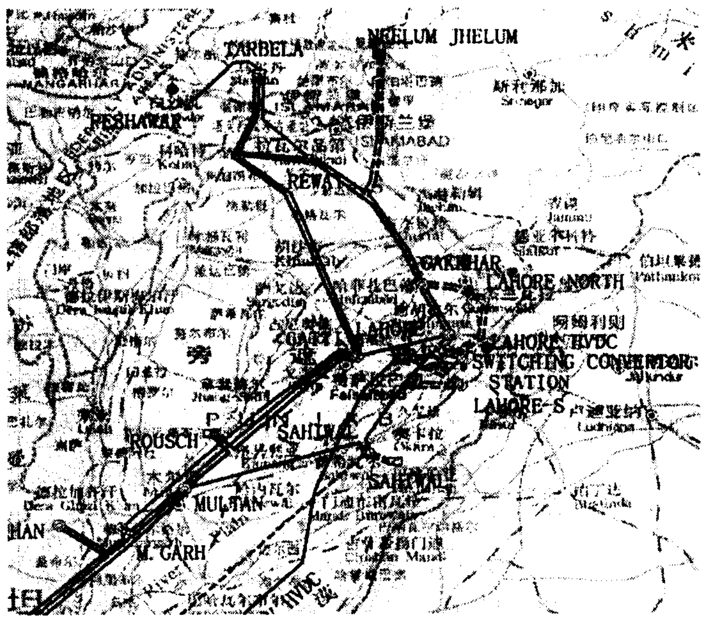

图 3.2 受端换流站接入系统示意图

Figure 3.2 Schematic diagram of access system of receiving-end converter station

3.2 静态安全分析判断标准

Contingency Analysis Criteria

在分析中，采用的仿真软件是 PSS/E，版本为 33，系统网架绘制软件为南瑞潮流图程序。计算边界条件及判断标准如下：

In this analysis, PSS/E version 33 was adopted. The software used to draw the system topology is NR Power Flow Chart. Assumptions and criteria are listed below:

系统潮流分析中包括 2018-2022 水平年的潮流计算及 2018 年 N-1 静态安全分析。

Power flow analysis includes power flow calculation of 2018-2022 and N-1 contingencies analysis in 2018.

- 2018 母线电压检查的标准为 Grid Code 2005 中的标准，如表 3-1 所示。
  The criteria used to check the limits of buses voltages is *Grid Code 2005* as shown in Table 3-1.

表3-1 运行电压范围

Table 3-1OPERATING VOLTAGE LIMTS

（正常/故障情况）

(Normal/Contingency Condition)

电压水平 Voltage level	正常情况 Normal condition		N-1情况 (N-1) condition	
	最大 Max	最小 Min	最大 Max	最小 Min
500 kV	540	475	550	450
220 kV	238	209	245	198
132 kV	143	125	145	119

- 2018 年线路功率过载判断的标准是依据线路功率极限（Rate A）来判断，线路功率极限见附件 1。
  The criteria used to check the line overload is the *Line Overload Limits* (Rate A) which is provided in Attachment 1.

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4. 潮流方式 Power Flow Scenarios

4.1 方式 Scenarios

NTDC 共提供了 12 种方式的数据，涵盖了 2018 水平年到 2022 水平年的主要方式。潮流分析即以这些数据为准。表 4-1 为每个方式中，直流与并联交流线路的断面输送功率、机组总出力及负荷水平，表 4-2 为方式描述及方式中直流线路的个数以及传输的功率。

Twelve scenarios were provided by NTDC ranging from the year 2018 to the year 2022. The power flow study was based on these data. The description of the scenarios, the power flow of DC and parallel AC lines, the total generation and load of each scenario are listed in Table 4-1. The description of the scenarios and the DC links existed in each scenario and their transmission power are shown in Table 4-2.

表 4-1 方式描述及各方式机组出力和负荷水平

Table 4-1 Scenarios Descriptions and Generation and load of each scenario

方式 SCENARIO		直流及交流通道断面潮流 Power Flow of HVDC and Parallel AC Channels	机组出力 Generation	负荷水平 Load
		MW	MW	MW
1	2018 年夏大 Summer peak in 2018	5416	27019.57	26062.71
2	2018 年丰小 Off peak in 2018	5375	24001.68	23136.38
3	2019 年夏大 Summer peak in 2019	6762	29296.97	28385.09
4	2019 年冬大 Winter peak in 2019	4561	20793.64	20130.88
5	2019 年夏小 Summer off peak in 2019	6803	26857.48	25904.17
6	2019 年冬小 Winter off peak in 2019	5213	16173.78	15535.56
7	2020 年冬大 Winter peak in 2020	6543	22320.65	21682.11
8	2020 年丰小 Off peak in 2020	6667	18000.25	17362.48
9	2021 年夏大 Summer peak in 2021*	8463 *:The PSS/E file of this Scenario is not convergent.	33901.85	32512.31
10	2021 年丰小 Off peak in 2021	8229	29747.65	28616.55
11	2022 年冬大	8956	25707.47	24862.74

	Winter peak in 202			
12	2022 年丰小 Off peak in 2022	7969	19845.44	19126.48

表 4-2 方式描述及各方式中直流线路信息

Table 4-2 Scenarios Descriptions and DC links in each scenario

方式 SCENARIO		直流线路 DC Links			
		Number of DC links	Matiari -Lahore	PrtQsm -Fbd west	Tajikistan -Peshawar
		/	(MW)	(MW)	(MW)
1	2018 年夏大 Summer peak in 2018	1	4000	----	----
2	2018 年丰小 Off peak in 2018	1	3300	----	----
3	2019 年夏大 Summer peak in 2019	2	2600	2600	----
4	2019 年冬大 Winter peak in 2019	1	3000	----	----
5	2019 年夏小 Summer off peak in 2019	3	3300	2000	1000
6	2019 年冬小 Winter off peak in 2019	1	3400	----	----
7	2020 年冬大 Winter peak in 2020	2	2600	2600	----
8	2020 年丰小 Off peak in 2020	2	2600	2600	----
9	2021 年夏大 Summer peak in 2021* (The PSS/E file of this Scenario is not convergent)	3	3200	3200	1000
10	2021 年丰小 Off peak in 2021	3	3200	3200	1000
11	2022 年冬大 Winter peak in 2022	2	3500	3500	----
12	2022 年丰小 Off peak in 2022	2	3100	3100	----

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4.1.1 方式 1—2018 年夏大 Scenario 1- Summer peak 2018

在该方式下，南部发电厂出力较大，默蒂亚里-拉合尔直流满功率运行，电力输送方向为从南向北。直流线路配套电源塔尔安格鲁、塔尔一区坑口、卡西姆港、胡布克燃煤电站均在运行中，直流线路向北部送电 4000 MW，同时并联交流通道的有功功率为 1416 MW，如图 4.1 所示。

This scenario represents the situation of the power plants in the south generating a large amount power and the Matiari-Lahore DC link running at a maximum transmission level to transmit the power to the north. With the dispatch of Engro Thar plant, SSRL plant, Hub and Port Qasim plants, the DC link is able to transfer 4000 MW to the north while the parallel AC lines transfer 1416 MW, as shown in Figure 4.1.

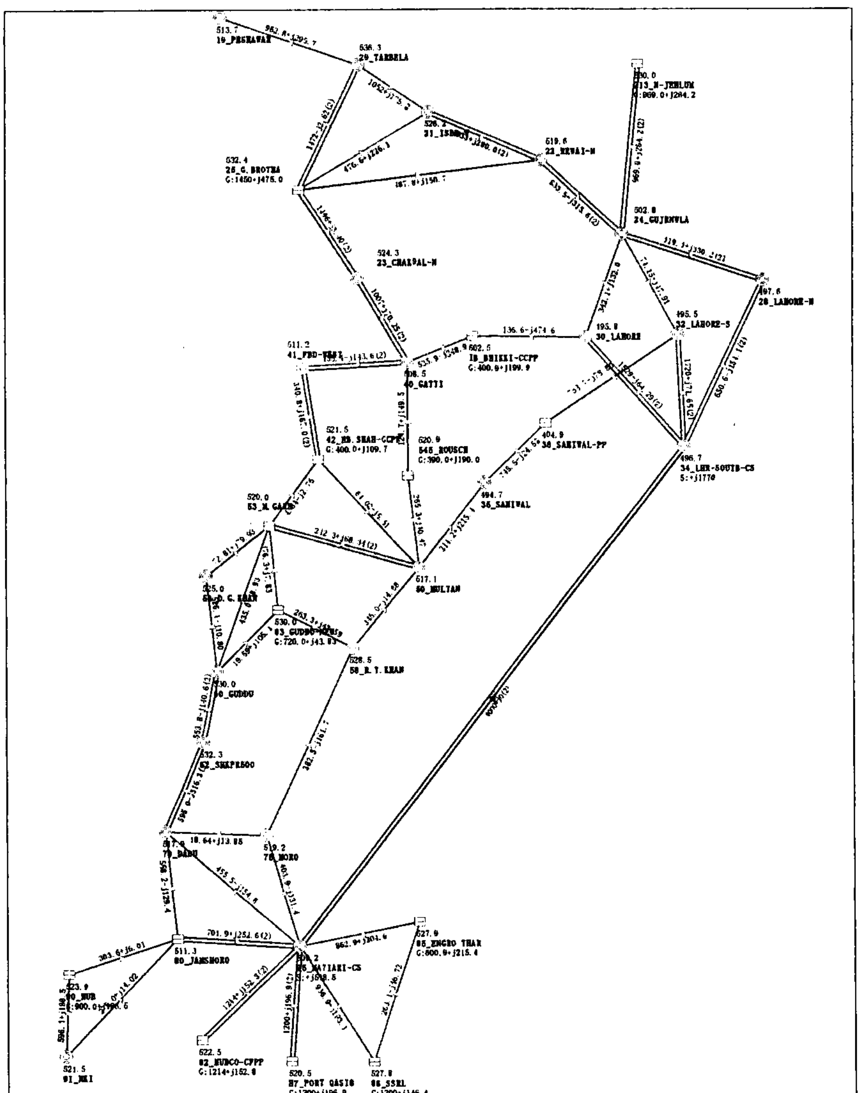

图 4.1 方式 1：:2018 年夏大
Figure 4.1 Scenario 1: Summer peak 2018

4.1.2 方式 2—2018 年丰小 Scenario 2- Off peak 2018

在该方式下，直流线路输送的功率水平较低，负荷比夏大时小。直流线路和并联的交流通道组成的断面输送功率为 5375 MW，和大方式时基本相同。塔尔安格鲁、塔尔坑口一区、胡布克燃煤电厂以及卡西姆港的出力为 4228 MW。

In this scenario, the DC link is running at a lower power level. The load in this scenariois less than that in the peak scenario. The transmission power of the section consisted with the DC link and parallel AC lines is 5375 MW, almost the same with that of the peak scenario. The generation of EngroThar, SSRL, Hubco CFPP and Port Qasim plant is 4228 MW.

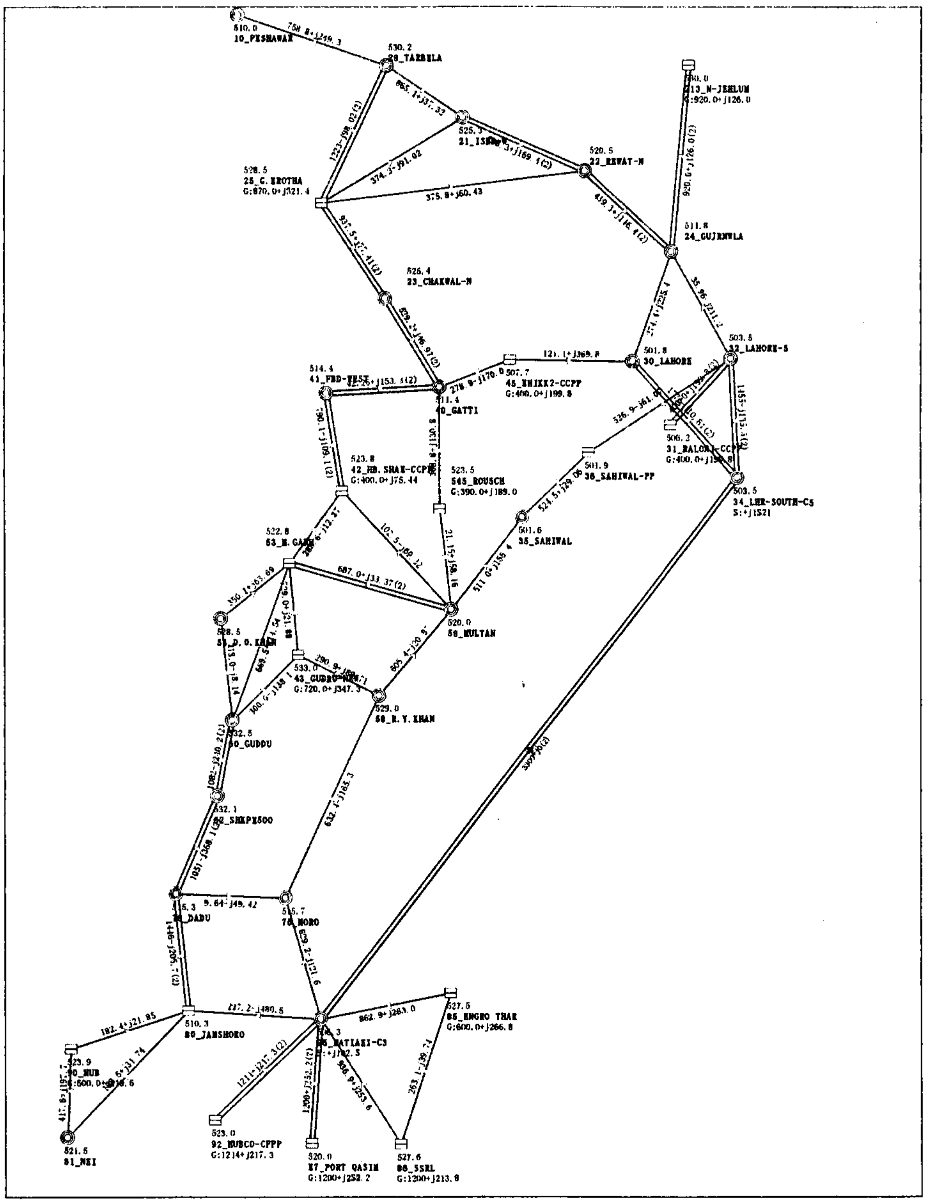

图 4.2 方式 2:2018 年丰小

Figure 4.2 Scenario 2: Off peak 2018

4.1.3 方式 3—2019 年夏大 Scenario 3- Summer peak 2019

在此方式下，电网中有两条直流输电线路，输送功率均为 2600 MW。直流线路与并联交流通道组成的断面输送功率为 6762 MW。与 2018 水平年相比，该方式下，南部有另外两个电厂投入运行，即 Lucky 燃煤电站、Sidqsns 燃煤电站。这两个电厂的出力为 920 MW。

In this scenario, there are 2 DC linksboth running at a power level of 2600 MW. The transmission power of the section consisted with the DC links and parallel AC lines (Matiari- Moro &Jamshoro-Dadu) is 6762 MW. Compared with 2018, there are two more power plants put into operation, i.e. Lucky CFPP and Sidqsns CFPP. The generation of these two plats is 920 MW.

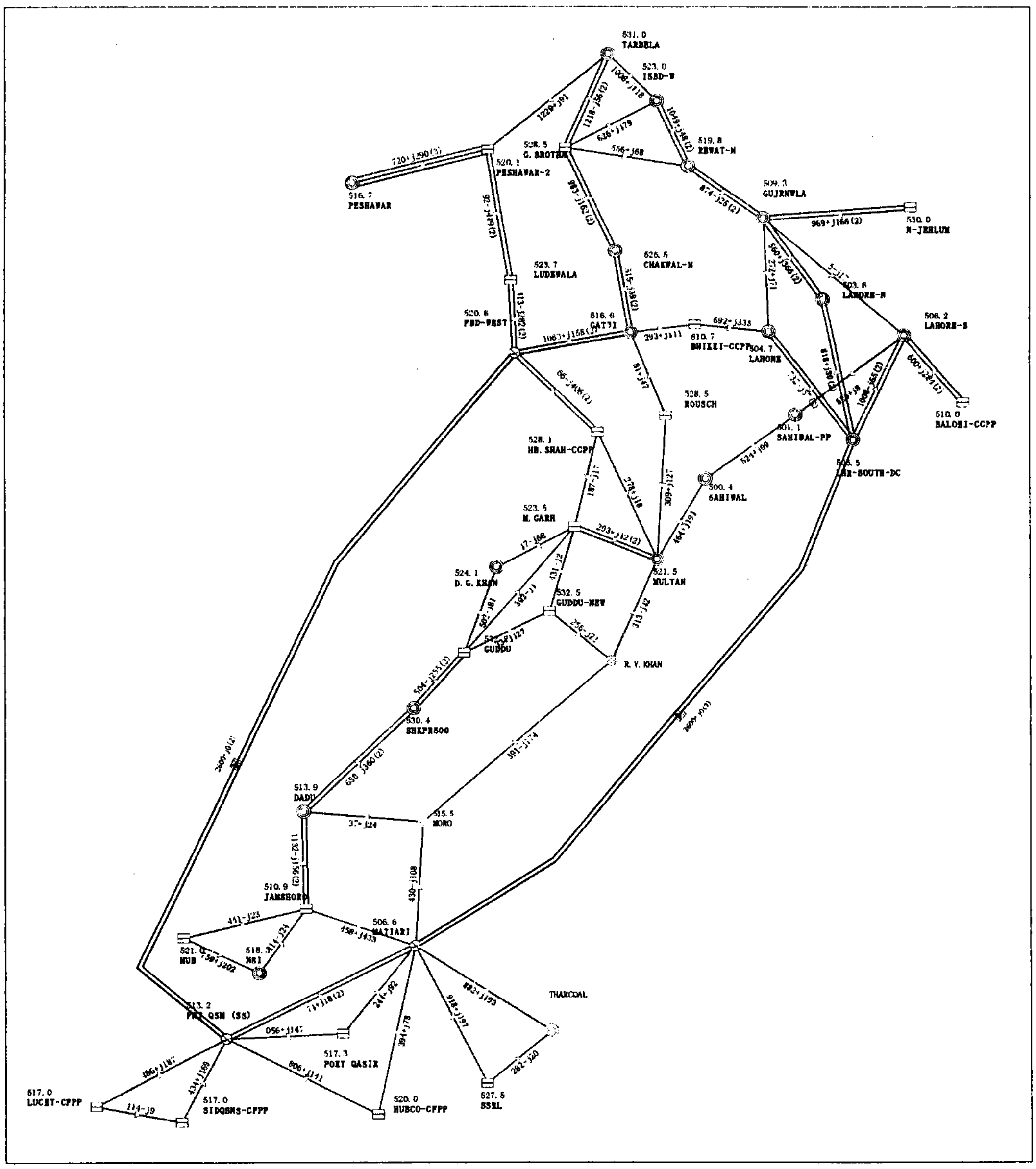

图 4.3 方式 3: 2019 年夏大
Figure 4.3 Scenario 3: Summer peak 2019

4.1.4 方式 4—2019 年冬大 Scenario 4- Winter peak 2019

在该方式下，直流输送功率为 3000 MW。直流和并联交流线路组成的断面输送功率为 4561 MW，南部四个电厂——塔尔安格鲁、塔尔坑口一区、胡布克燃煤电站、卡西姆港的出力为 4228 MW。

In this scenario, the DC link is running at a power level of 3000 MW. The transmission power of the section consisted with the DC link and parallel AC lines is 4561 MW, the generation of EngroThar, SSRL, Hubco CFPP and Port Qasim plant is 4228 MW.

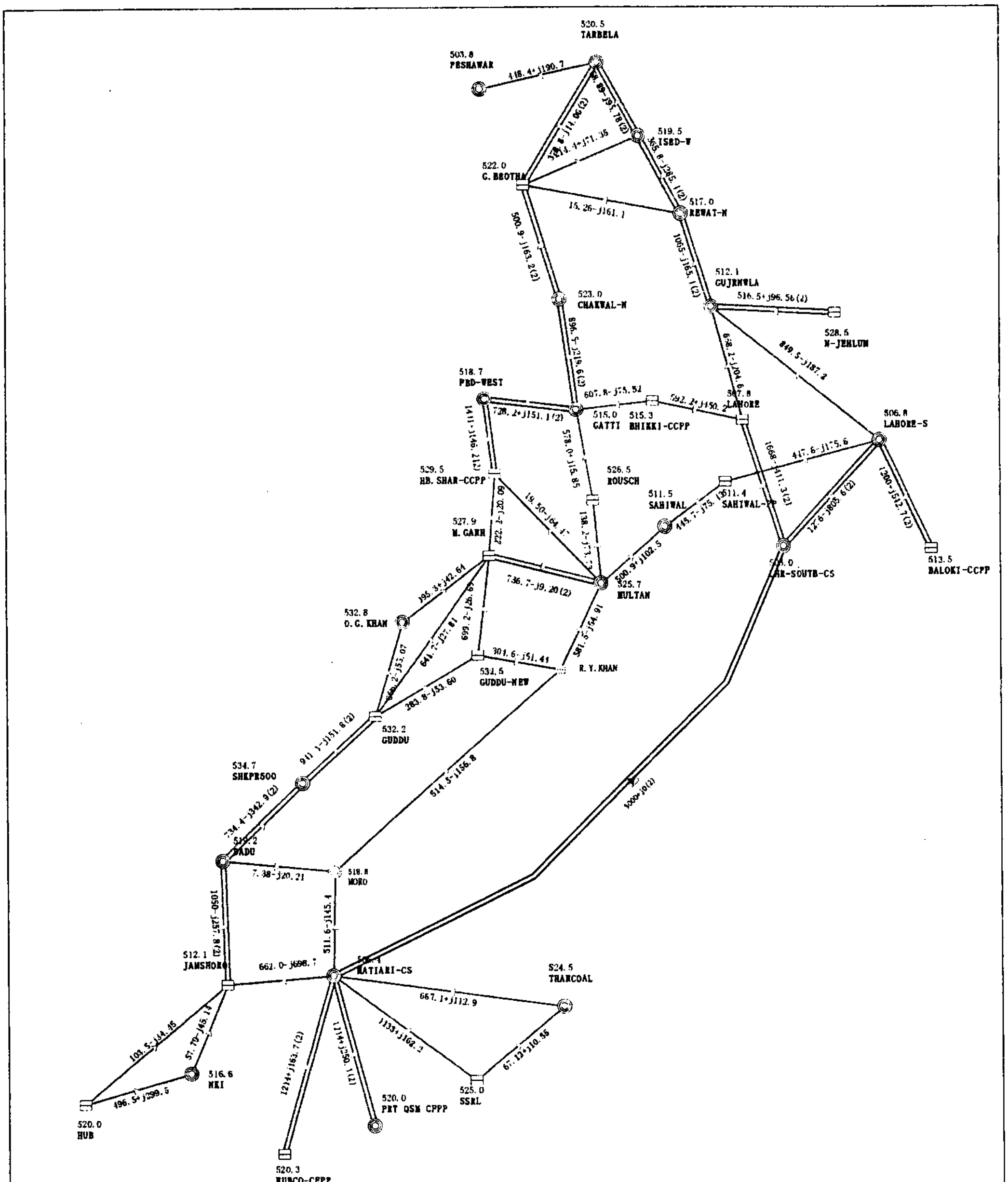

图 4.4 方式 4: 2019 年冬大

Figure 4.4 Scenario 4: Winter peak 2019

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4.1.5 方式 5—2019 年夏小 Scenario 5- Summer off peak 2019

该方式下共有 3 条直流输电线路，其中默蒂亚里-拉合尔直流的输送功率水平为 3300 MW。北部有一条直流与塔吉克斯坦相连。南部由直流和并联交流线路组成的断面输送功率为 6803 MW。与 2018 年相比，该方式下，南部有另外两个电厂投入运行，即 Lucky 燃煤电站、Sidqsns 燃煤电站。这两个电厂的出力为 920 MW。

In this scenario, there are 3 DC links. The transmission power of Matiari- Lahore is 3300 MW.It's noteworthy that in the north there is another DC link connecting with Tajikistan. The transmission power of the section consisted with the DC links and parallel AC lines (Matiari- Moro &Jamshoro-Dadu) is 6803 MW. Compared with 2018, there are two more power plants put into operation, i.e. Lucky CFPP and Sidqsns CFPP. The generation of these two plats is 920 MW.

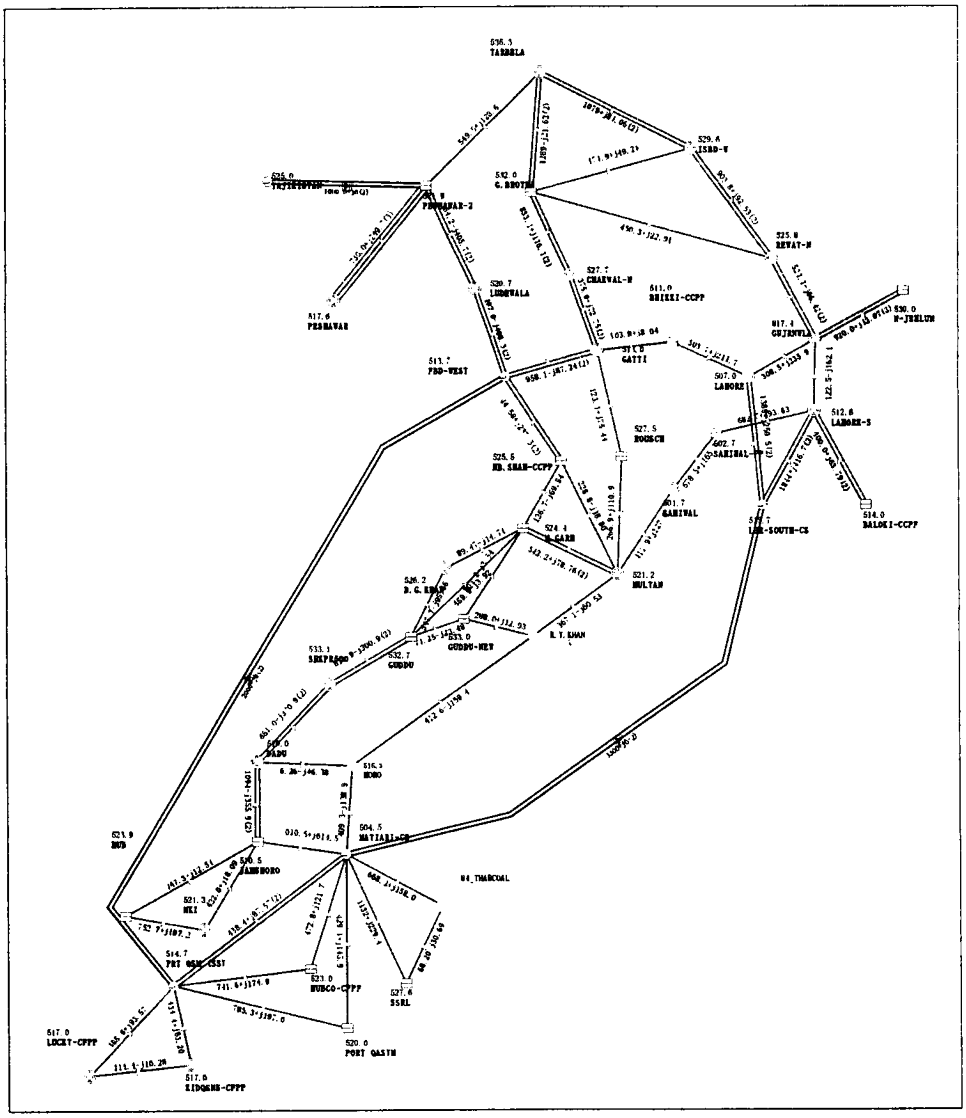

图 4.5 方式 5 2019 年夏小
Figure 4.5 Scenario 5: Summer off peak 2019

4.1.6 方式 6—2019 年冬小 Scenario 6- Winter off peak 2019

在该方式下，直流线路输送功率水平为 3400 MW。南部由直流线路和并联交流线路组成的短路输送功率为 5213 MW，南部四个电厂的出力为 4228 MW。

In this scenario, the DC link is running at a power level of 3400 MW. The transmission power of the section consisted with the DC link and parallel AC lines is 5213 MW. The generation of EngroThar, SSRL, Hubco CFPP and Port Qasim plant is 4228 MW.

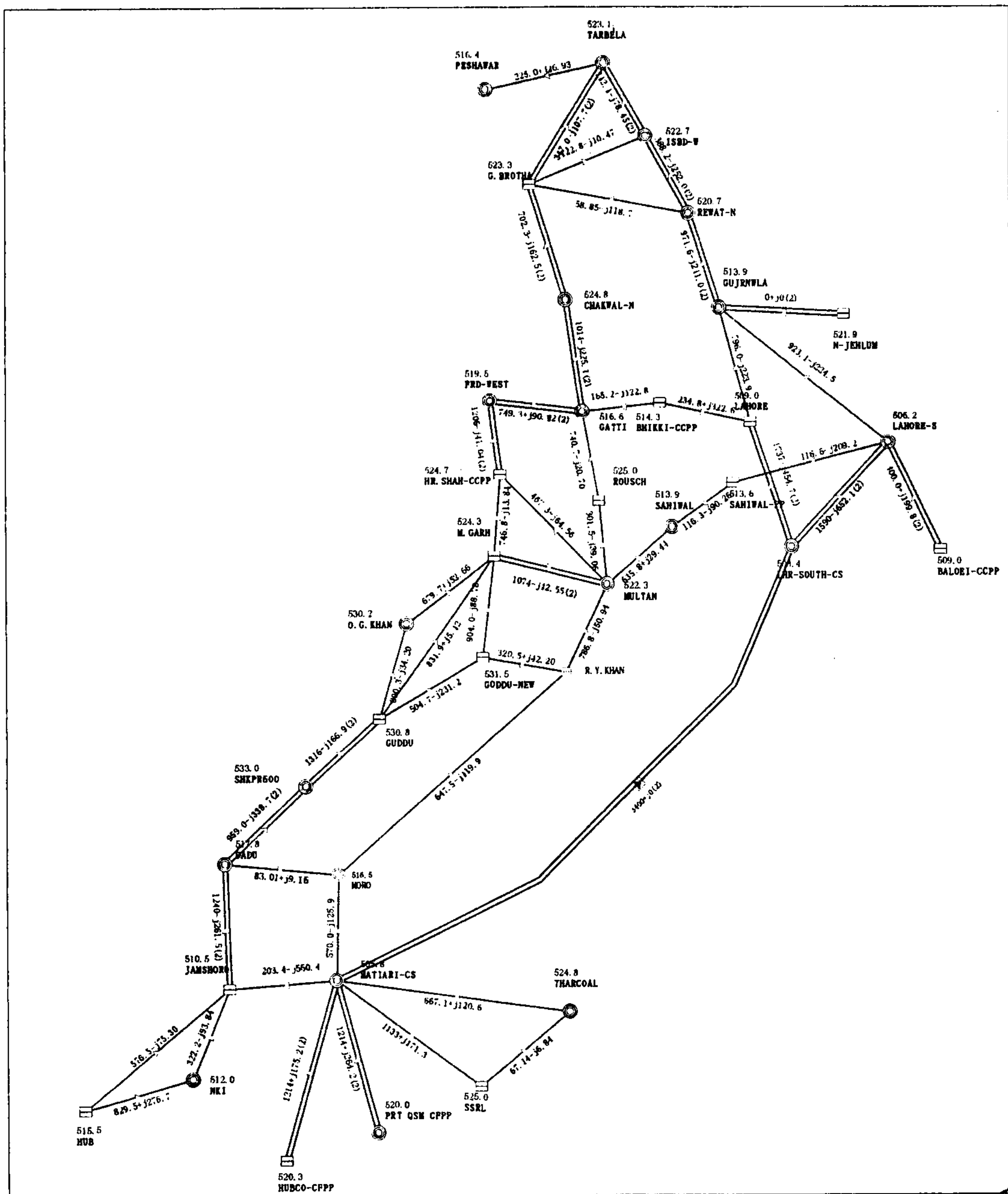

图 4.6 方式 6：2019 年冬小
Figure 4.6 Scenario 6: Winter off peak 2019

4.1.7 方式 7—2020 年冬小 Scenario 7- Winter peak 2020

在该方式下，两条直流输电线路的输送功率水平均为 2600 MW。由直流线路和并联交流通道组成的断面输送功率为 6543 MW。南部 6 个电厂的出力为 5120 MW。

In this scenario, there are 2 DC links both running at a power level of 2600 MW. The transmission power of the section consisted with the DC links and parallel AC lines (Matiari- Moro &Jamshoro-Dadu) is 6543 MW. The generation of power plants in the south including Engro char, SSRL, Port Qasim, Hubco CFPP, Lucky CFPP and Sidqsns CFPP is 5120 MW.

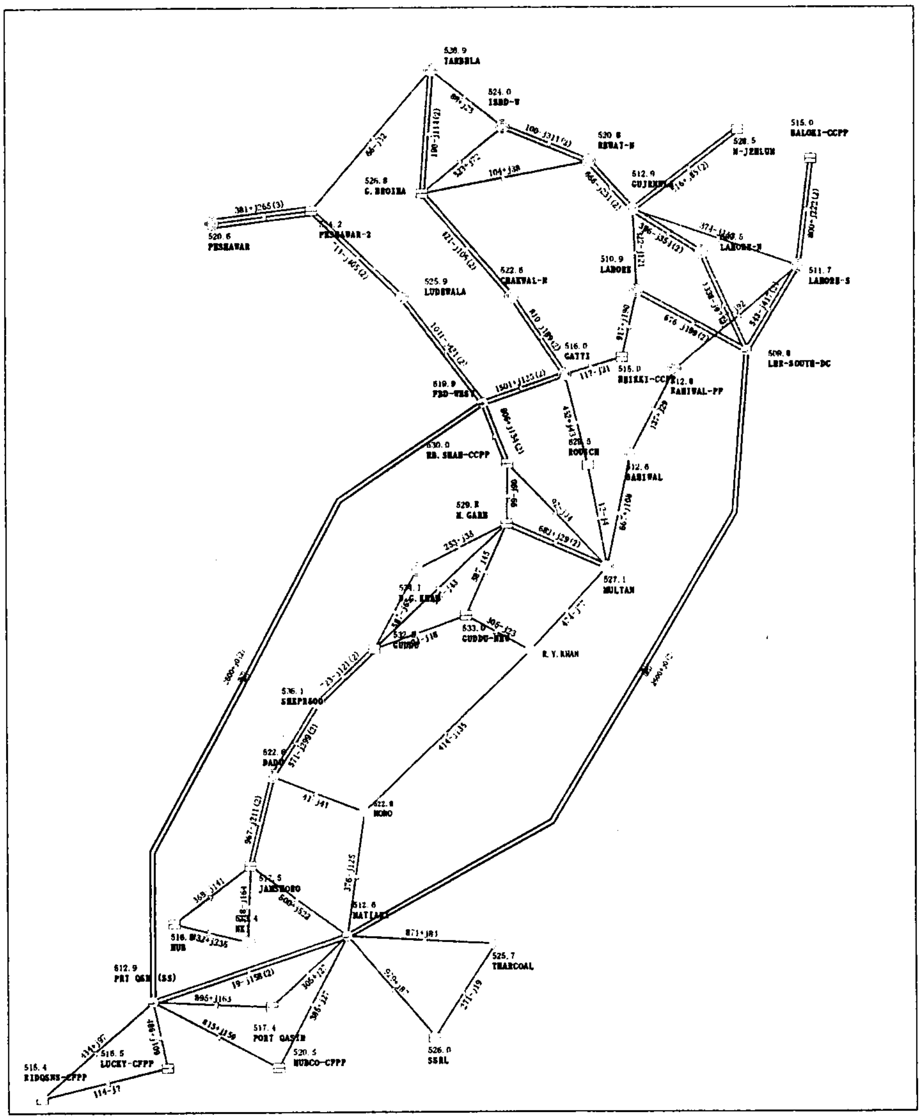

图 4.7 方式 7 2020 年冬大

Figure 4.7 Scenario 7: Winter peak 2020

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4.1.8 方式 8—2020 年丰小 Scenario 8- Off peak 2020

在该方式下，两条直流输电线路的输送功率水平均为 2600 MW。由直流线路和并联交流通道组成的断面输送功率为 6667 MW。南部 6 个电厂的出力为 5120 MW。

In this scenario, there are 2 DC links both running at a power level of 2600 MW. The transmission power of the section consisted with the DC links and parallel AC lines (Matiari- Moro &Jamshoro-Dadu) is 6667 MW. The generation of power plants in the south including Engro char, SSRL, Port Qasim, Hubco CFPP, Lucky CFPP and Sidqsns CFPP is 5120 MW.

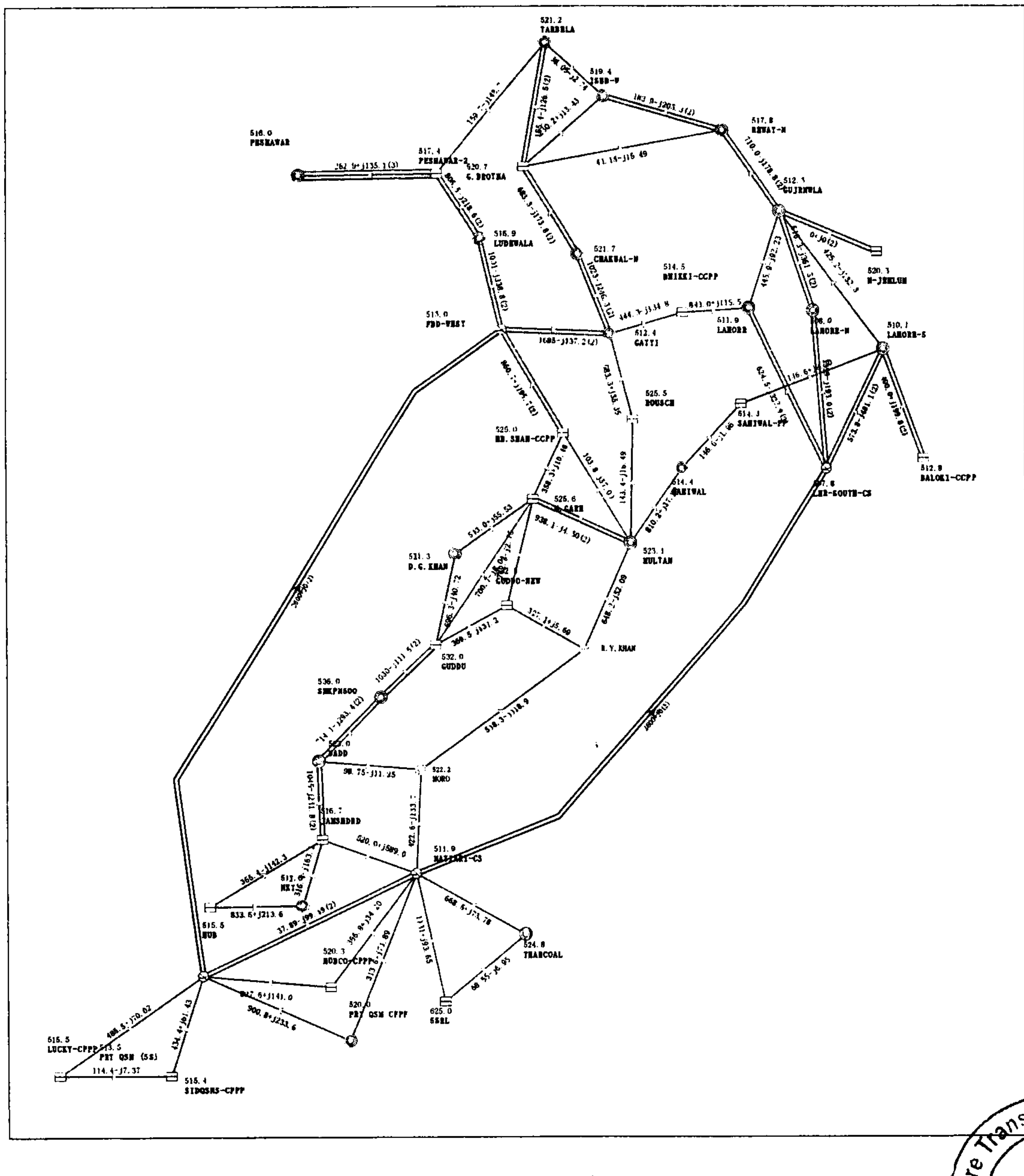

图 4.8 方式 8 2020 年丰小

Figure 4.8 Scenario 8: Off peak 2020

4.1.9 方式 9—2021 年夏大 Scenario 9- Summer peak 2021

该方式下共有 3 条直流输电线路，其中默蒂亚里-拉合尔直流的输送功率水平为 3200 MW。北部有一条直流与塔吉克斯坦相连。南部由直流和并联交流线路组成的短路输送功率为 8436 MW。在该方式下，K2/K3 核电厂投入运行，出力为 2035 MW。

In this scenario, there are 3 DC links. The transmission power of Matiari- Lahore is 3200 MW. It's noteworthy that in the north there is another DC link connecting with Tajikistan. The transmission power of the section consisted with the DC links and parallel AC lines (Matiari- Moro &Jamshoro-Dadu) is 8436 MW. There is a new power plant put into operation, i.e. K2/K3. Its generation is 2035 MW.

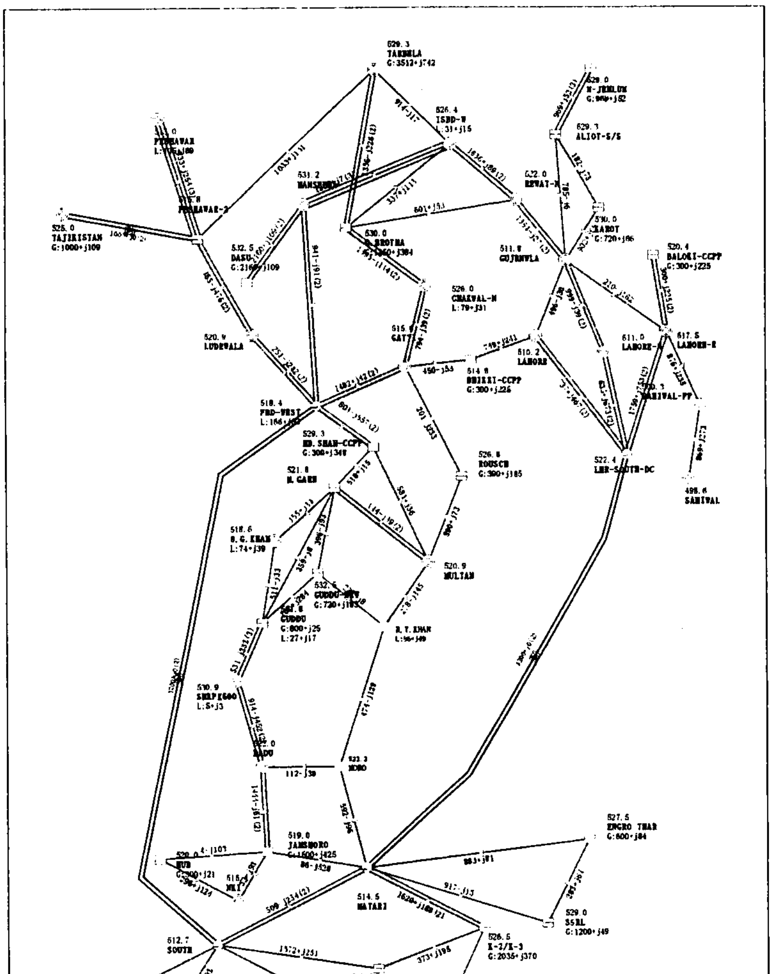

图 4.9 方式 9 2021 年夏大
Figure 4.9 Scenario 9: Summer peak 2021

4.1.10方式 10—2021 年丰小 Scenario 10- Off peak 2021

该方式下共有 3 条直流输电线路，其中默蒂亚里-拉合尔直流的输送功率水平为 3200 MW。北部有一条直流与塔吉克斯坦相连。南部由直流和并联交流线路组成的短路输送功率为 8229 MW。在该方式下，K2/K3 核电厂投入运行，出力为 2035 MW。

In this scenario, there are 3 DC links. The transmission power of Matiari- Lahore is 3200 MW. It's noteworthy that in the north there is another DC link connecting with Tajikistan. The transmission power of the section consisted with the DC links and parallel AC lines (Matiari- Moro &Jamshoro-Dadu) is 8229 MW. There is a new power plant put into operation, i.e. K2/K3. Its generation is 2035 MW.

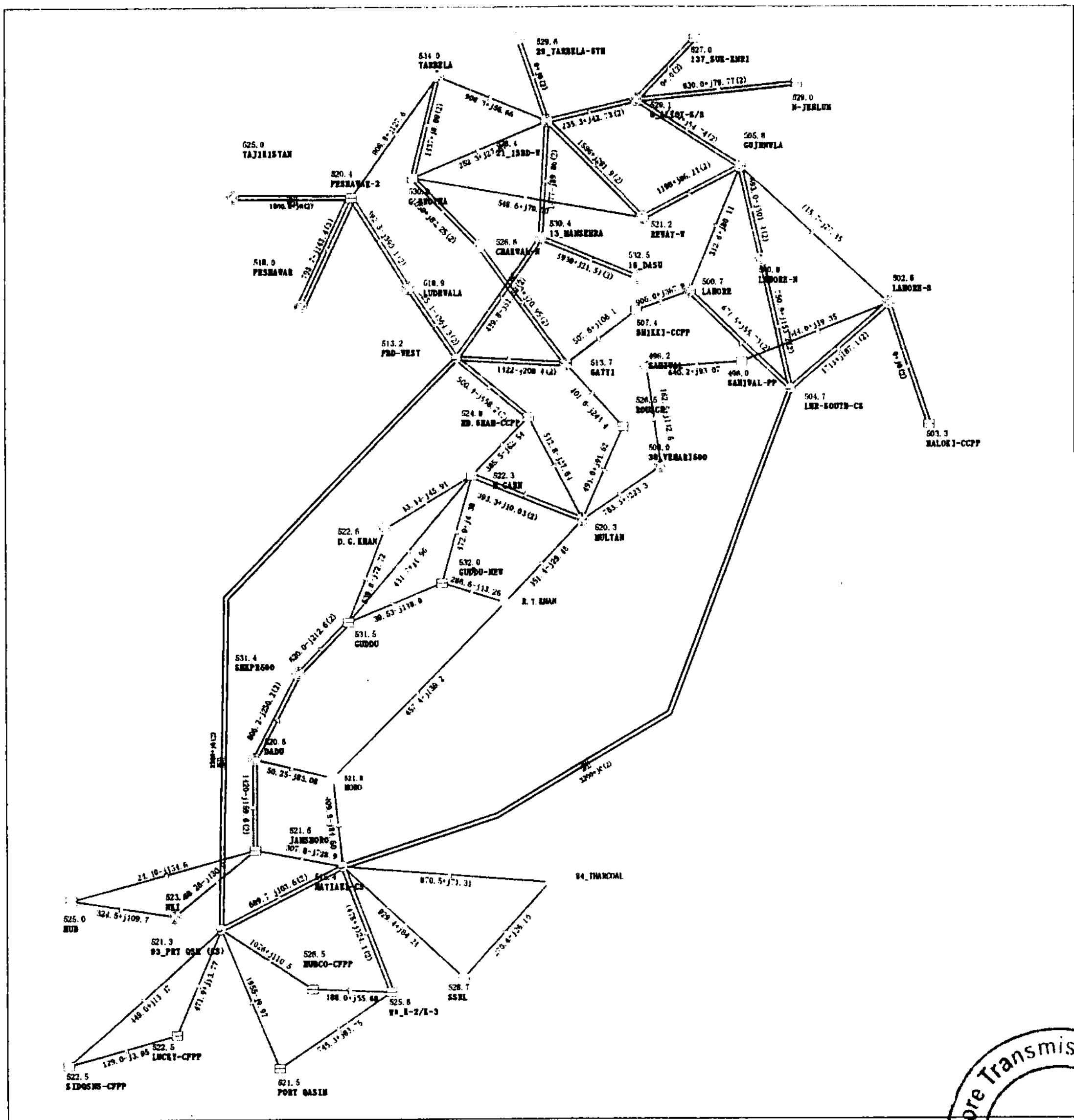

图 4.10 方式 10 2021 年丰小
Figure 4.10 Scenario 10: Off peak 2021

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4.1.11方式 11—2022 年冬大 Scenario 11- Winter peak 2022

在该方式下，共有两条直流线路。默蒂亚里-拉合尔直流输送功率水平为 3500 MW。由直流线路和并联交流通道组成的断面输送功率为 8956 MW。南部 7 个电厂的出力为 7183 MW。

In this scenario, there are 2 DC links. The transmission power of Matiari- Lahore is 3500 MW. The transmission power of the section consisted with the DC links and parallel AC lines (Matiari- Moro &Jamshoro- Dadu) is 8956 MW. The generation of power plants in the south including K2/K3, Engro char, SSRL, Port Qasim, Hubco CFPP, Lucky CFPP and Sidqsns CFPP is 7183 MW.

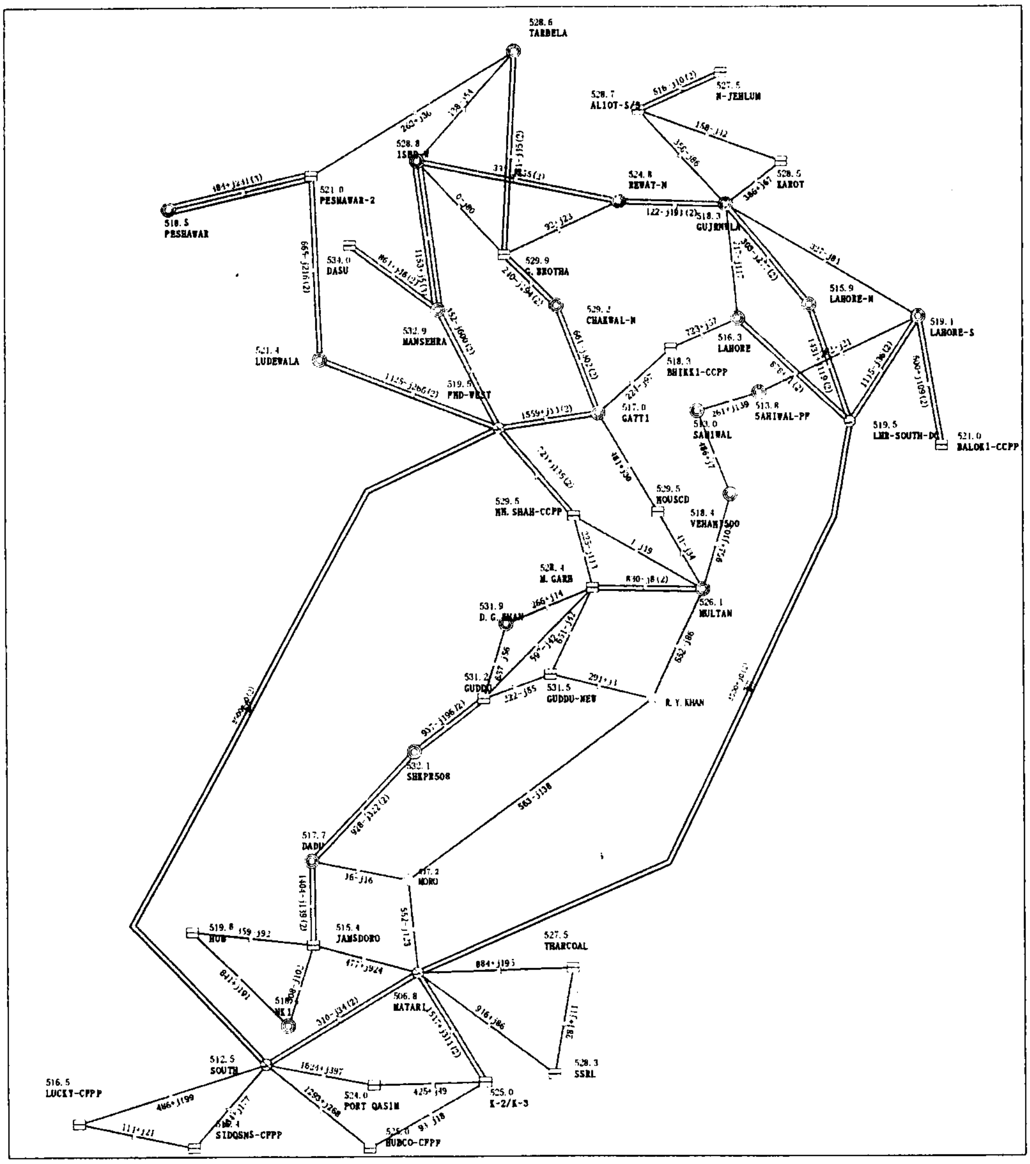

图 4.11 方式 11 2020 年冬大

Figure 4.11 Scenario 11: Winter peak 2022

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4.1.12方式 12—2022 年丰小 Scenario 12- Off peak 2022

在该方式下，共有两条直流线路。默蒂亚里-拉合尔直流输送功率水平为 3100 MW。由直流线路和并联交流通道组成的断面输送功率为 7969 MW。南部 7 个电厂的出力为 7183 MW。

In this scenario, there are 2 DC links. The transmission power of Matiari- Lahore is 3100 MW. The transmission power of the section consisted with the DC links and parallel AC lines (Matiari- Moro &Jamshoro- Dadu) is 7969 MW. The generation of power plants in the south including K2/K3, Engro char, SSRL, Port Qasim, Hubco CFPP, Lucky CFPP and Sidqsns CFPP is 7183 MW.

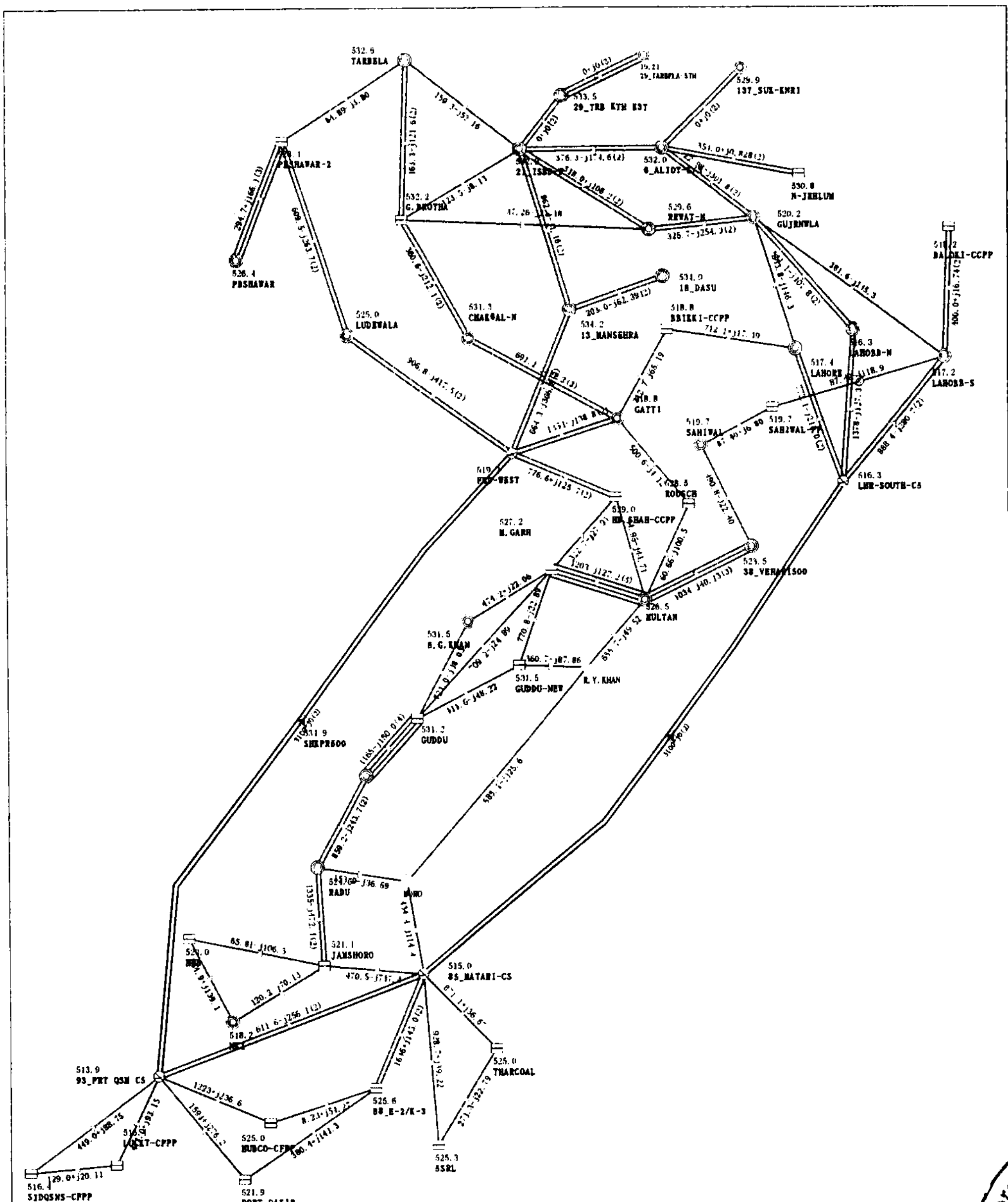

图 4.12 方式 12 2022 丰小
Figure 4.12 Scenario 12: Off peak 2022

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4.2 换流站数据 Converters Data

表 4-3 中为默蒂亚里和拉合尔换流站的数据，表 4-4 为直流线路主回路参数，表中提供的直流功率为额定值。在本报告分析的方式中，只有方式 1 中，直流按额定功率运行。表 4-5 中为触发角数据，这些数据在 PSS/E 中的直流数据中有使用。

The table 4-3 presents the Converter data of terminal Matiari and Lahore.The table 4-4 presents the main circuit data of the DC link. It should be noted that the DC power in this table is a nominal one. In the scenarios analyzed in this report, only for scenario 1 the DC link is operating at the nominal power. The table 4-5 presents the firing angle data.These data was used in PSS/E Program to represent the DC link.

表 4-3 换流站数据
Table 4-3 Converters Data

默蒂亚里站-六脉动桥 Terminal Matiati – 6 pulse bridge			拉合尔站-六脉动桥 Terminal Lahore – 6 pulse bridge		
描述 Description	单位 Unit	数值 Value	描述 Description	单位 Unit	数值 Value
换相电抗 Commutation Reactance	[%]	18	换相电抗 Commutation Reactance	[%]	18
交流额定电压 Nominal AC Voltage	[kV]	510	交流额定电压 Nominal AC Voltage	[kV]	510
串联桥数量 Number of Bridges in Series	-	2	串联桥数量 Number of Bridges in Series	-	2
最大档位 Maximum Tap Setting	[pu]	1.2875	最大档位 Maximum Tap Setting	[pu]	1.2875
最小档位 Minimum Tap Setting	[pu]	0.9125	最小档位 Minimum Tap Setting	[pu]	0.9125
档位步长 Tap Step	[pu]	0.0125	档位步长 Tap Step	[pu]	0.0125

表 4-4 直流额定数据
Table 4-4 DC link Nominal Data

数据 Data	数值 Value	单位 Unit
直流额定电压 Nominal DC Voltage	660	kV
直流额定功率 Nominal DC Power	4000	MW
直流线路电阻 DC line Resistance	5.646	Ω

表 4-5 触发角数据

Table 4-5 Firing Angle Data

默蒂亚里侧（α） Matiari Side (α)			拉合尔侧（γ） Lahore Side (γ)		
数据 Data	数值 Value	单位 Unit	数据 Data	数值 Value	单位 Unit
触发角 Firing Angle	15	°	熄弧角 ExtinctionAngle	17	°
最小触发角 Minimum Firing angle	12.5	°	最小熄弧角 Minimum Extinctionangle	-	°
最大触发角 Maximum Firing angle	17.5	°	最大熄弧角 Maximum Extinction angle	-	°

5. 2018 年静态安全分析的故障类型

Contingencies Analyzed in Power Flow in 2018 year

本节所用的方式为 2018 年夏大方式和丰小方式，其数据由 NTDC 提供，第 4 章中提供了这两个方式的具体描述。

The scenarios used in this report are 2018 summer peak and 2018 off peak whose data is provided by NTDC. The descriptions of these two scenarios can be found in Chapter 4.

在该两个方式中，需要校核以下三部分故障：
a) 换流站进出线 N-1 故障；
b）并联交流通道 N-1 故障；
c) 直流闭锁故障，包括单极和双极闭锁。

In these two scenarios, contingencies of 3 parts listed below are implemented.
a) AC N-1 contingencies for the ac lines out from both converter stations
b）For the parallel AC channels.
c) DC blocking faults, monopole or bipole.

具体校核的故障有以下四个部分：

The contingencies applied were divided in 4 parts:

■ 整流侧的 7 个故障:

7 contingencies in Rectifier side:

1) 摩洛-默蒂亚里换流站 500 kV 线路 N-1
500 kV MORO – MATIARI N-1
2) 大都-默蒂亚里换流站 500 kV 线路 N-1*
500 kV DADU – MATIARIN-1
3) 贾姆沙罗-默蒂亚里换流站 500 kV 线路 N-1
500 kV JAMSHORO – MATIARI N-1
4) 卡西姆港-默蒂亚里换流站 500 kV 线路 N-1
500 kV PORT QASIM – MATIARI N-1
5) 胡布克电厂-默蒂亚里换流站 500 kV 线路 N-1
500 kV HUBCO CFPP – MATIARI N-1
6) 塔尔安格鲁电厂-默蒂亚里换流站 500 kV 线路 N-1
500 kV SSRL – MATIARI N-1
7) 默蒂亚里换流站-塔尔坑口一区电厂 500 kV 线路 N-1
500 kV ENGRO THAR – MATIARI N-1

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*：*该故障在丰小方式下不校核*

**: not for off peak load scenario*

- 并联交流线路的 16 个故障：
  16 contingencies in AC Parallel Lines:

  1) 500 kV MORO -R.Y.KHAN N-1
  2) 500 kV DADU-SHKPR N-1
  3) 500 kV SHKPR-GUDDU N-1
  4) 500 kV D.G.KHAN-GUDDU N-1
  5) 500 kV M.GARH-GUDDU N-1
  6) 500 kV GUDDU-GUDDU-NEW N-1
  7) 500 kV D.G.KHAN- M.GARH N-1
  8) 500 kV GUDDU-NEW-M.GARH N-1
  9) 500 kV R.Y.KHAN –GUDDU-NEW N-1
  10) 500 kV R.Y.KHAN –MULTAN N-1
  11) 500 kV M.GARH-MULTAN N-1
  12) 500 kV MULTAN-SAHIWAL N-1
  13) 500 kV SAHIWAL-SAHIWAL-PP N-1
  14) 500 kV MULTAN-ROUSCH N-1
  15) 500 kV MULTAN-HB.SHAH-CCPP N-1
  16) 500 kV ROUSCH-GATTI N-1

这些故障标注在了图 5.1 中。

These contingencies can be clearly displaced in grid diagram as shown in Figure 5.1.

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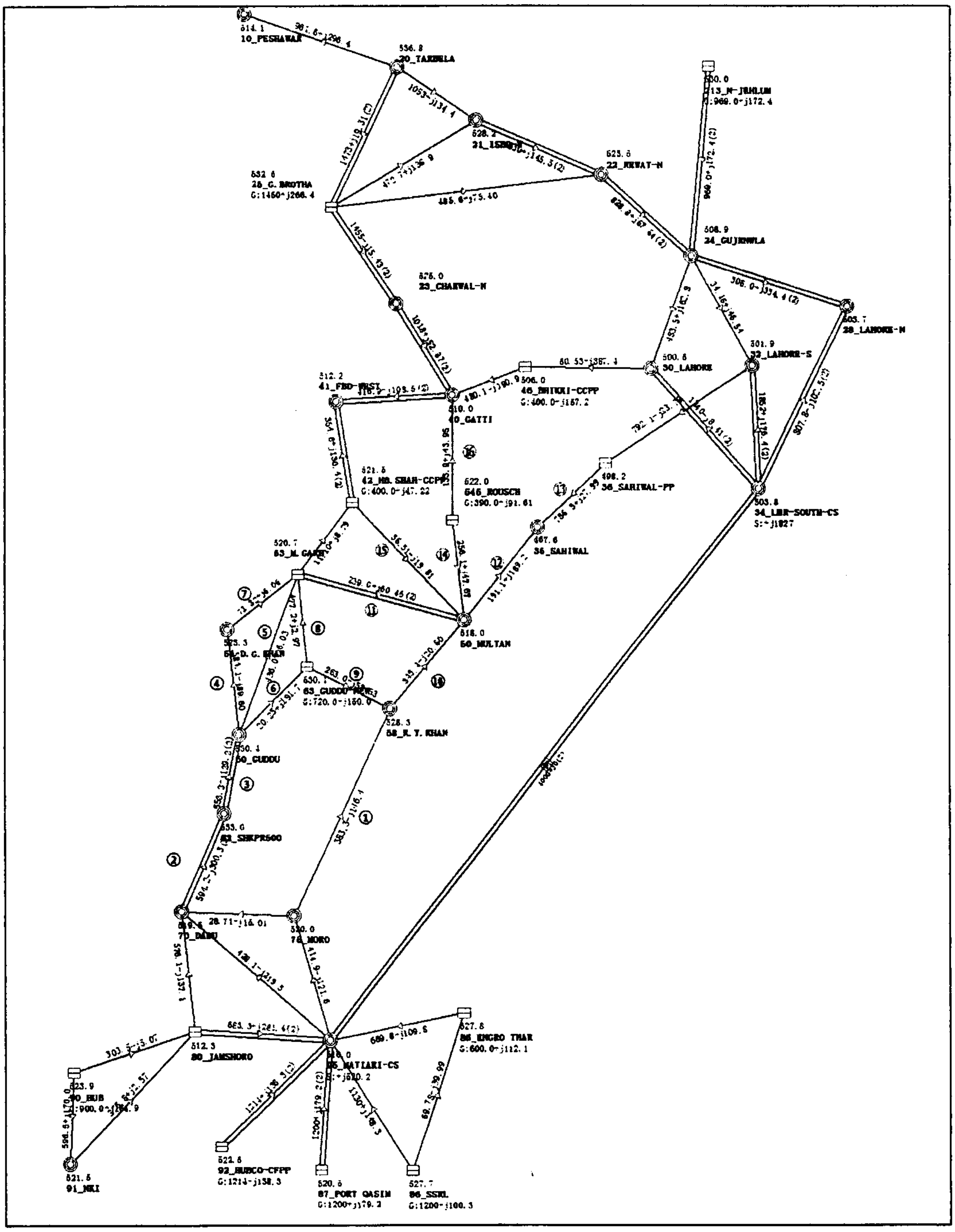

图 5.1 并联交流线路 N-1 故障
Figure 5.1 Parallel AC Lines N-1 Contingencies

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- 逆变侧的 3 个故障:
  3 contingencies in Inverter side:
  1) 拉合尔换流站-拉合尔 500 kV 线路 N-1

500 kV LAHORE - LHR SOUTH CS N-1

2) 拉合尔换流站-拉合尔南 500 kV 线路 N-1
500 kV LAHORE-S - LHR SOUTH CS N-1

3) 拉合尔换流站-拉合尔北 500 kV 线路 N-1*
500 kV LAHORE-N - LHR SOUTH CSN-1*

*: *该故障在丰小方式下不校核*

*: *not for off peak load scenario*

■ 直流闭锁故障:
DC blocking faults:

1) 单极闭锁
monopole

2) 双极闭锁
bipole

Pak Matiari Lahore Transmission Co. (Pvt) Ltd.

6. 2018 年静态安全分析结论

Contingencies Analysis Conclusion in 2018 year

6.1 交流 N-1 故障结论

AC Contingencies Conclusions

对并联交流通道上 500 kV 线路进行 N-1 开断校核，主要 500 kV 节点电压不越限，500 kV 线路无过载。具体数据见附录。

For N-1 contingencies of the 500 kV lines of parallel AC channels, the voltages of main 500 kV buses don't exceed the limits and the 500 kV lines aren't overloaded. The detailed data can be found in Appendix.

6.2 直流故障结论

DC Contingencies Conclusions

直流单极闭锁故障后，主要 500 kV 节点电压不越限，线路有过载现象，需要调整运行方式。过载及重载线路如图 6.1、6.2 所示，具体数据见附录。

After DC monopole block fault, the voltages of main 500 kV buses don't exceed the limits and lines are slightly overloaded. It is necessary to adjust the operation mode. The overload lines and heavy load lines are shown in Figure 6.1 and 6.2. The detailed data can be found in Appendix.

直流双极闭锁及采取切机切负荷的稳控措施后，主要 500 kV 节点电压不越限，500 kV 线路无过载。

For DC bipole block fault, after taken stability measures, i.e. tripping generators and load shedding, he voltages of main 500 kV buses don't exceed the limits and the 500 kV lines aren't overloaded. The detailed data can be found in Appendix. Table 6-1 is the simulation results of DC block faults.

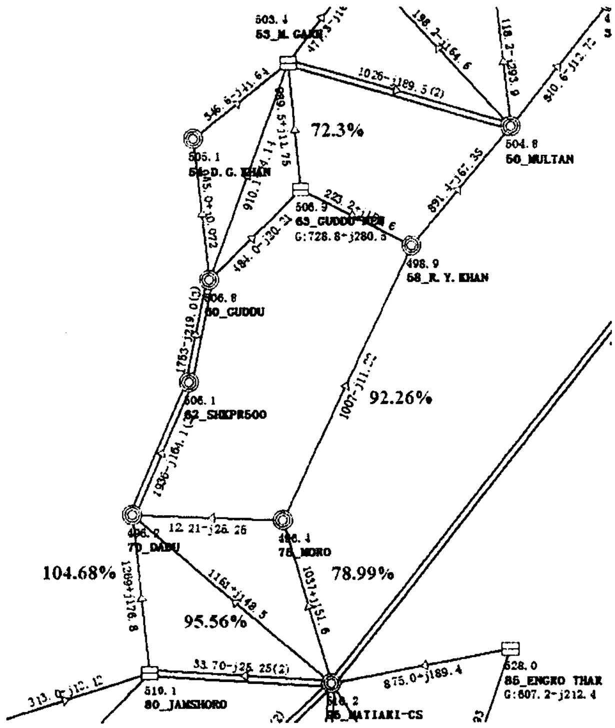

图 6.1 2018 年夏大方式直流单极闭锁后过载及重载线路

Figure 6.1 Overload Lines After DC Monopole Block Fault in summer 2018

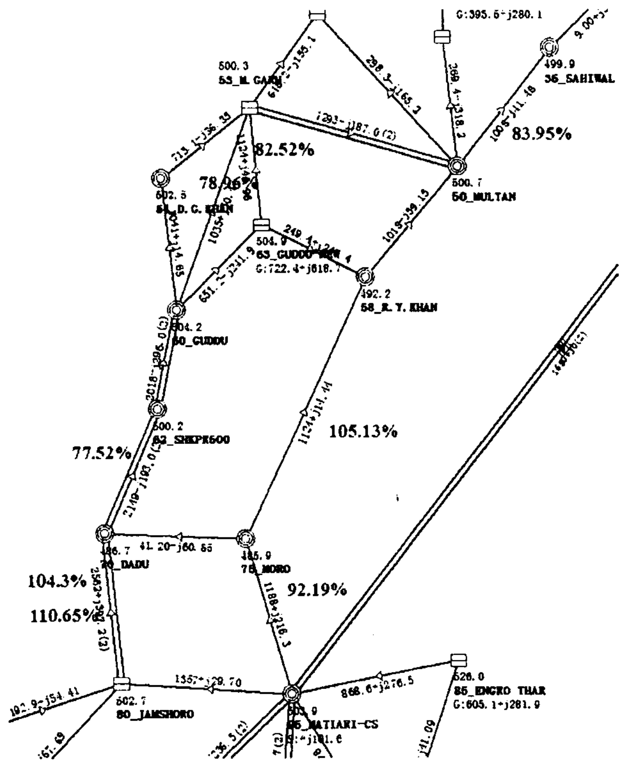

图 6.2 2018 年丰小方式直流单极闭锁后过载及重载线路

Figure 6.2 Overload Lines and Heavy Load Lines After DC Monopole Block Fault in off peak 2018

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7 附录 Appendix

7.1 方式 1 Scenario 1

7.1.1 整流侧故障 Contingencies on the rectifier side

Table7.1.1. Contingencies on MATIARI – Scenario 1

CASES	CONTINGENCIES
Case 1	"Scenario 1"
Case 2	"CONTINGENCY_01 - TL 500 kV MORO - MATIARI "
Case 3	"CONTINGENCY_02 - TL 500 kV DADU - MATIARI "
Case 4	"CONTINGENCY_03 - TL 500 kV JAMSHORO - MATIARI "
Case 5	"CONTINGENCY_04 - TL 500 kV PORT QASIM - MATIARI "
Case 6	"CONTINGENCY_05 - TL 500 kV HUBCO CFPP - MATIARI "
Case 7	"CONTINGENCY_06 - TL 500 kV SSRL - MATIARI "
Case 8	"CONTINGENCY_07 - TL 500 kV ENGRO THAR - MATIARI "

Table7.1.2. Voltages in the 500 kV bus station – Scenario 1

Bus		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
Number	Name								
500 kV busbars in the southern region									
80	JAMSHORO	1.02	1.02	1.02	1.03	1.02	1.02	1.02	1.02
85	ENGRO THAR	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
86	SSRL	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
87	PORT QASIM	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
90	HUB	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
91	NK1	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
92	HUBCO CFPP	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
95	MATIARI	1.02	1.02	1.02	1.02	1.02	1.02	1.01	1.01
Three busbars away from Lahore									
30	LAHORE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
32	LAHORE-S	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
28	LAHORE-N	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
24	GUIJRNWLA	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
46	BHIKKI-CCPP	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
36	SAHIWAL-PP	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
40	GATTI	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
35	SAHIWAL	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
22	REWAT	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
213	N-JEHLUM	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06

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Bus		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
Number	Name								
34	LHR-SOUTH-CS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
500 kV busbars in the parallel AC lines									
70	DADU	1.04	1.04	1.04	1.04	1.04	1.04	1.03	1.03
75	MORO	1.04	1.05	1.04	1.04	1.04	1.04	1.04	1.04
62	SHKPR500	1.07	1.07	1.07	1.07	1.06	1.06	1.06	1.06
60	GUDDU	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
58	R.Y.KHAN	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
54	D.G.KHAN	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
63	GUDDU-NEW	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
53	M.GARH	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
50	MULTAN	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
42	HB.SHAH	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
545	ROUSCH	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
41	FBD-WEST	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02

Table7.1.3. Emergency loading percentage on main 500 kV circuits - Scenario 1

From Bus		To bus		Nc	Emergency loading percentage [%]							
					Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
80	JAMSHORO	95	MATIARI-CS	1	24.85	18.82	17.07	0	25.56	25.71	26.95	26.94
80	JAMSHORO	95	MATIARI-CS	3	7.81	5.77	5.16	22.55	8	8.04	8.4	8.39
80	JAMSHORO	70	DADU	2	46.57	62.48	67.33	51.33	46.44	46.4	46.11	46.17
95	MATIARI-CS	70	DADU	1	39.16	54.76	0	36.32	39.13	39.11	38.98	39.04
95	MATIARI-CS	75	MORO	1	31.93	0	45.25	30.04	31.89	31.87	31.74	31.79
75	MORO	70	DADU	1	1.17	17.91	8.89	0.72	1.13	1.12	1.06	1.06
70	DADU	62	SHKPR500	1	20.32	20.83	19.57	20.34	20.31	20.3	20.22	20.26
70	DADU	62	SHKPR500	2	22.71	23.26	21.89	22.73	22.71	22.7	22.63	22.68
75	MORO	58	R.Y.KHAN	1	36.22	32.56	37.25	35.98	36.14	36.11	35.9	35.96
62	SHKPR500	60	GUDDU	1	17.17	17.82	16.57	17.2	17.05	17.02	16.79	16.83
62	SHKPR500	60	GUDDU	2	18.5	19.21	17.86	18.53	18.38	18.35	18.1	18.14
60	GUDDU	54	D.G.KHAN	1	35.47	35.5	35.29	35.45	35.33	35.29	35.02	35.05
60	GUDDU	53	M.GARH	1	31.58	31.63	31.37	31.56	31.41	31.37	31.05	31.08
60	GUDDU	63	GUDDU-NEW	1	6.44	7.11	6.86	6.44	6.07	6.01	5.52	5.49
54	D.G.KHAN	53	M.GARH	1	6.83	6.87	6.73	6.82	6.74	6.71	6.55	6.57
63	GUDDU-NEW	53	M.GARH	1	33.3	33.32	33.1	33.28	33.12	33.08	32.75	32.78
53	M.GARH	50	MULTAN	1	7.94	8.06	7.86	7.94	7.92	7.91	7.88	7.89
53	M.GARH	50	MULTAN	2	8.06	8.19	7.98	8.07	8.05	8.04	8.01	8.01
53	M.GARH	42	HB.SHAH	1	0.2	0.23	0.17	0.2	0.19	0.18	0.15	0.16
50	MULTAN	35	SAHIWAL	1	23.67	23.69	23.66	23.67	23.65	23.65	23.62	23.62
50	MULTAN	545	ROUSCH	1	19.83	19.84	19.84	19.84	19.85	19.85	19.87	19.87

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From Bus		To bus		Nc	Emergency loading percentage [%]							
					Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
35	SAHIWAL	36	SAHIWAL-PP	1	27.25	27.25	27.25	27.25	27.25	27.25	27.25	27.25
36	SAHIWAL-PP	32	LAHORE-S	2	27.96	27.97	27.96	27.96	27.97	27.97	27.97	27.97
42	HB.SHAH	41	FBD-WEST	1	7.58	7.57	7.57	7.58	7.57	7.57	7.55	7.55
545	ROUSCH	40	GATTI	1	13.2	13.22	13.2	13.2	13.19	13.19	13.18	13.18
40	GATTI	46	BHIKKI-CCPP	1	23.9	23.9	23.9	23.9	23.9	23.9	23.91	23.91
46	BHIKKI-CCPP	30	LAHORE	1	19.26	19.27	19.26	19.26	19.26	19.26	19.27	19.27

7.1.2 并联交流线路故障 Contingencies on Parallel AC lines

Table7.1.4. Contingencies on Parallel AC Lines – Scenario 1

CASES	CONTINGENCIES
Case 1	"CONTINGENCY_01 - TL 500 kV MORO -R.Y.KHAN "
Case 2	"CONTINGENCY_02 - TL 500 kV DADU-SHKPR"
Case 3	"CONTINGENCY_03 - TL 500 kV SHKPR-GUDDU"
Case 4	"CONTINGENCY_04 - TL 500 kV D.G.KHAN-GUDDU "
Case 5	"CONTINGENCY_05 - TL 500 kV M.GARH-GUDDU "
Case 6	"CONTINGENCY_06 - TL 500 kV GUDDU-GUDDU-NEW"
Case 7	"CONTINGENCY_07 - TL 500 kV D.G.KHAN- M.GARH"
Case 8	"CONTINGENCY_08 - TL 500 kV GUDDU-NEW-M.GARH

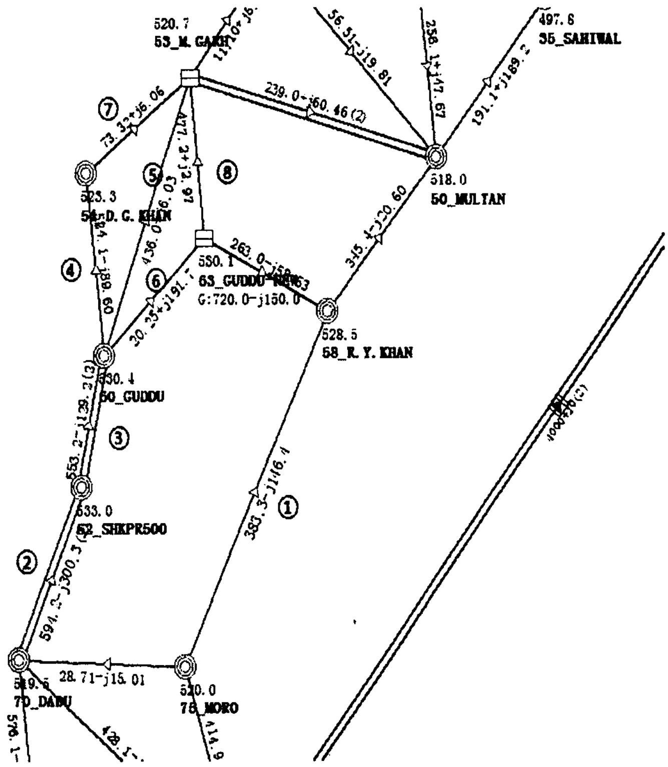

Figure 2 Parallel AC Lines N-1 Contingencies 1-8

Table7.1.5. Voltages in the 500 kV bus station – Scenario 1

Bus Number	Bus Name	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
500 kV busbars in the southern region									
80	JAMSHORO	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
85	ENGRO THAR	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
86	SSRL	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
87	PORT QASIM	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
90	HUB	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
91	NKI	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
92	HUBCO CFPP	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
95	MATIARI	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Three busbars away from Lahore									
30	LAHORE	1.00	1.00	1.00	0.99	0.99	1.00	0.99	0.99
32	LAHORE-S	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
28	LAHORE-N	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
24	GUIJRNWLA	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
46	BHIKKI-CCPP	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
36	SAHIWAL-PP	0.99	0.99	0.99	0.99	0.99	0.99	[illegible]	0.99
40	GATTI	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02

Bus		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
Number	Name								
500 kV busbars in the southern region									
35	SAHIWAL	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
22	REWAT	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
213	N-JEHLUM	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
34	LHR-SOUTH-CS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
500 kV busbars in the parallel AC lines									
70	DADU	1.03	1.03	1.04	1.04	1.04	1.04	1.04	1.04
75	MORO	1.03	1.03	1.04	1.04	1.04	1.04	1.04	1.04
62	SHKPR500	1.06	1.06	1.06	1.07	1.07	1.07	1.07	1.06
60	GUDDU	1.06	1.06	1.06	1.06	1.06	1.07	1.06	1.06
58	R.Y.KHAN	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
54	D.G.KHAN	1.05	1.05	1.05	1.03	1.05	1.05	1.07	1.05
63	GUDDU-NEW	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
53	M.GARH	1.04	1.04	1.04	1.03	1.04	1.04	1.04	1.04
50	MULTAN	1.03	1.03	1.03	1.03	1.03	1.04	1.03	1.03
42	HB.SHAH	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
545	ROUSCH	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
41	FBD-WEST	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02

Table 7.1.6 Emergency loading percentage on main 500 kV circuits - Scenario 1

From Bus		To bus		Nc	Emergency loading percentage [%]							
					Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
80	JAMSHORO	95	MATIARI-CS	1	23.71	24.92	24.95	24.90	24.90	24.87	24.86	24.90
80	JAMSHORO	95	MATIARI-CS	3	7.44	7.84	7.85	7.83	7.83	7.82	7.82	7.83
80	JAMSHORO	70	DADU	2	48.35	45.41	46.19	46.42	46.44	46.66	46.56	46.44
95	MATIARI-CS	70	DADU	1	40.74	37.86	38.76	39.00	39.03	39.28	39.15	39.02
95	MATIARI-CS	75	MORO	1	26.14	32.25	32.31	32.09	32.10	32.06	31.97	32.07
75	MORO	70	DADU	1	16.81	2.91	1.18	0.61	0.62	0.86	1.03	0.64
70	DADU	62	SHKPR500	1	30.96	0.00	18.93	19.74	19.83	20.44	20.28	19.86
70	DADU	62	SHKPR500	2	34.37	35.17	21.19	22.09	22.18	22.87	22.68	22.21
75	MORO	58	R.Y.KHAN	1	0.00	42.23	39.55	37.59	37.58	36.49	36.43	37.43
62	SHKPR500	60	GUDDU	1	26.97	15.29	0.00	15.99	16.43	17.23	17.24	16.44
62	SHKPR500	60	GUDDU	2	29.09	16.47	29.62	17.23	17.71	18.58	18.58	17.71
60	GUDDU	54	D.G.KHAN	1	36.91	35.11	35.10	0.00	44.91	35.78	32.67	45.91
60	GUDDU	53	M.GARH	1	33.40	31.17	31.26	44.08	0.00	32.02	33.18	44.06
60	GUDDU	63	GUDDU-NEW	1	17.88	6.65	6.25	17.47	16.21	0.00	10.4[illegible]	19.83
54	D.G.KHAN	53	M.GARH	1	7.94	6.66	6.84	24.80	14.63	7.70	0.00	15.58

From Bus		To bus		Nc	Emergency loading percentage [%]							
					Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
63	GUDDU-NEW	53	M.GARH	1	34.81	32.95	33.01	46.11	44.88	32.61	34.92	0.00
53	M.GARH	50	MULTAN	1	9.70	7.65	7.77	4.99	5.14	8.12	7.23	4.64
53	M.GARH	50	MULTAN	2	9.91	7.76	7.88	5.09	5.19	8.25	7.37	4.69
53	M.GARH	42	HB.SHAH	1	0.62	0.13	0.16	1.84	1.16	0.34	0.81	1.47
50	MULTAN	35	SAHIWAL	1	23.51	23.65	23.67	23.16	23.34	23.77	23.37	23.24
50	MULTAN	545	ROUSCH	1	19.99	19.83	19.83	20.01	19.92	19.79	19.98	19.96
35	SAHIWAL	36	SAHIWAL-PP	1	27.28	27.24	27.24	27.21	27.21	27.25	27.25	27.21
36	SAHIWAL-PP	32	LAHORE-S	2	28.00	27.96	27.96	27.93	27.93	27.96	27.97	27.92
42	HB.SHAH	41	FBD-WEST	1	7.63	7.57	7.57	7.56	7.51	7.57	7.56	7.51
545	ROUSCH	40	GATTI	1	13.08	13.19	13.20	12.77	12.94	13.28	12.97	12.86
40	GATTI	46	BHIKKI-CCPP	1	23.88	23.90	23.90	23.91	23.93	23.90	23.91	23.93
46	BHIKKI-CCPP	30	LAHORE	1	19.25	19.26	19.26	19.19	19.22	19.27	19.23	19.21

Table 7.1.7 Contingencies on Parallel AC Lines – Scenario 1

CASES	CONTINGENCIES
Case 9	"CONTINGENCY_09 - TL 500 kV R.Y.KHAN –GUDDU-NEW"
Case 10	"CONTINGENCY_10 - TL 500 kV R.Y.KHAN -MULTAN"
Case 11	"CONTINGENCY_11 - TL 500 kV M.GARH-MULTAN"
Case 12	"CONTINGENCY_12 - TL 500 kV MULTAN-SAHIWAL "
Case 13	"CONTINGENCY_13 - TL 500 kV SAHIWAL-SAHIWAL-PP "
Case 14	"CONTINGENCY_14 - TL 500 kV MULTAN-ROUSCH"
Case 15	"CONTINGENCY_15 - TL 500 kV MULTAN-HB.SHAH-CCPP"
Case 16	"CONTINGENCY_16 - TL 500 kV ROUSCH-GATTI"

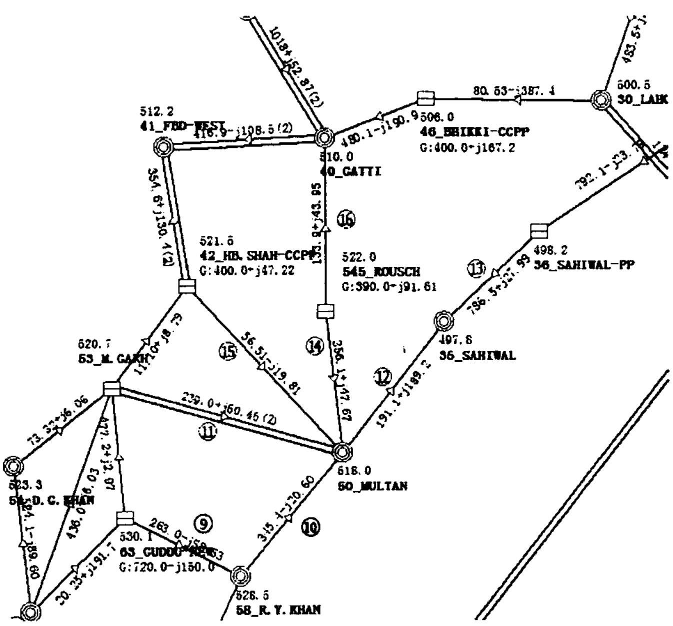

Figure 2 Parallel AC Lines N-1 Contingencies 9-16

Table 7.1.8 Voltages in the 500 kV bus station – Scenario 1

Bus		Case 9	Case 10	Case 11	Case 12	Case 13	Case 14	Case 15	Case 16
Number	Name								
500 kV busbars in the southern region									
80	JAMSHORO	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
85	ENGRO THAR	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
86	SSRL	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
87	PORT QASIM	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
90	HUB	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
91	NKI	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
92	HUBCO CFPP	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
95	MATIARI	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Three busbars away from Lahore									
30	LAHORE	0.99	0.99	1.00	0.99	0.99	0.99	0.99	0.99
32	LAHORE-S	1.00	0.99	1.00	0.99	1.00	0.99	1.00	0.99
28	LAHORE-N	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00
24	GUIJRNWLA	1.01	1.01	1.01	1.00	1.01	1.01	1.01	1.01
46	BHIKKI-CCPP	1.01	1.01	1.01	1.00	1.01	1.01	1.01	1.00
36	SAHIWAL-PP	0.99	0.99	0.99	0.96	1.00	0.99	0.99	0.99
40	GATTI	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.01
35	SAHIWAL	0.99	0.99	0.99	0.96	0.99	0.99	0.99	0.99
22	REWAT	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
213	N-JEHLUM	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
34	LHR-SOUTH-CS	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00
500 kV busbars in the parallel AC lines									
70	DADU	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
75	MORO	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
62	SHKPR500	1.06	1.06	1.07	1.07	1.07	1.07	1.07	1.07
60	GUDDU	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
58	R.Y.KHAN	1.04	1.06	1.06	1.06	1.06	1.06	1.06	1.06
54	D.G.KHAN	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
63	GUDDU-NEW	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
53	M.GARH	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
50	MULTAN	1.03	1.03	1.03	1.04	1.03	1.03	1.03	1.03
42	HB.SHAH	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
545	ROUSCH	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
41	FBD-WEST	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02

Table 7.1.9 Emergency loading percentage on main 500 kV circuits - Scenario 1

From Bus	To bus	Nc	Emergency loading percentage [%]

					Case 9	Case 10	Case 11	Case 12	Case 13	Case 14	Case 15	Case 16
80	JAMSHORO	95	MATIARI-CS	1	25.15	24.68	24.86	24.85	24.85	24.85	24.85	24.85
80	JAMSHORO	95	MATIARI-CS	3	7.91	7.76	7.82	7.81	7.81	7.81	7.81	7.81
80	JAMSHORO	70	DADU	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	MATIARI-CS	70	DADU	1	45.88	46.89	46.56	46.58	46.56	46.56	46.56	46.57
95	MATIARI-CS	75	MORO	1	38.45	39.48	39.15	39.17	39.15	39.14	39.15	39.16
75	MORO	70	DADU	1	32.77	31.31	31.95	31.95	31.93	31.92	31.92	31.92
70	DADU	62	SHKPR500	1	3.07	3.28	1.11	1.24	1.12	1.11	1.14	1.18
70	DADU	62	SHKPR500	2	18.06	21.69	20.28	20.32	20.30	20.31	20.32	20.33
75	MORO	58	R.Y.KHAN	1	20.27	24.21	22.67	22.71	22.69	22.71	22.71	22.73
62	SHKPR500	60	GUDDU	1	43.34	31.94	36.35	36.28	36.26	36.20	36.20	36.19
62	SHKPR500	60	GUDDU	2	14.62	18.43	17.13	17.17	17.15	17.15	17.16	17.17
60	GUDDU	54	D.G.KHAN	1	15.75	19.86	18.46	18.51	18.48	18.48	18.49	18.51
60	GUDDU	53	M.GARH	1	38.35	41.74	35.29	35.57	35.35	35.36	35.42	35.52
60	GUDDU	63	GUDDU-NEW	1	34.92	39.10	31.34	31.63	31.46	31.50	31.54	31.63
54	D.G.KHAN	53	M.GARH	1	12.25	8.39	6.82	7.32	6.21	5.82	6.06	6.43
63	GUDDU-NEW	53	M.GARH	1	8.63	11.85	6.52	6.37	6.91	7.14	7.00	6.83
53	M.GARH	50	MULTAN	1	37.11	41.44	33.04	33.37	33.17	33.20	33.25	33.35
53	M.GARH	50	MULTAN	2	11.16	16.03	0.00	5.85	10.58	10.60	9.19	6.94
53	M.GARH	42	HB.SHAH	1	11.41	16.44	12.54	6.01	10.80	10.79	9.34	7.02
50	MULTAN	35	SAHIWAL	1	1.03	2.30	1.17	1.84	3.01	2.39	1.30	1.40
50	MULTAN	545	ROUSCH	1	23.20	22.09	23.41	0.00	46.71	19.42	22.67	25.93
35	SAHIWAL	36	SAHIWAL-PP	1	20.20	20.98	20.14	15.11	27.06	0.00	20.82	28.01
36	SAHIWAL-PP	32	LAHORE-S	2	27.31	27.43	27.33	31.84	0.00	28.99	27.48	26.51
42	HB.SHAH	41	FBD-WEST	1	28.03	28.15	28.05	32.68	0.00	29.75	28.21	27.20
545	ROUSCH	40	GATTI	1	7.70	7.86	7.70	9.44	5.00	5.20	8.14	9.55
40	GATTI	46	BHIKKI-CCPP	1	12.81	11.96	13.00	16.72	10.95	28.39	12.32	0.00
46	BHIKKI-CCPP	30	LAHORE	1	23.85	23.78	23.85	21.38	36.23	22.05	23.67	24.25

7.1.3 逆变侧故障

Contingencies on the inverter side

Table 7.1.10 Contingencies on LAHORE – Scenario 1

CASES	CONTINGENCIES
Case 1	"CONTINGENCY_01 - TL 500 kV LAHORE - LHR SOUTH CS "
Case 2	"CONTINGENCY_02 - TL 500 kV LAHORE-S - LHR SOUTH CS "
Case 3	"CONTINGENCY_03 - TL 500 kV LAHORE-N - LHR SOUTH CS "

Table 7.1.11 Voltages in the 500 kV bus station – Scenario 1

Bus		Case 1	Case 2	Case 3
Number	Name			
500 kV busbars in the southern region				
80	JAMSHORO	1.02	1.02	1.02
85	ENGRO THAR	1.06	1.06	1.06
86	SSRL	1.06	1.06	1.06
87	PORT QASIM	1.04	1.04	1.04
90	HUB	1.05	1.05	1.05
91	NK1	1.04	1.04	1.04
92	HUBCO CFPP	1.04	1.04	1.04
95	MATIARI	1.02	1.02	1.02
Three busbars away from Lahore				
30	LAHORE	0.99	0.99	0.99
32	LAHORE-S	0.99	0.99	0.99
28	LAHORE-N	1.00	1.00	1.00
24	GUIJRNWLA	1.01	1.01	1.01
46	BHIKKI-CCPP	1.01	1.01	1.01
36	SAHIWAL-PP	0.99	0.99	0.99
40	GATTI	1.02	1.02	1.02
35	SAHIWAL	0.99	0.99	0.99
22	REWAT	1.04	1.04	1.04
213	N-JEHLUM	1.06	1.06	1.06
34	LHR-SOUTH-CS	1.00	1.00	1.00
500 kV busbars in the parallel AC lines				
70	DADU	1.04	1.04	1.04
75	MORO	1.04	1.04	1.04
62	SHKPR500	1.07	1.07	1.07
60	GUDDU	1.06	1.06	1.06
58	R.Y.KHAN	1.06	1.06	1.06
54	D.G.KHAN	1.05	1.05	1.05
63	GUDDU-NEW	1.06	1.06	1.06
53	M.GARH	1.04	1.04	1.04
50	MULTAN	1.03	1.03	1.03
42	HB.SHAH	1.04	1.04	1.04
545	ROUSCH	1.04	1.04	1.04
41	FBD-WEST	1.02	1.02	1.02

Table 7.1.12 Emergency loading percentage on main 500 kV circuits - Scenario 1

From Bus		To Bus		Nc	Emergency loading percentage (%)		
					Case 1	Case 2	Case 3
80	JAMSHORO	95	MATIARI-CS	1	24.85	24.8[illegible]	24.85

80	JAMSHORO	95	MATIARI-CS	3	7.81	7.81	7.81
80	JAMSHORO	70	DADU	2	46.57	46.57	46.57
95	MATIARI-CS	70	DADU	1	39.16	39.16	39.16
95	MATIARI-CS	75	MORO	1	31.93	31.93	31.93
75	MORO	70	DADU	1	1.17	1.17	1.17
70	DADU	62	SHKPR500	1	20.32	20.32	20.32
70	DADU	62	SHKPR500	2	22.72	22.71	22.72
75	MORO	58	R.Y.KHAN	1	36.21	36.22	36.21
62	SHKPR500	60	GUDDU	1	17.17	17.16	17.17
62	SHKPR500	60	GUDDU	2	18.50	18.50	18.50
60	GUDDU	54	D.G.KHAN	1	35.47	35.46	35.47
60	GUDDU	53	M.GARH	1	31.59	31.58	31.59
60	GUDDU	63	GUDDU-NEW	1	6.40	6.40	6.40
54	D.G.KHAN	53	M.GARH	1	6.85	6.84	6.85
63	GUDDU-NEW	53	M.GARH	1	33.31	33.29	33.30
53	M.GARH	50	MULTAN	1	7.88	8.12	7.93
53	M.GARH	50	MULTAN	2	8.01	8.26	8.06
53	M.GARH	42	HB.SHAH	1	0.44	0.05	0.25
50	MULTAN	35	SAHIWAL	1	23.12	25.12	23.73
50	MULTAN	545	ROUSCH	1	19.32	20.28	19.72
35	SAHIWAL	36	SAHIWAL-PP	1	28.45	25.76	27.65
36	SAHIWAL-PP	32	LAHORE-S	2	29.19	26.44	28.37
42	HB.SHAH	41	FBD-WEST	1	7.86	7.41	7.67
545	ROUSCH	40	GATTI	1	13.62	12.94	13.32
40	GATTI	46	BHIKKI-CCPP	1	22.18	25.14	24.49
46	BHIKKI-CCPP	30	LAHORE	1	19.38	19.89	19.88

7.1.4 直流线路故障

DC links Contingencies

Table 7.1.13 Voltages in the 500 kV bus station – Scenario 1

Bus		N-1	N-2
Number	Name		
80	JAMSHORO	1.02	1.05
85	ENGRO THAR	1.05	1.07
86	SSRL	1.05	1.07
87	PORT QASIM	1.04	1.06
90	HUB	1.04	1.06
91	NKI	1.04	1.05
92	HUBCO CFPP	1.04	1.06

Bus		N-1	N-2
Number	Name		
95	MATIARI	1.02	1.06
30	LAHORE	1.03	1.03
32	LAHORE-S	1.03	1.03
28	LAHORE-N	1.03	1.04
24	GUIJRNWLA	1.03	1.04
46	BHIKKI-CCPP	1.03	1.04
36	SAHIWAL-PP	1.01	1.03
40	GATTI	1.02	1.05
35	SAHIWAL	1.01	1.02
22	REWAT	1.05	1.05
213	N-JEHLUM	1.07	1.08
34	LHR-SOUTH-CS	1.04	1.04
70	DADU	0.99	1.05
75	MORO	0.99	1.05
62	SHKPR500	1.01	1.06
60	GUDDU	1.01	1.06
58	R.Y.KHAN	1.00	1.05
54	D.G.KHAN	1.01	1.05
63	GUDDU-NEW	1.01	1.06
53	M.GARH	1.01	1.04
50	MULTAN	1.01	1.04
42	HB.SHAH	1.03	1.06
545	ROUSCH	1.03	1.05
41	FBD-WEST	1.02	1.05

Table 7.1.14 Emergency loading percentage on main 500 kV circuits - Scenario 1

From Bus		To bus		Nc	Emergency loading percentage [%]	
					N-1	N-2
80	JAMSHORO	95	MATIARI-CS	1	1.4	14.12
80	JAMSHORO	95	MATIARI-CS	3	0.99	4.9
80	JAMSHORO	70	DADU	2	104.68	72.39
95	MATIARI-CS	70	DADU	1	95.56	68.19
95	MATIARI-CS	75	MORO	1	78.99	56.25
75	MORO	70	DADU	1	1.41	0.74
70	DADU	62	SHKPR500	1	62.06	40.03
70	DADU	62	SHKPR500	2	68.47	44.24
75	MORO	58	R.Y.KHAN	1	92.26	[illegible]
62	SHKPR500	60	GUDDU	1	55.95	38.23
62	SHKPR500	60	GUDDU	2	60.4	41.23

From Bus		To bus		Nc	Emergency loading percentage [%]	
					N-1	N-2
60	GUDDU	54	D.G.KHAN	1	66.6	54.32
60	GUDDU	53	M.GARH	1	69.08	54.48
60	GUDDU	63	GUDDU-NEW	1	28.12	17.98
54	D.G.KHAN	53	M.GARH	1	36.18	24.39
63	GUDDU-NEW	53	M.GARH	1	72.3	57.13
53	M.GARH	50	MULTAN	1	33.98	25.79
53	M.GARH	50	MULTAN	2	35.1	26.62
53	M.GARH	42	HB.SHAH	1	21.77	14.13
50	MULTAN	35	SAHIWAL	1	69.5	59.22
50	MULTAN	545	ROUSCH	1	22.45	12.77
35	SAHIWAL	36	SAHIWAL-PP	1	12.63	5.09
36	SAHIWAL-PP	32	LAHORE-S	2	12.96	5.22
42	HB.SHAH	41	FBD-WEST	1	22.42	17.38
545	ROUSCH	40	GATTI	1	35.67	27.71
40	GATTI	46	BHIKKI-CCPP	1	12.17	14.22
46	BHIKKI-CCPP	30	LAHORE	1	26.56	33.43

7.2 方式 2 Scenario 2

7.2.1 整流侧故障 Contingencies on the rectifier side

Table7.2.1. Contingencies on MATIARI – Scenario 2

CASES	CONTINGENCIES
Case 1	"Scenario 1"
Case 2	"CONTINGENCY_01 - TL 500 kV MORO - MATIARI "
Case 3	"CONTINGENCY_03 - TL 500 kV JAMSHORO - MATIARI "
Case 4	"CONTINGENCY_04 - TL 500 kV PORT QASIM - MATIARI "
Case 5	"CONTINGENCY_05 - TL 500 kV HUBCO CFPP - MATIARI "
Case 6	"CONTINGENCY_06 - TL 500 kV SSRL - MATIARI "
Case 7	"CONTINGENCY_07 - TL 500 kV ENGRO THAR - MATIARI "

Table7.2.2. Voltages in the 500 kV bus station – Scenario 2

Bus		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Number	Name							
500 kV busbars in the southern region								
80	JAMSHORO	1.02	1.02	1.04	1.02	1.02	1.01	1.01
85	ENGRO THAR	1.06	1.06	1.05	1.06	1.06	1.05	1.06

Bus		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Number	Name							
86	SSRL	1.06	1.06	1.06	1.06	1.06	1.06	1.06
87	PORT QASIM	1.04	1.04	1.04	1.04	1.04	1.04	1.04
90	HUB	1.05	1.05	1.05	1.05	1.05	1.05	1.05
91	NKI	1.04	1.04	1.04	1.04	1.04	1.04	1.04
92	HUBCO CFPP	1.05	1.05	1.05	1.05	1.05	1.05	1.05
95	MATIARI	1.01	1.01	1.00	1.01	1.01	1.00	1.00
Three busbars away from Lahore								
30	LAHORE	1.00	1.00	1.00	1.00	1.00	1.00	1.00
32	LAHORE-S	1.01	1.01	1.01	1.01	1.01	1.01	1.01
24	GUIJRNWLA	1.02	1.02	1.02	1.02	1.02	1.02	1.02
46	BHIKKI-CCPP	1.02	1.02	1.02	1.02	1.02	1.02	1.02
36	SAHIWAL-PP	1.00	1.00	1.00	1.00	1.00	1.00	1.00
40	GATTI	1.02	1.02	1.02	1.02	1.02	1.02	1.02
35	SAHIWAL	1.00	1.00	1.00	1.00	1.00	1.00	1.00
22	REWAT	1.04	1.04	1.04	1.04	1.04	1.04	1.04
213	N-JEHLUM	1.06	1.06	1.06	1.06	1.06	1.06	1.06
34	LHR-SOUTH-CS	1.01	1.01	1.01	1.01	1.01	1.01	1.01
500 kV busbars in the parallel AC lines								
70	DADU	1.03	1.03	1.04	1.03	1.03	1.03	1.03
75	MORO	1.03	1.04	1.03	1.03	1.03	1.03	1.03
62	SHKPR500	1.06	1.06	1.07	1.06	1.06	1.06	1.06
60	GUDDU	1.06	1.06	1.07	1.06	1.06	1.06	1.06
58	R.Y.KHAN	1.06	1.06	1.06	1.06	1.06	1.06	1.06
54	D.G.KHAN	1.06	1.06	1.06	1.06	1.06	1.06	1.06
63	GUDDU-NEW	1.07	1.07	1.07	1.07	1.07	1.07	1.07
53	M.GARH	1.05	1.05	1.05	1.05	1.05	1.05	1.05
50	MULTAN	1.04	1.04	1.04	1.04	1.04	1.04	1.04
42	HB.SHAH	1.05	1.05	1.05	1.05	1.05	1.05	1.05
545	ROUSCH	1.05	1.05	1.05	1.05	1.05	1.05	1.05
41	FBD-WEST	1.03	1.03	1.03	1.03	1.03	1.03	1.03

Table7.2.3. Emergency loading percentage on main 500 kV circuits - Scenario 2

From Bus		To bus		Nc	Emergency loading percentage [%]						
					Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
80	JAMSHORO	95	MATIARI-CS	1	26.77	50.05	0.00	29.60	29.97	32.76	32.60
80	JAMSHORO	70	DADU	1	58.20	82.22	48.07	58.10	58.07	57.79	57.84
80	JAMSHORO	70	DADU	2	61.92	87.41	51.11	61.83	61.79	61.51	61.56
75	MORO	70	DADU	1	49.11	0.00	67.85	49.09	49.07	48.89	48.93
70	DADU	62	SHKPR500	1	1.02	28.94	11.87	1.20	1.23	1.40	1.39

From Bus		To bus		Nc	Emergency loading percentage [%]						
					Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
70	DADU	62	SHKPR500	2	34.51	35.58	33.30	34.49	34.47	34.32	34.35
75	MORO	58	R.Y.KHAN	1	38.28	39.45	36.92	38.26	38.24	38.07	38.11
62	SHKPR500	60	GUDDU	1	58.04	52.61	59.37	57.94	57.90	57.63	57.68
62	SHKPR500	60	GUDDU	2	33.67	34.73	32.85	33.56	33.53	33.30	33.33
60	GUDDU	54	D.G.KHAN	1	36.33	37.47	35.44	36.21	36.18	35.93	35.97
60	GUDDU	53	M.GARH	1	48.34	48.29	48.24	48.20	48.17	47.93	47.96
60	GUDDU	63	GUDDU-NEW	1	48.58	48.54	48.46	48.41	48.37	48.09	48.12
54	D.G.KHAN	53	M.GARH	1	18.57	20.85	16.88	18.46	18.43	18.25	18.27
63	GUDDU-NEW	53	M.GARH	1	22.60	22.61	22.52	22.45	22.42	22.18	22.21
53	M.GARH	50	MULTAN	1	50.90	50.80	50.79	50.72	50.68	50.39	50.43
53	M.GARH	50	MULTAN	2	21.65	21.84	21.55	21.62	21.62	21.58	21.58
53	M.GARH	42	HB.SHAH	1	22.28	22.49	22.18	22.26	22.25	22.21	22.22
50	MULTAN	35	SAHIWAL	1	12.03	12.06	12.01	12.02	12.02	11.99	12.00
50	MULTAN	545	ROUSCH	1	42.83	42.78	42.84	42.80	42.79	42.74	42.75
35	SAHIWAL	36	SAHIWAL-PP	1	9.26	9.06	9.25	9.27	9.27	9.28	9.28
36	SAHIWAL-PP	32	LAHORE-S	2	18.88	18.89	18.88	18.88	18.88	18.89	18.89
42	HB.SHAH	41	FBD-WEST	1	19.38	19.38	19.38	19.38	19.38	19.38	19.38
545	ROUSCH	40	GATTI	1	16.21	16.20	16.21	16.20	16.20	16.18	16.18
40	GATTI	46	BHIKKI-CCPP	1	26.72	26.67	26.73	26.70	26.70	26.67	26.67
46	BHIKKI-CCPP	30	LAHORE	1	12.52	12.52	12.52	12.52	12.52	12.53	12.53

7.2.1 并联交流线路故障 Contingencies on Parallel AC lines

Table7.2.4. Contingencies on Parallel AC Lines – Scenario 2

CASES	CONTINGENCIES
Case 1	"CONTINGENCY_01 - TL 500 kV MORO -R.Y.KHAN "
Case 2	"CONTINGENCY_02 - TL 500 kV DADU-SHKPR"
Case 3	"CONTINGENCY_03 - TL 500 kV SHKPR-GUDDU"
Case 4	"CONTINGENCY_04 - TL 500 kV D.G.KHAN-GUDDU "
Case 5	"CONTINGENCY_05 - TL 500 kV M.GARH-GUDDU "
Case 6	"CONTINGENCY_06 - TL 500 kV GUDDU-GUDDU-NEW"
Case 7	"CONTINGENCY_07 - TL 500 kV D.G.KHAN- M.GARH"
Case 8	"CONTINGENCY_08 - TL 500 kV GUDDU-NEW-M.GARH

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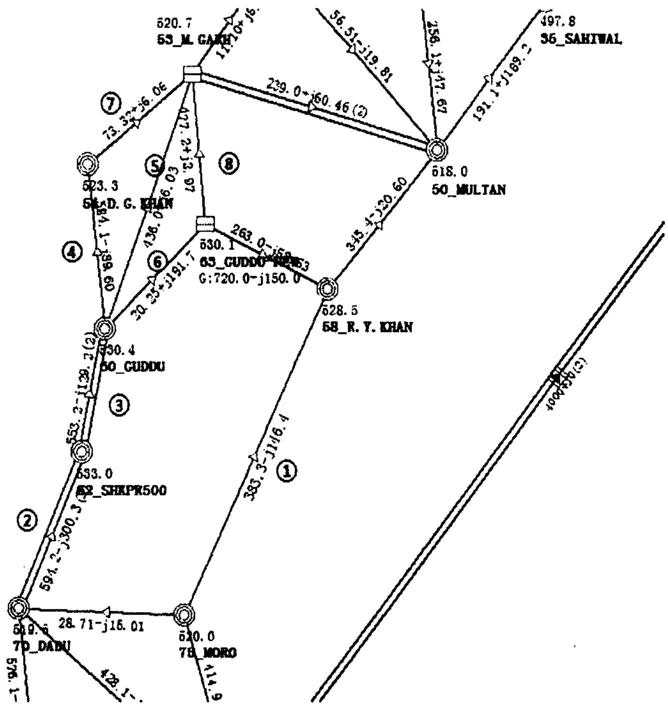

Figure 3 Parallel AC Lines N-1 Contingencies 1-8

Table7.2.5. Voltages in the 500 kV bus station – Scenario 2

Bus		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
Number	Name								
500 kV busbars in the southern region									
80	JAMSHORO	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
85	ENGRO THAR	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
86	SSRL	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
87	PORT QASIM	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
90	HUB	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
91	NKI	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
92	HUBCO CFPP	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
95	MATIARI	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Three busbars away from Lahore									
30	LAHORE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
32	LAHORE-S	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
24	GUIJRNWLA	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
46	BHIKKI-CCPP	1.02	1.02	1.02	1.01	1.01	1.02	1.01	1.01
36	SAHIWAL-PP	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
40	GATTI	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
35	SAHIWAL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
22	REWAT	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
213	N-JEHLUM	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06

Bus		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
Number	Name								
34	LHR-SOUTH-CS	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
500 kV busbars in the parallel AC lines									
70	DADU	1.02	1.02	1.03	1.03	1.03	1.03	1.03	1.03
75	MORO	1.01	1.02	1.03	1.03	1.03	1.03	1.03	1.03
62	SHKPR500	1.05	1.06	1.06	1.06	1.06	1.06	1.06	1.06
60	GUDDU	1.06	1.06	1.06	1.06	1.06	1.06	1.07	1.06
58	R.Y.KHAN	1.06	1.05	1.06	1.05	1.05	1.06	1.06	1.05
54	D.G.KHAN	1.05	1.06	1.06	1.04	1.05	1.05	1.08	1.05
63	GUDDU-NEW	1.06	1.06	1.07	1.06	1.06	1.07	1.07	1.06
53	M.GARH	1.04	1.05	1.05	1.04	1.04	1.04	1.04	1.04
50	MULTAN	1.04	1.04	1.04	1.03	1.04	1.04	1.04	1.04
42	HB.SHAH	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
545	ROUSCH	1.05	1.05	1.05	1.04	1.04	1.05	1.05	1.04
41	FBD-WEST	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03

Table7.2.6. Emergency loading percentage on main 500 kV circuits - Scenario 2

From Bus		To bus		Nc	Emergency loading percentage [%]							
					Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
80	JAMSHORO	95	MATIARI-CS	1	27.23	24.29	26.01	26.33	26.41	26.16	26.73	26.40
80	JAMSHORO	70	DADU	1	61.51	56.90	57.59	57.96	57.97	57.60	58.12	57.98
80	JAMSHORO	70	DADU	2	65.36	60.49	61.27	61.66	61.68	61.29	61.84	61.69
95	MATIARI-CS	75	MORO	1	40.47	49.98	49.86	49.23	49.30	50.08	49.27	49.25
75	MORO	70	DADU	1	26.20	5.49	3.78	2.02	2.11	4.38	1.60	2.02
70	DADU	62	SHKPR500	1	52.49	0.00	31.85	33.61	33.66	31.87	34.22	33.73
70	DADU	62	SHKPR500	2	58.01	60.88	35.34	37.28	37.34	35.37	37.96	37.41
75	MORO	58	R.Y.KHAN	1	0.00	68.76	64.79	59.95	60.21	65.95	59.26	59.94
62	SHKPR500	60	GUDDU	1	50.03	30.21	0.00	32.03	32.50	31.04	33.76	32.53
62	SHKPR500	60	GUDDU	2	54.01	32.60	58.28	34.56	35.06	33.48	36.42	35.09
60	GUDDU	54	D.G.KHAN	1	50.82	47.70	47.59	0.00	63.16	55.05	30.99	64.62
60	GUDDU	53	M.GARH	1	51.71	47.83	47.92	66.04	0.00	56.48	56.67	68.01
60	GUDDU	63	GUDDU-NEW	1	47.13	12.71	14.63	38.85	39.07	0.00	26.84	16.59
54	D.G.KHAN	53	M.GARH	1	25.27	22.03	22.52	17.71	36.82	28.56	0.00	38.28
63	GUDDU-NEW	53	M.GARH	1	53.51	50.25	50.29	68.81	69.05	40.79	59.19	0.00
53	M.GARH	50	MULTAN	1	24.72	21.08	21.29	18.03	17.63	23.06	19.30	16.96
53	M.GARH	50	MULTAN	2	25.48	21.70	21.91	18.58	18.15	23.75	19.87	17.47
53	M.GARH	42	HB.SHAH	1	12.79	11.91	11.95	11.75	11.38	12.40	11.59	11.33
50	MULTAN	35	SAHIWAL	1	42.43	42.82	42.83	42.85	42.83	42.65	42.64	42.81
50	MULTAN	545	ROUSCH	1	9.53	9.39	9.30	10.46	10.10	9.43	9.75	10.28
35	SAHIWAL	36	SAHIWAL-PP	1	18.95	18.88	18.88	18.87	18.86	18.92	18.88	18.85

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From Bus		To bus		Nc	Emergency loading percentage[%]							
					Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
36	SAHIWAL-PP	32	LAHORE-S	2	19.45	19.38	19.38	19.36	19.35	19.41	19.38	19.35
42	HB.SHAH	41	FBD-WEST	1	16.30	16.19	16.20	16.15	16.08	16.26	16.07	16.06
545	ROUSCH	40	GATTI	1	26.39	26.71	26.72	26.69	26.72	26.56	26.62	26.72
40	GATTI	46	BHIKKI-CCPP	1	12.48	12.52	12.53	12.51	12.55	12.50	12.56	12.55
46	BHIKKI-CCPP	30	LAHORE	1	16.67	16.67	16.68	16.58	16.60	16.67	16.63	16.58

Table7.2.7. Contingencies on Parallel AC Lines – Scenario 2

CASES	CONTINGENCIES
Case 9	"CONTINGENCY_09 - TL 500 kV R.Y.KHAN –GUDDU-NEW"
Case 10	"CONTINGENCY_10 - TL 500 kV R.Y.KHAN -MULTAN"
Case 11	"CONTINGENCY_11 - TL 500 kV M.GARH-MULTAN"
Case 12	"CONTINGENCY_12 - TL 500 kV MULTAN-SAHIWAL "
Case 13	"CONTINGENCY_13 - TL 500 kV SAHIWAL-SAHIWAL-PP "
Case 14	"CONTINGENCY_14 - TL 500 kV MULTAN-ROUSCH"
Case 15	"CONTINGENCY_15 - TL 500 kV MULTAN-HB.SHAH-CCPP"
Case 16	"CONTINGENCY_16 - TL 500 kV ROUSCH-GATTI"

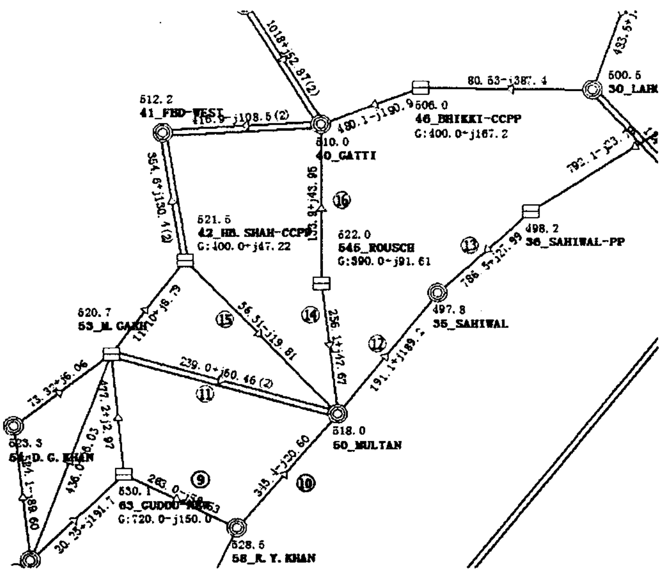

Figure 4 Parallel AC Lines N-1 Contingencies 9-16

Table7.2.8. Voltages in the 500 kV bus station – Scenario 2

Bus		Case 9	Case 10	Case 11	Case 12	Case 13	Case 14	Case 15	Case 16
Number	Name								
500 kV busbars in the southern region									
80	JAMSHORO	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
85	ENGRO THAR	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06

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Bus Number	Bus Name	Case 9	Case 10	Case 11	Case 12	Case 13	Case 14	Case 15	Case 16
86	SSRL	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
87	PORT QASIM	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
90	HUB	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
91	NKI	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
92	HUBCO CFPP	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
95	MATIARI	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Three busbars away from Lahore									
30	LAHORE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
32	LAHORE-S	1.01	1.01	1.01	1.00	1.01	1.01	1.01	1.00
28	LAHORE-N	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
24	GUIJRNWLA	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
46	BHIKKI-CCPP	1.01	1.01	1.02	1.01	1.01	1.01	1.01	1.01
36	SAHIWAL-PP	1.00	1.00	1.00	0.98	1.01	1.00	1.00	1.00
40	GATTI	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.01
35	SAHIWAL	1.00	1.00	1.00	0.98	1.00	1.00	1.00	1.00
22	REWAT	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
213	N-JEHLUM	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
34	LHR-SOUTH-CS	1.01	1.01	1.01	1.00	1.01	1.01	1.01	1.00
500 kV busbars in the parallel AC lines									
70	DADU	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
75	MORO	1.02	1.03	1.03	1.03	1.03	1.03	1.03	1.03
62	SHKPR500	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
60	GUDDU	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
58	R.Y.KHAN	1.03	1.06	1.06	1.06	1.06	1.06	1.06	1.06
54	D.G.KHAN	1.05	1.05	1.06	1.06	1.06	1.05	1.06	1.06
63	GUDDU-NEW	1.07	1.06	1.07	1.07	1.07	1.06	1.07	1.07
53	M.GARH	1.04	1.04	1.05	1.05	1.04	1.04	1.04	1.04
50	MULTAN	1.04	1.03	1.04	1.04	1.04	1.04	1.04	1.04
42	HB.SHAH	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
545	ROUSCH	1.05	1.04	1.05	1.05	1.05	1.05	1.05	1.05
41	FBD-WEST	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.02

Table7.2.9. Emergency loading percentage on main 500 kV circuits - Scenario 2

From Bus		To bus		Nc	Emergency loading percentage [%]							
					Case 9	Case 10	Case 11	Case 12	Case 13	Case 14	Case 15	Case 16
80	JAMSHORO	95	MATIARI-CS	1	26.12	26.76	26.75	26.79	26.74	26.69	26.73	26.74
80	JAMSHORO	70	DADU	1	57.53	58.67	58.17	58.20	58.18	58.18	58.19	58.19
80	JAMSHORO	70	DADU	2	61.20	62.41	61.90	61.93	61.91	61.90	61.92	61.92
95	MATIARI-CS	75	MORO	1	49.98	47.90	49.16	49.11	49.10	49.07	49.08	49.08

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From Bus		To bus		Nc	Emergency loading percentage [%]							
					Case 9	Case 10	Case 11	Case 12	Case 13	Case 14	Case 15	Case 16
75	MORO	70	DADU	1	6.08	3.65	1.17	0.93	1.06	1.08	1.04	1.01
70	DADU	62	SHKPR500	1	31.98	36.99	34.40	34.54	34.50	34.51	34.53	34.54
70	DADU	62	SHKPR500	2	35.52	40.98	38.15	38.30	38.26	38.27	38.29	38.30
75	MORO	58	R.Y.KHAN	1	66.50	49.77	58.42	57.98	58.05	57.95	57.93	57.91
62	SHKPR500	60	GUDDU	1	31.00	35.77	33.57	33.69	33.65	33.66	33.68	33.69
62	SHKPR500	60	GUDDU	2	33.45	38.60	36.22	36.35	36.31	36.32	36.34	36.35
60	GUDDU	54	D.G.KHAN	1	51.93	59.60	47.82	48.53	48.28	48.38	48.44	48.50
60	GUDDU	53	M.GARH	1	52.81	61.99	47.89	48.70	48.52	48.65	48.71	48.74
60	GUDDU	63	GUDDU-NEW	1	9.86	6.98	19.08	18.08	18.58	18.36	18.36	18.31
54	D.G.KHAN	53	M.GARH	1	25.88	33.28	21.89	22.42	22.60	22.74	22.75	22.70
63	GUDDU-NEW	53	M.GARH	1	55.67	65.45	50.15	51.04	50.83	50.97	51.04	51.08
53	M.GARH	50	MULTAN	1	25.77	35.80	0.00	17.34	23.42	22.00	20.11	18.61
53	M.GARH	50	MULTAN	2	26.54	36.91	34.91	17.86	24.11	22.62	20.68	19.13
53	M.GARH	42	HB.SHAH	1	13.04	15.43	14.71	15.77	9.76	11.95	14.47	15.63
50	MULTAN	35	SAHIWAL	1	42.36	41.03	41.74	0.00	61.17	42.13	43.92	50.93
50	MULTAN	545	ROUSCH	1	9.86	10.71	9.39	10.55	11.44	0.00	9.78	27.82
35	SAHIWAL	36	SAHIWAL-PP	1	18.98	19.20	19.10	28.75	0.00	19.06	18.55	16.60
36	SAHIWAL-PP	32	LAHORE-S	2	19.48	19.71	19.60	29.50	0.00	19.56	19.04	17.04
42	HB.SHAH	41	FBD-WEST	1	16.39	16.67	16.61	20.83	13.69	16.01	15.31	20.59
545	ROUSCH	40	GATTI	1	26.28	25.19	25.79	36.19	21.57	28.08	27.86	0.00
40	GATTI	46	BHIKKI-CCPP	1	12.44	12.30	12.36	5.53	21.52	12.38	12.85	14.75
46	BHIKKI-CCPP	30	LAHORE	1	16.65	16.63	16.72	20.48	16.71	16.77	16.56	14.90

7.2.3 逆变侧故障 Contingencies on the inverter side

Table7.2.10. Contingencies on LAHORE – Scenario 1

CASES	CONTINGENCIES
Case 1	"CONTINGENCY_01 - TL 500 kV LAHORE - LHR SOUTH CS "
Case 2	"CONTINGENCY_02 - TL 500 kV LAHORE-S - LHR SOUTH CS "

Table7.2.11. Voltages in the 500 kV bus station – Scenario 1

Bus		Case 1	Case 2
Number	Name		
500 kV busbars in the southern region			
80	JAMSHORO	1.02	1.03
85	ENGRO THAR	1.06	1.06
86	SSRL	1.06	1.06

Bus		Case 1	Case 2
Number	Name		
87	PORT QASIM	1.04	1.04
90	HUB	1.05	1.05
91	NKI	1.04	1.04
92	HUBCO CFPP	1.05	1.05
95	MATIARI	1.01	1.01
Three busbars away from Lahore			
30	LAHORE	1.00	1.00
32	LAHORE-S	1.01	1.00
24	GUIJRNWLA	1.02	1.02
46	BHIKKI-CCPP	1.01	1.01
36	SAHIWAL-PP	1.00	1.00
40	GATTI	1.02	1.02
35	SAHIWAL	1.00	1.00
22	REWAT	1.04	1.04
213	N-JEHLUM	1.06	1.06
34	LHR-SOUTH-CS	1.01	1.00
500 kV busbars in the parallel AC lines			
70	DADU	1.03	1.03
75	MORO	1.03	1.03
62	SHKPR500	1.06	1.06
60	GUDDU	1.06	1.06
58	R.Y.KHAN	1.06	1.06
54	D.G.KHAN	1.06	1.06
63	GUDDU-NEW	1.07	1.07
53	M.GARH	1.05	1.05
50	MULTAN	1.04	1.04
42	HB.SHAH	1.05	1.05
545	ROUSCH	1.05	1.05
41	FBD-WEST	1.03	1.03

Table7.2.12. Emergency loading percentage on main 500 kV circuits - Scenario 1

From Bus		To Bus		Nc	Emergency loading percentage [%]	
					Case 1	Case 3
80	JAMSHORO	95	MATIARI-CS	1	26.77	26.76
80	JAMSHORO	70	DADU	1	58.20	58.19
80	JAMSHORO	70	DADU	2	61.92	61.92
95	MATIARI-CS	75	MORO	1	49.11	49.1[illegible]
75	MORO	70	DADU	1	1.02	1.03

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70	DADU	62	SHKPR500	1	34.52	34.51
70	DADU	62	SHKPR500	2	38.28	38.28
75	MORO	58	R.Y.KHAN	1	58.03	58.03
62	SHKPR500	60	GUDDU	1	33.67	33.67
62	SHKPR500	60	GUDDU	2	36.33	36.33
60	GUDDU	54	D.G.KHAN	1	48.34	48.34
60	GUDDU	53	M.GARH	1	48.59	48.58
60	GUDDU	63	GUDDU-NEW	1	18.56	18.55
54	D.G.KHAN	53	M.GARH	1	22.61	22.62
63	GUDDU-NEW	53	M.GARH	1	50.91	50.90
53	M.GARH	50	MULTAN	1	21.51	21.79
53	M.GARH	50	MULTAN	2	22.14	22.42
53	M.GARH	42	HB.SHAH	1	12.34	11.89
50	MULTAN	35	SAHIWAL	1	41.00	44.32
50	MULTAN	545	ROUSCH	1	9.14	9.04
35	SAHIWAL	36	SAHIWAL-PP	1	20.60	17.81
36	SAHIWAL-PP	32	LAHORE-S	2	21.15	18.28
42	HB.SHAH	41	FBD-WEST	1	16.55	16.09
545	ROUSCH	40	GATTI	1	27.41	26.44
40	GATTI	46	BHIKKI-CCPP	1	10.63	14.17
46	BHIKKI-CCPP	30	LAHORE	1	17.54	17.61

7.2.4 直流线路故障 DC links Contingencies

Table7.2.13. Voltages in the 500 kV bus station – Scenario 1

Bus		N-1	N-2
Number	Name		
80	JAMSHORO	1.01	1.03
85	ENGRO THAR	1.05	1.06
86	SSRL	1.05	1.06
87	PORT QASIM	1.04	1.04
90	HUB	1.04	1.05
91	NKI	1.03	1.04
92	HUBCO CFPP	1.04	1.05
95	MATIARI	1.01	1.04
30	LAHORE	1.03	1.02

Bus		N-1	N-2
Number	Name		
32	LAHORE-S	1.04	1.02
28	LAHORE-N	1.00	1.00
24	GUIJRNWLA	1.04	1.04
46	BHIKKI-CCPP	1.03	1.03
36	SAHIWAL-PP	1.00	1.01
40	GATTI	1.01	1.02
35	SAHIWAL	1.00	1.01
22	REWAT	1.05	1.05
213	N-JEHLUM	1.07	1.06
34	LHR-SOUTH-CS	1.04	1.02
70	DADU	0.97	1.01
75	MORO	0.97	1.01
62	SHKPR500	1.00	1.03
60	GUDDU	1.01	1.03
58	R.Y.KHAN	0.98	1.01
54	D.G.KHAN	1.00	1.02
63	GUDDU-NEW	1.01	1.03
53	M.GARH	1.00	1.01
50	MULTAN	1.00	1.01
42	HB.SHAH	1.02	1.03
545	ROUSCH	1.02	1.03
41	FBD-WEST	1.01	1.03

Table7.2.14. Emergency loading percentage on main 500 kV circuits - Scenario 1

From Bus		To bus		Nc	Emergency loading percentage [%]	
					N-1	N-2
80	JAMSHORO	95	MATIARI-CS	1	67.35	58.35
80	JAMSHORO	70	DADU	1	104.3	89.82
80	JAMSHORO	70	DADU	2	110.65	95.3
95	MATIARI-CS	75	MORO	1	92.19	80.08
75	MORO	70	DADU	1	3.78	1.82
70	DADU	62	SHKPR500	1	70.26	58.79
70	DADU	62	SHKPR500	2	77.52	64.88
75	MORO	58	R.Y.KHAN	1	105.13	93.46
62	SHKPR500	60	GUDDU	1	65.37	58.77
62	SHKPR500	60	GUDDU	2	70.57	63.43
60	GUDDU	54	D.G.KHAN	1	73.71	70.87
60	GUDDU	53	M.GARH	1	78.96	76.02
60	GUDDU	63	GUDDU-NEW	1	40.52	37.58

From Bus		To bus		Nc	Emergency loading percentage [%]	
					N-1	N-2
54	D.G.KHAN	53	M.GARH	1	47.5	45.96
63	GUDDU-NEW	53	M.GARH	1	82.52	79.45
53	M.GARH	50	MULTAN	1	42.83	42.48
53	M.GARH	50	MULTAN	2	44.22	43.84
53	M.GARH	42	HB.SHAH	1	28.96	27.81
50	MULTAN	35	SAHIWAL	1	83.95	87.34
50	MULTAN	545	ROUSCH	1	29.74	26.62
35	SAHIWAL	36	SAHIWAL-PP	1	13.3	10.97
36	SAHIWAL-PP	32	LAHORE-S	2	13.65	11.26
42	HB.SHAH	41	FBD-WEST	1	28.17	27.76
545	ROUSCH	40	GATTI	1	46.31	46.1
40	GATTI	46	BHIKKI-CCPP	1	18.61	25.68
46	BHIKKI-CCPP	30	LAHORE	1	31.66	43.5

Pak Matiari Lahore Transmission Co. (Pvt) Ltd.

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Pak Matiari Lahore Transmission Co. (Pvt) Ltd.

国家电网公司
STATE GRID
CORPORATION OF CHINA

报告编号：
Report No.:
WA00191K-SS-02B

巴基斯坦默蒂亚里—拉合尔±660kV 直流输电工程

±660kV HVDC Project from Matiari to Lahore in Pakistan

可行性研究

Feasibility Study

电力系统一次

Power System Primary Part

安全稳定专题研究报告

Security and Stability Study Report

中国电力技术装备有限公司
CHINA ELECTRIC POWER EQUIPMENT AND TECHNOLOGY CO., LTD.
中国电力科学研究院
CHINA ELECTRIC POWER RESEARCH INSTITUTE

2016 年 4 月
April 2016

工作单位：　中国电力科学研究院
Institute: China Electric Power Research Institute

工作时间：2015年3月-2016年4月
Time: March 2015 – April 2016

项目负责人：高超
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Prepared by: Gao Chao, Guo Xiaojiang, Zhang Yantao, Qin Qin, Wang Yating, Han Jiahui, Wu Junling and Zhang Yuhong

内容摘要

针对巴基斯坦默蒂亚里～拉合尔±660kV 直流工程，结合《中巴经济走廊能源规划报告》、《巴基斯坦电网发展规划（National Power System Expansion Plan）报告》中提出的直流接入系统推荐方案以及双方专家多次沟通的技术会议纪要，对巴基斯坦默蒂亚里～拉合尔直流开展安全稳定专题研究。主要针对 2018 年投产水平年电网交直流故障对系统稳定性影响以及交直流并联系统的潮流转移等问题开展计算分析，还考虑了不同运行方式下的电网安全稳定性。报告中进一步分析了 2022 远景年巴基斯坦默蒂亚里～拉合尔±660kV 直流的安全稳定情况。得出的研究结论为默蒂亚里～拉合尔±660kV 直流方案满足安全稳定导则要求，远期最大短路电流均在合理水平，同步加强的 500kV 交流网架可提高系统安全稳定性，降低直流双极闭锁故障后的措施量。报告为巴基斯坦默蒂亚里～拉合尔直流工程的规划、设计和运行提供了重要的技术参考。

关键词：接入方案；安全稳定；短路电流

ABSTRACT

China Electric Power Research Institute conducts the Security and Stability Study for Pakistan Matiari～Lahore ±660kV HVDC Project according to the recommended HVDC access scheme in "National Power System Expansion Plan of Pakistan", "China-Pakistan Economic Corridor Energy Plan" and Technical Minutes of Meeting with NTDC. The study carries out calculation and analysis on the AC/DC N-1 and N-2 contingencies for the paralleled AC/DC power system of year 2018 and 2022. The security and stability of different modes in 2018 is also carried out. The conclusion is that Matiari～Lahore ±660kV HVDC project is sufficient to satisfy the Guild on Security and Stability for Power System. When constructing parallel 500kV AC channels, system security and stability can be improved and reduce the load shedding amount for DC bipolar block fault. This study can provide a technical reference for planning, design and operation of Pakistan Matiari～Lahore HVDC project.

KEYWORDS：access scheme, security and stability, short circuit current

目 录
Contents

Pak Lahore Transmission Co. (Pvt) Ltd.

1 前言
Preface

中巴经济走廊，是指以中国新疆喀什直通巴基斯坦西南港口城市瓜达尔港的交通走廊为轴线，以能源项目及工业园区为辐射的经济地带。2013 年 5 月，在中国国务院总理李克强访问巴基斯坦期间，两国同意启动建设中巴经济走廊，旨在加强中巴互联互通，深化两国战略合作，促进两国共同发展。

China-Pakistan Economic Corridor refers to the economic zone with the traffic corridor from Kashgar in Xinjiang, China to Gwadar Port in the southwest of Pakistan as the axis and that radiates energy projects and industrial parks. During Premier Li Keqiang's visit to Pakistan in May 2013, both countries agreed to initiate the construction of China-Pakistan Economic Corridor to strengthen the connection between China and Pakistan, intensify the strategic cooperation between the two countries and promote the common development of both nations.

能源领域的合作是中巴经济走廊建设的重要内容。巴基斯坦一直面临能源短缺的问题，尤其是电力短缺已经成为巴基斯坦经济发展的掣肘，巴基斯坦政府希望能在未来三四年内解决能源短缺危机。根据 2014 年 11 月《中华人民共和国政府与巴基斯坦伊斯兰共和国政府关于中巴经济走廊能源项目合作的协议》和 2015 年 4 月中方领导人出访巴基斯坦中巴双方签署的 51 项合作协议，在中巴两国领导人见证下，国家电网公司与巴基斯坦水电部和国家输电公司签署项目合作协议，明确国家电网公司将以 BOOT（建设-拥有-经营-转让）模式开发默蒂亚里～拉合尔及默蒂亚里～费萨拉巴德两个输变电项目。根据巴方计划，优先推进默蒂亚里～拉合尔输电项目。

The cooperation in energy field is the focal part in the construction of China-Pakistan Economic Corridor. Pakistan has been facing the energy shortage problem, especially the power shortage has constrained the economic development of Pakistan, and the government of Pakistan hopes to solve the energy shortage crisis in the next 3-4 years. According to the *Agreement between the People's Republic of China and the Islamic Republic of Pakistan on Cooperation on Energy Projects in China-Pakistan Economic Corridor* in November 2014 and 51 cooperation agreements signed by and between China and Pakistan during Chinese leaders' visit to Pakistan in April 2015, State Grid of China, the Ministry of Water and Power of Pakistan and National Transmission & Despatch Company (NTDC) Limited, under the witness of leaders of both countries, signed a project cooperation agreement, in which, it is clearly stated that State Grid will develop Matiari – Lahore and Matiari – Faisalabad power transmission and transform projects with BOOT (build, own, operate, transfer) mode. According to the plan of Pakistani side, Matiari – Lahore HVDC Project is to be conducted preferentially.

旁遮普省和伊斯兰堡地区为巴基斯坦最大的负荷中心，负荷约占全国的 60%，根据电力平衡分析，2017～2020 年旁遮普省及伊斯兰堡地区逐年电力缺额在 10000MW 左右，到 2023 年电力缺额增大到 14000MW 左右。本工程的建设可将巴基斯坦南部的大规模电力送至巴基斯坦负荷中心，满足巴基斯坦特别是旁遮普省及伊斯兰堡地区电力负荷供电需要，为经济的持续快速发展提供保障。

Punjab and Islamabad Region are the two largest load centers of Pakistan, with load accounting for 60% of loads nationwide. According to the power balance analysis, the annual power shortage in Punjab and Islamabad Region will be around 10,000MW in 2017-2020, and increase to about 14,000MW in 2023. With the construction of the Project, the large volume of electric power may be transmitted from South Pakistan to the load centers, to meet the power supply requirements of Pakistan, especially Punjab and Islamabad Region, and to guarantee the continuous and fast economic development.

电力供应不足问题已严重制约了巴基斯坦经济的持续快速发展。巴基斯坦电源构成长期保持以油电、气电为主导地位的格局，发电成本高、出力不足、能源对外依存度高，严重影响电厂的发电效率，进一步加剧了网内缺电形势，电源结构亟待优化调整。为缓解巴基斯坦电力供应不足的问题，巴基斯坦将在南部塔尔煤田建设大型煤电电源，并在南部港口建设进口燃煤电站。由于项目距离负荷中心较远，本工程的建设可以满足巴基斯坦南部电力远距离送出的需要。

The shortage in power supply has materially constrained the continuous and fast economic development of Pakistan. The composition of Pakistan's power supply has maintained the pattern of oil and gas generated power as the leading role for a long time, which is high in power generation cost, inadequate in output and high in foreign-trade dependence of energy, and has materially affected the generation efficiency of power plants, further aggravated the power shortage in grid. The structure of power supply needs urgent optimization and adjustment. To mitigate the power supply shortage problem, Pakistan will build a large coal power source at Thar Coal Field in the south, and construct an imported coal fired power plant at a southern port. As the Project is far from the load centers, the construction of the Project can meet the long-distance transmission requirement of electric power from South Pakistan.

满足国民经济和社会发展的电力供应需求是本阶段巴基斯坦电力工业发展的第一要务。能源资源与负荷分布不均衡的特点，决定了巴基斯坦电力供应问题的解决需依托电网、交通等平台实现最大范围内的能源资源优化配置，建立多元化能源供应渠道，提高用电安全可靠性。因此，本工程建设是实现巴基斯坦能源资源优化配置、满足缺能地区电力供应的需要。

Meeting the power supply requirements of national economy and social development is the priority of developing Pakistan's power industry at the current stage. The unbalanced distribution of energy resources and loads has decided that the resolution of power supply shortage problem of Pakistan shall be based on platforms such as grid, traffic, etc. to realize the optimized configuration of energies in the larges range, building diversified energy supply channels and improving the security and reliability of power utilization. Therefore, the construction of the Project is the need to realize the optimized configuration of energy and meet the power shortage in energy deficient regions of Pakistan.

本报告为"巴基斯坦默蒂亚里～拉合尔±660kV 直流输电工程可行性研究（系统一次）"的第三册《安全稳定专题研究报告》。根据《巴基斯坦电网发展规划（National Power System Expansion Plan）报告》和双方多次沟通后的会议纪要中提出的直流接入系统推荐方案，对巴基斯坦默蒂亚里～拉合尔±660kV 直流开展安全稳定专题研究，主要针对交直流故障和交直流并联系统的潮流转移等问题开展计算分析，同时针对直流不同方式下的安全稳定校核结果进行对比分析，得出的研究结论可为巴基斯坦默蒂亚里～拉合尔±660kV 直流工程的规划、设计和运行提供参考。

This report is Book III Security and Stability Study Report of Pakistan Matiari-Lahore ±660kV HVDC Project Feasibility Study (Primary System). Based on the recommended DC access scheme proposed in the *National Power System Expansion Plan Report* and in the meeting minutes communicated for many times between both parties, we will conduct a special security and stability study on Pakistan Matiari - Lahore ±660kV HVDC Project to mainly calculate and analyze issues such as AC-DC fault, load flow transfer of AC-DC parallel system, etc., and compare and analyze the security and stability checking results under different DC conditions, from which, the conclusions may provide references to the planning, design and operation of Pakistan Matiari - Lahore HVDC Project.

Pak Matiari Lahore Transmission Co. (Pvt) Ltd.

2 计算边界条件
Boundary Conditions of Calculation

计算边界条件和安全稳定标准按理应遵循巴基斯坦本国的条件和标准，由于巴基斯坦电网没有关于直流的安全稳定计算要求和标准，因此经调研和双方一致协商，本次可研阶段的安全稳定计算校核参照中国的计算要求和《电力系统安全稳定导则》标准。

The boundary conditions of calculation and the security and stability standards shall follow the conditions and standards of Pakistan. However, there is not standard for the security and the stability with HVDC in Pakistan. According to the discussions and minutes of meeting, the calculation and analysis of security and stability is conducted by referring to the requirements and the *Guide on Security and Stability for Power System* of China in the feasibility stage.

2.1 计算水平年及方式
Calculation level year and mode

课题研究的水平年和方式为：工程投产水平年2018年夏大方式、2018年夏小方式和远景年2022年冬大方式。对上述方案的电气计算，条件如下：

The level year and mode studied are: level-year summer maximum-load mode (2018, when the project is operated), and long-run-year winter maximum-load (2022). For the calculation of the above modes, the conditions are as follows:

（1）计算负荷和装机
Load and Generation installation

在潮流稳定计算中，以巴方推荐的负荷和装机方案为基础，全网机组旋转备用按一台最大单机容量考虑。

The calculation of load flow and stability is based on the scheme recommended by Pakistan, and the maximum unit installed capacity is considered as the spinning reserve in the whole grid.

（2）运行方式
Operation mode

基础运行方式为2018年夏大方式，交直流并联运行输电系统的断面潮流约为5400MW。

The basic operation mode is 2018 summer maximum-load mode, the maximum power transferred from south to north is 5400MW.

2.2 计算工具
Calculation tools

采用中国电力科学研究院"PSD 电力系统软件工具包（PSD Power Tools）"作为本次研究的计算分析工具，主要包括：

The PSD Power Tools of China Electric Power Research Institute is used as the calculation and analysis tools for the study, which mainly include:

- PSD-BPA 潮流计算程序；
  PSD-BPA load flow calculation program
- PSD-BPA 暂态稳定计算程序；
  PSD-BPA transient stability calculation program
- PSD-SCCP 短路电流计算程序。
  PSD-SCCP short circuit current calculation program

2.3 计算模型及参数
Model and parameters for calculation

原始数据为巴基斯坦电力公司 2015 年 3 月提供的 PSS/E 数据，我方通过 PSS/E 转换 BPA 的程序对原数据进行转换，生成初始 BPA 格式数据文件。然后根据水平年规划图和装机负荷预测，对网架进行调整加入直流模型得出方式数据，从而对数据进行仿真分析。

巴方原始数据中，所有发电机组都直接挂在 500kV，220kV 和 132kV 变电站高压侧母线上，而且机组容量较乱，一台大容量机组替代多台机组。我方针对巴方可提供准确参数的机组，使用巴方提供的机组参数，对于巴方无法提供具体参数的机组，对应巴方数据中的机组类型和总出力，我方使用我国现有电网中的同类型机组的经典参数对初始数据进行完善，考虑励磁、调速及 PSS，替换基本原则为保持机组类型一致，容量过大机组分拆成几台容量合理的同类型机组，机组通过升压变接入母线。规划电网和发电机组按照同型号、同容量设备采用相同典型参数原则。所有 300MW 以上机组都配置 PSS。

The raw data are PSS/E data provided by NTDC in March, 2015, and we transform the raw data to the initial data file of BPA format through the PSS/E-to-BPA program. Then, the network has been adjusted according to the level-year planning chart and the estimation of installed generation and load, HVDC is added to the data thus to make a simulated analysis on the data.

In the raw data provided by the NTDC, all generator units are on the buses at the HV side of 500kV, 220kV and 132kV substations, and the capacities of generator units are confusing as multiple generator units are replaced by one large generator unit. Some generators are using the parameters which NTDC provided with detailed information. For the generators witout detailed information from NTDC, typical parameters of generator are used according to the type and total output of generator units in the PSS/E data, and make considerations to excitation, speed regulation and PSS, where the basic substitutional principles are keeping the same generator unit types, dividing the excessive large generator unit into several generator units of the same type and of reasonable capacity and connecting the generator units to bus through boosting transformers.All generators whose capacity are above 300MW are assumpted to be installed with PSS.

发电机模型：采用 Ed"、Eq"变化详细模型，并考虑励磁、PSS 和调速系统。

负荷模型：采用 50%恒功率，50%恒阻抗负荷模型。有功、无功频率因子为 1.8、-2.0。

参数：规划电网和发电机组按照同型号、同容量设备采用相同参数原则，采用典型参数。

Generator model: Ed" and Eq" modified detail model is used, with excitation, PSS and speed regulation system.

Load model: 50% constant power and 50% constant impedance load models is used. The frequency factors of active and reactive power are 1.8 and -2.0 respectively.

Parameter: For the planning grid and generators, using the same typical parameters of equipment which are the same type and capacity.

2.4 故障模拟
Fault simulation

巴基斯坦电网没有关于直流的安全稳定计算要求和标准，因此安全稳定计算校核参照中国的计算要求和《电力系统安全稳定导则》标准。

There is not requirements and standards of Pakistan for calculating the security and the stability with HVDC system, the security and the stability is calculated by referring to the calculation requirements and the *Guide on Security and Stability for Power System* of China.

A. 在计算中，对应《电力系统安全稳定导则》第一级安全稳定标准，故障类型主要有：

A1.500kV 交流线路三相永久故障跳单回故障：0.0 秒线路发生三相永久性接地故障，故障侧 0.09 秒跳开三相开关，对侧 0.1 秒跳开三相开关。

A2.直流单极闭锁故障：0.0 秒直流单极闭锁，0.1 秒整流侧和逆变侧一定容量的滤波器退出运行。

A. In calculation, the fault types corresponding to the Class 1 security and stability criteria in the *Guide on Security and Stability for Power System* mainly include:

A1.Permanent three-phase short circuit tripping single-circuit fault of 500kV AC line: A permanent three-phase ground fault occurs on the line at 0.0 second, the three-phase switch at the fault side is tripped at 0.09 second, and the three-phase switch at the opposite side are tripped at 0.1 second.

A2.HVDC monopole block fault: The HVDC monopole is blocked at 0.0 second, and the filters with certain capacity at the both converter stations are tripped at 0.1 second.

B. 对应《电力系统安全稳定导则》第二级安全稳定标准，故障类型主要有：

B1. 500kV 交流线路三相永久故障跳双回路故障：0.0 秒一回线路发生三相永久性短路故障，0.09 秒跳开故障侧三相开关，0.1 秒跳开并列两回线路两侧三相开关。

B2. 直流双极闭锁故障：0.0 秒直流双极闭锁，0.1 秒整流侧和逆变侧滤波器全部退出运行。

B. The fault types corresponding to the Class 2 security and stability criteria in the *Guide on Security and Stability for Power System* mainly include:

B1. Permanent three-phase short circuit tripping double-circuit fault of 500kV AC line: A permanent three-phase ground fault occurs on one circuit at 0.0 second, the three-phase switch at the fault side is tripped at 0.09 second, and the three-phase switches at both sides of the parallel double-circuit line are tripped at 0.1 second.

B2. HVDC bipole block fault: The HVDC bipole is blocked at 0.0 second, and the filters at the both converter stations are tripped at 0.1 second.

C. 现有安全稳定导则与计算标准，仅考虑了直流系统单双极闭锁故障形态。而实际故障实例与互联电网的计算结论表明，直流换相失败、再启动对强直弱交电网稳定性影响加剧，局部电网已取代交流"N-1"、"N-2"故障，成为系统稳定运行的制约故障。因此，针对直流多种故障形态进行计算校核：

C1. 直流换相失败故障：双极阀组换相失败引起的直流功率大幅波动，一次功率波动过程持续 0.2 秒。

C2. 直流再启动故障：直流故障去游离时间为 0.15 秒。

C. Only the monopole and bipole block fault situations of HVDC system are considered in the current guide and calculation criteria for security and stability. However, the actual fault instances and the interconnected grid calculation conclusions have indicated that HVDC commutation failure and restart have a heavier impact on the stability of strong HVDC and weak HVAC grid, and local grid has replaced AC "N-1" and "N-2" faults as the restraining fault for system stable. Therefore, a calculation checking is conducted for various HVDC fault situations:

C1. HVDC commutation failure: A large fluctuation of DC power is caused by the commutation failure of the bipole valve bank, and the primary power fluctuation is continued for 0.2 second.

C2. HVDC restart fault: The interval from HVDC fault to free time is 0.15s.

2.5 安全稳定标准
Security and stability criteria

2.5.1 安全稳定性分类

根据《电力系统安全稳定导则》规定，安全稳定性包括：静态安全性、暂态稳定性和动态稳定性。

1)静态安全性指线路、变压器等单一元件开断后（即一般所指的静态"N-1"），其它元件不过负荷，电网电压水平符合要求。

2)暂态稳定性指电力系统遭受输电线短路等大扰动后，过渡到新的稳定运行状态的能力。

3)动态稳定性指电力系统受到扰动后，保持运行稳定性、不发生发散振荡的能力

2.5.1 Type of Security and Stability

According to the *Guide on Security and Stability for Power System*, the security and the stability include: steady state security, transient stability and dynamic stability.

1)Steady state security means other elements are not over loaded and the grid voltage level meets the requirement after the disconnection of single elements such as line, transformer, etc. (i.e. what is known as steady state "N-1").

2)Transient stability means the electric power system has the capability to transit to a new stable operation state after a large disturbance such as short circuit fault of transmission line, etc.

3)Dynamic stability means the electric power system has the capability to maintain the operation stability without divergent oscillation after disturbance.

2.5.2 安全稳定性的三级标准

《电力系统安全稳定导则》根据故障严重程度相应提出了三级安全稳定标准。

第一级标准：正常运行方式下的电力系统受到单一故障扰动后，当保护、重合闸和断路器正确动作时，不采取稳定控制措施，必须保持电力系统稳定运行和正常供电，其它元件不超过规定的事故后过负荷能力，不发生连锁跳闸。

第二级标准：正常运行方式下的电力系统受到较严重的故障扰动后，当保护、重合闸和断路器正确动作时，应能保持稳定运行，但允许损失部分负荷，必要时采取切机和切负荷等稳定控制措施。

第三级标准：电力系统因一些情况导致稳定破坏时，必须采取措施，防止系统崩溃，避免造成大面积停电和对用户（包括厂用电）的灾害性停电，使负荷损失尽可能减少到最小，电力系统应尽快恢复正常运行。

2.5.2 Three Classe of Security and Stability Criteria

Three classes of security and stability criteria are specified in the *Guide on Security and Stability for Power System* according to the severity level of faults.

Class 1 criteria: When an electric power system under normal operation is disturbed by a single fault, and if the protection, the reclosure and the circuit breaker are acting properly, the stable operation and the normal power supply of the system must be maintained, other elements shall not exceed the specified post-accident overload capacity, and no interlocked trip shall occur without taking the stability control measures.

Class 2 criteria: When an electric power system under normal operation is disturbed by a serious fault, and if the protection, the reclosure and the circuit breaker are acting properly, the stable operation of the system shall be able to be maintained, loss of part of the load is allowed nevertheless, and the stability control measures such as unit switch-off, load shedding, etc. shall be taken where necessary.

Class 3 criteria: When the stability of an electric power system is destroyed due to some conditions, measures must be taken to prevent the system breakdown, to avoid the black-out of large area and the catastrophic power failure to users (including station service) and minimize the load loss, and the normal operation of the system shall be recovered at the earliest time possible.

2.6 稳定判据
Stability criteria

系统稳定判据分为功角稳定、电压稳定、频率稳定三个方面，判据如下：

功角方面：在同步系统中任何主力机组之间不发生相对功角失步。

电压方面：故障消除后的中长期过程中，主要枢纽变电站的母线电压能够恢复到运行允许范围，负荷母线电压能够保持或恢复到 0.9p.u.以上。

频率方面：不发生系统频率崩溃，能够恢复到正常范围且不影响大机组的安全运行。

The system stability criteria are related to power angle stability, voltage stability and frequency stability, and are as follows:

Power angle: No relative power angle step-out shall occur between any main generator units in a synchronized system.

Voltage: In the mid- and long-run after the elimination of fault, the bus voltage of the main load center unit substation shall be able to be recovered to the allowable range for operation, and the bus voltage of the load shall be able to be maintained or recovered to 0.9p.u. or higher.

Frequency: The system shall be free of frequency crash, and can be recovered to the normal range, and the safe operation of the large generator unit shall not be affected.

2.7 稳控措施
Stability control measures

计算中拟采取的措施主要有切机、解列、切负荷等稳定控制措施，采用原则：切除与故障线路直接相连发电厂机组，切机时间按 0.2 秒考虑；遥切远方发电厂机组，切机时间按 0.26 秒考虑；集中切负荷措施根据需要在变电站采用，故障后收到远方信号切除变电站负荷，切负荷时间按 0.3 秒考虑。

The measures to be used in calculation mainly include the stability control measures such as unit switch-off, splitting, load shedding, etc., and the principles is: switching off the generator units directly connected with the fault line within 0.2s; remotely switching off the generator units within 0.26s; applying the centralized load shedding measure at the substation as the circumstances may require, in which case, the substation load shall be shed upon receiving the remote signal after the fault happened, and the load shedding time shall be considered as 0.3s.

Pak Matiari Lahore Transmission Co. (Pvt) Ltd

3 默蒂亚里～拉合尔±660kV 直流安全稳定分析
Analysis on security and stability of M-L ±660kV HVDC Project

3.1 电网现况
Current conditions of power grid

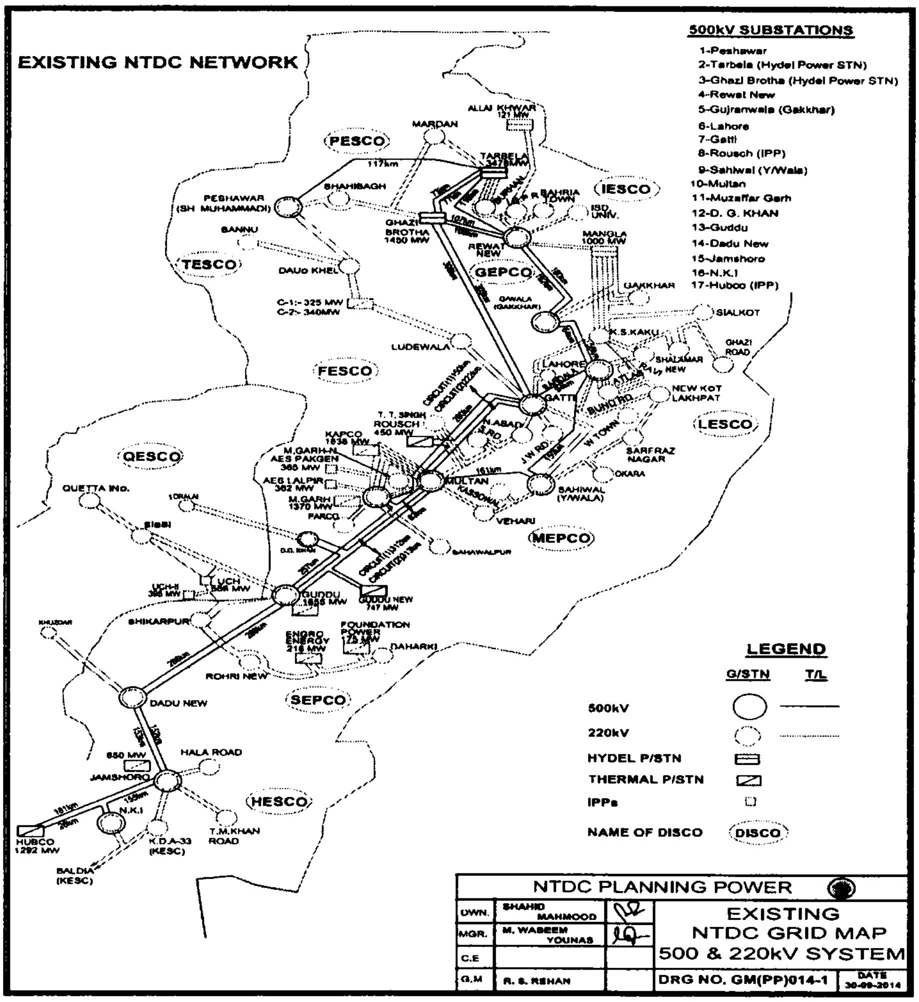

图 3-1　2014 年巴基斯坦电网接线示意图

Fig. 3-1 Schematic connecting diagram of Pakistan's power grid in 2014

根据中巴能源规划专家组于 2014 年 8 月提供的《中巴经济走廊能源规划报告》中关于巴基斯坦电网概况内容，目前巴基斯坦电网最高电压等级为 500kV。2014 年实际最大负荷 18830MW，装机 24110MW。巴基斯坦的伊斯兰堡、旁遮普省为主要负荷中心，已形成 500kV 环网结构。电力流向总体呈现北部、南部向中部送电格局，电网已建成由南至北 2-4 回 500kV 线路输电通道，南电北送主要断面为 JAMSHORO～DADU-NEW～GUDDU 双回 500kV 线路断面。巴基斯坦电网结构如图 3-1 所示。

According to contents of the State Grid of Pakistan in *Energy Planning of China-Pakistan Economic Corridor Report* provided by China-Pakistan energy planning expert group in August 2014, at present, the highest voltage class of the grid of Pakistan is 500kV. In 2014, the maximum load was 18830MW, and the installed capacity was 24110MW. Islamabad and Punjab are the main load centers in Pakistan, and a 500kV looped network structure has formed. The power generally flows from the north and the south to Central Pakistan, a south-north 500kV power transmission line with 2-4 circuits has been built for the grid, and the main cross section for power transmission from south to north is the cross section of JAMSHORO-DADU-NEW-GUDDU double-circuit 500kV line. The grid structure of Pakistan is as shown in Fig. 3-1.

巴基斯坦 500kV 交流电网整体潮流较轻，负荷中心 500kV 线路潮流最重的为塔佩拉(TARBELA)～瑞瓦特(REWAT)单回线路，约 700MW；巴基斯坦电网南北输电通道送电潮流在 170～1650MW 左右。2014 年夏大方式巴基斯坦 500kV 主通道潮流分布如图 3-2 所示。

The overall load flow of Pakistan's 500kV AC grid is light, and the heaviest load flow in the load center 500kV line is TARBELA- REWAT single-circuit line, of which, the load flow is about 700MW; the power transmission load flow of the south-to-north power transmission channel in the grid of Pakistan is around 170-1650MW. The load flow of Pakistan's main 500kV channels in summer maximum-load mode in 2014 is as shown in Fig. 3-2.

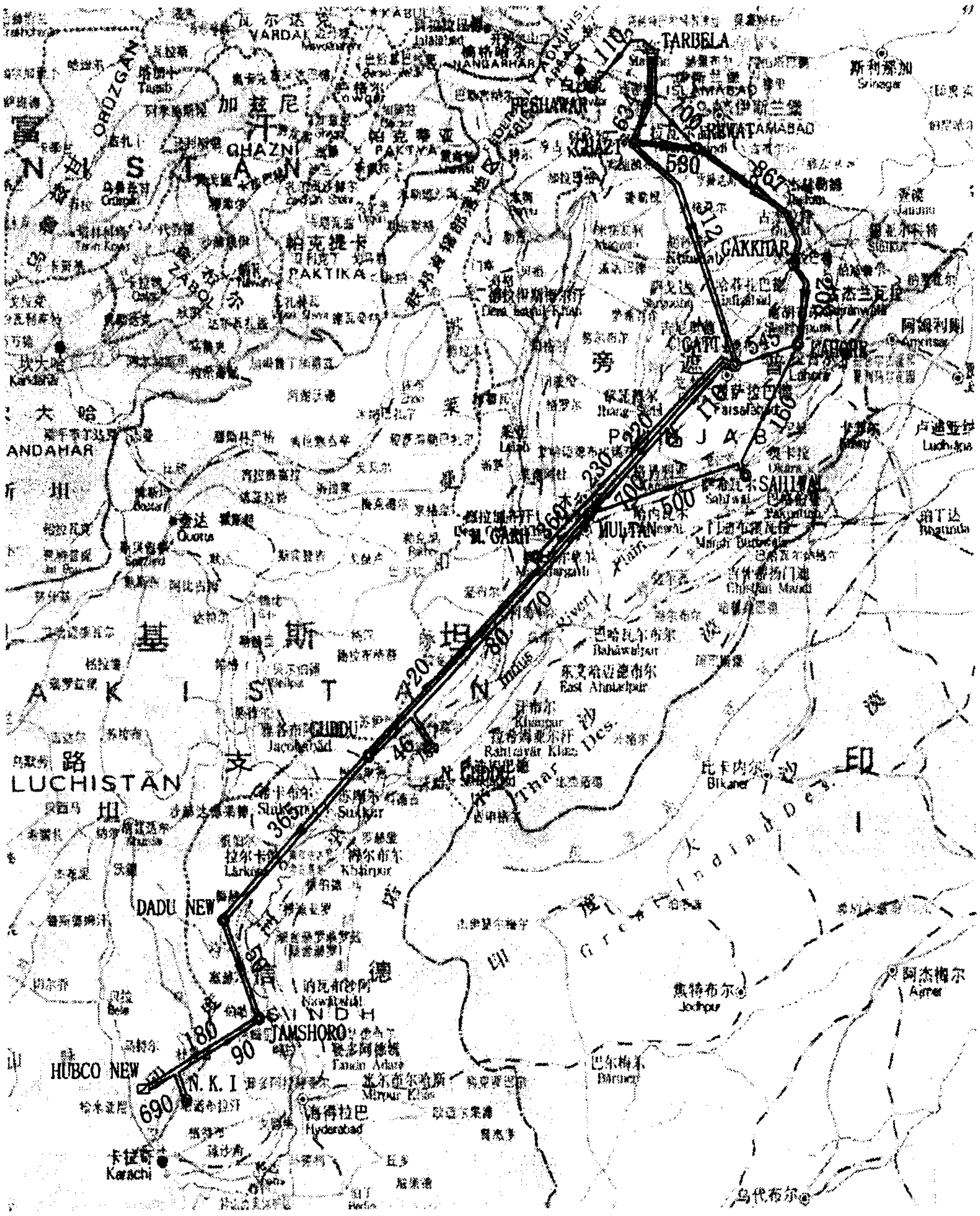

图 3-2 巴基斯坦 500kV 电网潮流示意图

Fig. 3-2 Schematic map of load flow of Pakistan's 500kV grid

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3.2 巴基斯坦电力系统规划简介
Introduction of Pakistan's power system planning

3.2.1 电力需求预测
Forecast of power demand

1971 年以来，巴基斯坦用电量基本呈持续上升趋势，分别在 1998 年、2008 年出现回落，2010 年至今用电增速放缓，基本呈持平态势。1972～2012 年期间，巴基斯坦全社会用电量年均增长率为 6.9%。

The power consumption of Pakistan has risen continuously since 1971, dropped respectively in 1998 and 2008, and grown with a lower rate from 2010 to date, but basically maintained a stable situation. During 1972 and 2012, the annual growth rate of the whole society of Pakistan was 6.9%.

巴基斯坦国家电网按输电区域划分为巴基斯坦国家输电公司（NTDC）及卡拉奇 KESC 工业园负荷，根据巴方提供最新的负荷预测数据，巴基斯坦电网 2017 年、2023 年最大负荷将分别达到 26680MW、38250MW，2015～2020 年年均增长率 4.9%，2020～2022 年年均增长率 7.5%。巴基斯坦电力需求如表 3-1 所示。

The State Grid of Pakistan is divided into National Transmission & Despatch Company (NTDC) Limited and KESC Industrial Park loads by power transmission regions, and according to the latest estimated load data provided by the Pakistani side, the maximum loads of Pakistan's grid will reach 26680MW and 38250MW in 2017 and 2023 respectively, the annual average growth rate in 2015-2020 will be 4.9%, and the annual average growth rate in 2020-2022 will be 7.5%. The power demands of Pakistan are as shown in Table 3-1.

表 3-1 巴基斯坦电力需求预测表
Table 3-1 Pakistan Power Demand Forecast

单位：10MW
Unit: 10MW

年份 Year	2015 年 2015	2017 年 2017	2018 年 2018	2020 年 2020	2015-2020 年年均增长率 Annual average growth rate from 2015 to 2020	2022 年 2022	2020-2022 年年均增长率 Annual average growth rate from 2020 to 2022
全国 Nationwide	2422	2668	2802	3082	4.9%	3825	7.5%
其中：NTDC Incl: NTDC	2121	2335	2449	2685	4.8%	3364	7.6%
KESC	301	333	353	397	5.7%	461	6.4%

3.2.2 电源安排
Genation arrangement

为推进中巴经济走廊建设，促进巴基斯坦社会经济发展，2014 年国家能源局牵头开展了中巴经济走廊能源规划，双方政府于 2014 年 11 月签署了"中巴经济走廊能源项目合作的协议"，相应合作框架内火电、水电项目纳入平衡。按照协议巴基斯坦 2023 年前投产的规划电源共 21 项，总规模为 17705MW，其中火电 13665MW、水电 2690MW、新能源 1350MW，分为优先实施项目和积极推动项目两大类。

To promote the construction of China-Pakistan Economic Corridor and the social and economic development of Pakistan, the National Energy Administration of China led the energy planning for China-Pakistan Economic Corridor in 2014, and the governments of both sides signed the *Agreement on the Energy Project Cooperation of the China–Pakistan Economic Corridor*, and thermal power and hydropower projects are balanced in corresponding cooperation frameworks in November 2014. According to the Agreement, Pakistan will have 21 planned power sources turn into production by 2022, of which, the total capacity will be 17705MW, including 13665MW thermal power, 2690MW hydropower

Pak Matiari ... Co. (Pvt.) Ltd.

and 1350MW renewable energy, and the projects fall into two categories, namely preferential implementation project and active promotion project.

电源投产时间为 2015 年 5 月电源项目开发商上报的商业运行时间。考虑融资关闭时间能够按照上报情况落实，安排规划电源的投产时序。中巴经济走廊电源项目 2017 年、2018 年、2020 年累计投产规模分别达到 2010MW、7590MW、9180MW，其余电源考虑 2021～2023 年投产。考虑现有、在建和规划电源项目后，至 2017 年、2018 年、2020 年和 2022 年，巴基斯坦电网年末装机将分别达到 28550MW、34130MW、36320MW 和 47045MW。巴基斯坦电网电源建设安排如表 3-2 所示。

The commissioning time of the power supply projects will be the commercial operation time reported by the project developers in May 2015. Considering the closing time of financing can be implemented according to the reported time, the commissioning sequence will be arranged for the planned power supply projects. The commissioning scales of the power supply projects in China-Pakistan Economic Corridor will reach 2010 MW, 7590 MW and 9180 MW respectively in 2017, 2018 and 2020, and other projects are considered to be commissioned in 2021-2022. After putting the existing, in-progress and planned power supply projects into consideration, the year-end installed capacities of Pakistan's grid will reach 28550 MW, 34130 MW, 36320 MW and 47045 MW in 2017, 2018, 2020 and 2022 respectively. The power supply construction arrangement for Pakistan's grid is as shown in Table 3-2.

表 3-2 巴基斯坦电网电源建设安排表

Table 3-2 Construction Arrangement for Planned Power Supply Projects of Pakistan Power Grid

单位：10MW
Unit: 10MW

Sr. #	Fiscal Year	Name of Project	Fuel	Location	Installed Capacity (MW)	Expected Comissioning Date
		Existing capacity				
1	2015-16	CHASNUPP-III	Nucl	Chashma, KPK	340	May-16
2		Zonergy-II	Solar	Lal Sohnra (Cholistan), Punjab	100	May-16
3		M/s Hamza Sugar Mills Ltd.	Baggase	Khanpur, Punjab	15	May-16
4		M/s Yunus Energy Ltd.	Wind	Jhimpir, Sindh	50	Jun. 2016
5		M/s Metro Power Co. Ltd.	Wind	Jhimpir, Sindh	50	Jun. 2016
6		M/s Gul Ahmed Energy Limited	Wind	Jhimpir, Sindh	50	Jun. 2016
7		M/s Tapal Wind Energy (Pvt.) Limited	Wind	Jhimpir, Sindh	30	Jun. 2016
8	2016-17	Zonergy-III, IV & V	Solar	Lal Sohnra (Cholistan), Punjab	300	Jul. 2016
9		M/s Tenaga Generasi Limited	Wind	Gharo/Bhambore/Kuttikun, Sindh	49.5	Sep. 2016
10		M/s Master Wind Energy Limited	Wind	Jhimpir, Sindh	49.5	Sep. 2016
11		M/s HydroChina Dawood Power Ltd.	Wind	Gharo, Sindh	49.5	Sep. 2016
12		M/s United Energy Pakistan Limited	Wind	Jhimpir, Sindh	99	Sep. 2016

13		M/s Tenaga Generasi Limited		Gharo, Sindh	49.5	Sep. 2016
14		M/s Layyah Sugar Mills Ltd.	Baggase	Layyah, Punjab	41	Dec. 2016
15		CHASHNUPP-IV	Nucl	Chashma, KPK	340	Dec. 2016
16		Zonergy-VI	Solar	Lal Sohnra (Cholistan), Punjab	100	Dec. 2016
17		Zonergy-VII	Solar	Lal Sohnra (Cholistan), Punjab	100	Jan. 2017
18		Zonergy-VIII & IX	Solar	Lal Sohnra (Cholistan), Punjab	200	Feb. 2017
19		LNG Based Plants (2*GT)	LNG	Bhikki, Punjab	800	Mar. 2017
20		Patrind HPP	Hydel	Kunhar River, KPK/AJK	147	Mar. 2017
21		LNG Based Plants (2*GT)	LNG	Haveli Bahadur Shah (Jhang), Punjab	800	Apr. 2017
22		Gas Based Power Plants	LNG	Existing Plant Sites	1000	Apr. 2017
23		LNG Based Plants (2*GT)	LNG	Baloki, Punjab	800	May. 2017
24		M/s Alliance Sugar Mills Ltd.	Baggase	Ghotki, Sindh	19	Feb. 2017
25		M/s Chanar Sugar Mills Ltd.	Baggase	Tandlianwala, Punjab	22	Jun. 2017
26		M/s Sachal Energy Development (Pvt.) Limited	Wind	Jhimpir, Sindh	49.5	Jun. 2017
27		Tarbela 4th Ext. Project	Hydel	Tarbela, KPK	1410	Jun. 2017
28	2017-18	Neelum Jhelum Hydel	Hydel	Nauseri/Muzaffarabad, AJK	969	Aug. 2017
29		M/s Etihad Power Generation Ltd.	Baggase	Rahim Yar Khan, Punjab	67	Feb. 2017
30		M/s Almoiz Industries Ltd.	Baggase	Mianwali, Punjab	36	Dec. 2017
31		M/s Safina Sugar Mills	Baggase	Lalian, Sagodha	20	Dec. 2017
32		M/s Shahtaj Sugar Mills Ltd.	Baggase	Mandi Bahauddin, Punjab	32	Dec. 2017
33		M/s RYK Energy Ltd.	Baggase	Rahim Yar Khan, Punjab	32	Dec. 2017
34		M/s SSJD Bioenergy	Baggase	Mirpurkhas, Sindh	12	Dec. 2017
35		M/s Lumen Energia Pvt Ltd	Baggase	Jhang, Punjab	12	Dec. 2017
36		Shandong Imported Coal Based Power Project	Coal	Sahiwal, Punjab	1320	Dec. 2017

37		LNG Based Plants (1*ST)	LNG	Bhikki, Punjab	400	Dec. 2017
38		LNG Based Plants (1*ST)	LNG	Baloki, Punjab	400	Dec. 2017
39		LNG Based Plants (1*ST)	LNG	Haveli Bahadur Shah (Jhang), Punjab	400	Dec. 2017
40		M/s Jhampir Wind Power (Pvt.) Limited	Wind	Jhimpir, Sindh	50	Feb. 2018
41		M/s Hawa Energy (Pvt.) Limited	Wind	Jhimpir, Sindh	50	Mar. 2018
42		M/s Hartford Alternative Energy (Pvt.) Limited	Wind	Jhimpir, Sindh	50	Apr. 2018
43		M/s Tricon Boston Consulting Corporation (Pvt.) Limited (A)	Wind	Jhimpir, Sindh	50	Apr. 2018
44		M/s Tricon Boston Consulting Corporation (Pvt.) Limited (B)	Wind	Jhimpir, Sindh	50	May. 2018
45		M/s Tricon Boston Consulting Corporation (Pvt.) Limited (C)	Wind	Jhimpir, Sindh	50	May. 2018
46		M/s Three Gorges Second Wind Fram Pakistan Ltd (Wind Eagle Limited)	Wind	Jhimpir, Sindh	49.5	Jun. 2018
47		M/s Three Gorges Second Wind Fram Pakistan Ltd (Wind Eagle Limited)	Wind	Jhimpir, Sindh	49.5	Jun. 2018
48		Port Qasim Power Project	Coal	Port Qasim Karachi, Sindh	1320	Jun. 2018
49	2018-19	Golen Gol HPP	Hydel	Chitral, KPK	106	Jul. 2018
50		Engro Powergen Project	Coal	Thar, Sindh	660	Oct. 2018
51		Gulpur Poonch river	Hydel	Poonch River/Gulpur, AJK	102	Oct. 2018
52		M/s Zephyr Power Pvt. Ltd.	Wind	Gharo, Sindh	50	Nov. 2018
53		Coal Plant at Salt Range	Coal	Salt Range, Punjab	300	Jan. 2019
54		Shanghai Electric Power Project	Coal	Thar, Sindh	1320	Jan. 2019
55		Grange Holding	Coal	Arifwala, Punjab	163	Jan. 2019
56		HUB Power Company Ltd.	Coal	HUB, Baluchistan	1320	Jan. 2019

57		Lucky Electric Power Company Ltd.	Coal	Port Qasim, Sindh	660	Mar. 2019
58		Siddiqsons Limited	Coal	Port Qasim, Sindh	350	Mar. 2019
59	2019-20	TPS Jamshoro (Phase-1)	Coal	Jamshoro, Sindh	660	Jun. 2019
60		CASA	Import	Cross Border Interconnection	1000	Jul. 2019
61		Coal Plant at Muzaffargarh	Coal	Muzaffargarh, Punjab	600	Sep. 2019
62		TPS Jamshoro (Phase-2)	Coal	Jamshoro, Sindh	660	Dec. 2019
63		Keyal Khwar	Hydel	Dasu District, KPK	128	Jan. 2020
64		Other Wind Power Plants	Wind	Sindh	524	Feb. 2020
65	2020-21	Karachi Coastal Power Plant (unit-1)	Nucl	Karachi	1100	Nov. 2020
66		Dasu HPP (Phase-1)	Hydel	7km upstream of Dasu Village on Indus River, KPK	2160	Feb. 2021
67		Karot HPP	Hydel	Jehlum River, Distt. Rawalpindi, Punjab	720	Jun. 2021
68		Tarbela 5th Ext. Project	Hydel	Tarbela, KPK	1410	Jun. 2021
69	2021-22	Suki Kinari HPP	Hydel	Kunhar River/Mansehra, KPK	870	Jul. 2021
70		Karachi Coastal Power Plant (unit-2)	Nucl	Karachi	1100	Oct. 2021
71		Kotli	Hydel	Poonch River/Kotli, AJK	100	Jun. 2022
72		Coal Plant at Lakhra	Coal	Lakhra, Sindh	660	Jun. 2022

注：根据业主意见，胡布克电站规模改为 2×660MW
Note: According to the Employer's opinions, the scale of Hubco Power Plant is changed to be 2×660MW.

3.2.3 电网规划
Grid planning

根据巴基斯坦国家输电公司（NTDC）提供的《巴基斯坦电网发展规划（National Power System Expansion Plan）（2011 年版）报告》及后续调整资料，巴基斯坦今后电网发展目标是：

According to the *National Power System Expansion Plan Report (2011 edition)* and subsequent adjustment information provided by NTDC, the grid development objectives of Pakistan in the future are to:

（1）加强 500kV 主网架及输配电网，提高电网传输能力及可靠性，同时应通过提高技术和管理水平，减少输电损失；

Enhance the 500kV main network and the transmission and distribution grid, improve the transmission capacity and reliability of the grid, and also reduce the loss in power transmission through improving the technical and management levels;

（2）新建电源的配套送出线路应与电源同步规划、实施并投产，保障电力电量及时送出。

Plan, execute and operate the outlet line of the new power supply at the same time with the power supply, to ensure the timely delivery of electric power.

巴基斯坦的电网规划以巴方提供的《巴基斯坦2011-2030年电力系统发展规划》为基础，水平年考虑2018年,远景年考虑2022年；同时考虑中巴经济走廊能源规划电源项目的接入及送电需求。2015年～2018年，规划建设默蒂亚里至拉合尔输电工程满足中部负荷中心电力缺口及南部电源送出需要；建成第三回南电北送500kV输电线路(贾母肖罗～摩洛～R.Y汉)；建设拉合尔南等500kV输变电工程；配合中巴经济走廊电源项目，建设萨希瓦尔电厂及南部火电500kV送出工程。巴基斯坦2018年500kV电网规划如图3-3所示。

The grid planning of Pakistan is based on the *2011-2030 National Power System Expansion Plan* provided by the Pakistani side, in which, 2018 and 2022 are considered as the level-year and long-run-year; the access and power transmission requirements of the power supply projects for energy planning of China-Pakistan Economic Corridor shall be considered in the meantime. In 2015-2018, it is planned to construct Matiari-Lahore Power Transmission Project to meet the power shortage of the load center in Central Pakistan and the power transmission requirement of South Pakistan, build the South-to-North 3rd-circuit 500kV AC channel (Jamshoro-Moro-R.Y. Khan), construct the 500kV power transmission and transformation projects at Lahore South, etc., and construction Sahiwal Power Plant and South Thermal Power 500kV Outlet Project in coordination with the power supply projects in China-Pakistan Economic Corridor. The 500kV gird planning of Pakistan in 2018 is as shown in Fig. 3-3.

至2022年，随着K-2、K-3核电项目、规划火电项目的投产，规划建设默蒂亚里至费萨拉巴德第二回南电北送输电工程满足电力送出及负荷需要。建设塔吉克斯坦至白沙瓦直流及500kV配套工程；旁遮普省和伊斯兰堡负荷中心建设Chakwal、Isd West、Ludewala等500kV变电站，受端500kV环网结构供电能力进一步提高。配合中巴经济走廊电源项目，建设穆扎法格、拉希姆亚尔汗、Oracle及北部水电500kV送出工程，巴基斯坦2022年500kV电网规划如图3-4所示。

With the commissioning of K2 and K3 nuclear power projects and the planned thermal power project by 2022, it is planned to construct Matiari- Faisalabad South-to-North 2nd-circuit Power Transmission Project to meet the power transmission and load requirements, build Tajikistan-Peshawar DC and 500kV auxiliary projects, construct Chakwal, Isd West, Ludewala, etc. 500kV substations for Punjab and Islamabad load centers, further improve the power supply capacity of receiving-end 500kV looped network structure, and construct Muzaffargarh, Rahimyar Khan , Oracle and North Hydropower 500kV transmission projects in coordination with the power supply projects in China-Pakistan Economic Corridor. The 500kV gird planning of Pakistan in 2022 is as shown in Fig. 3-4.

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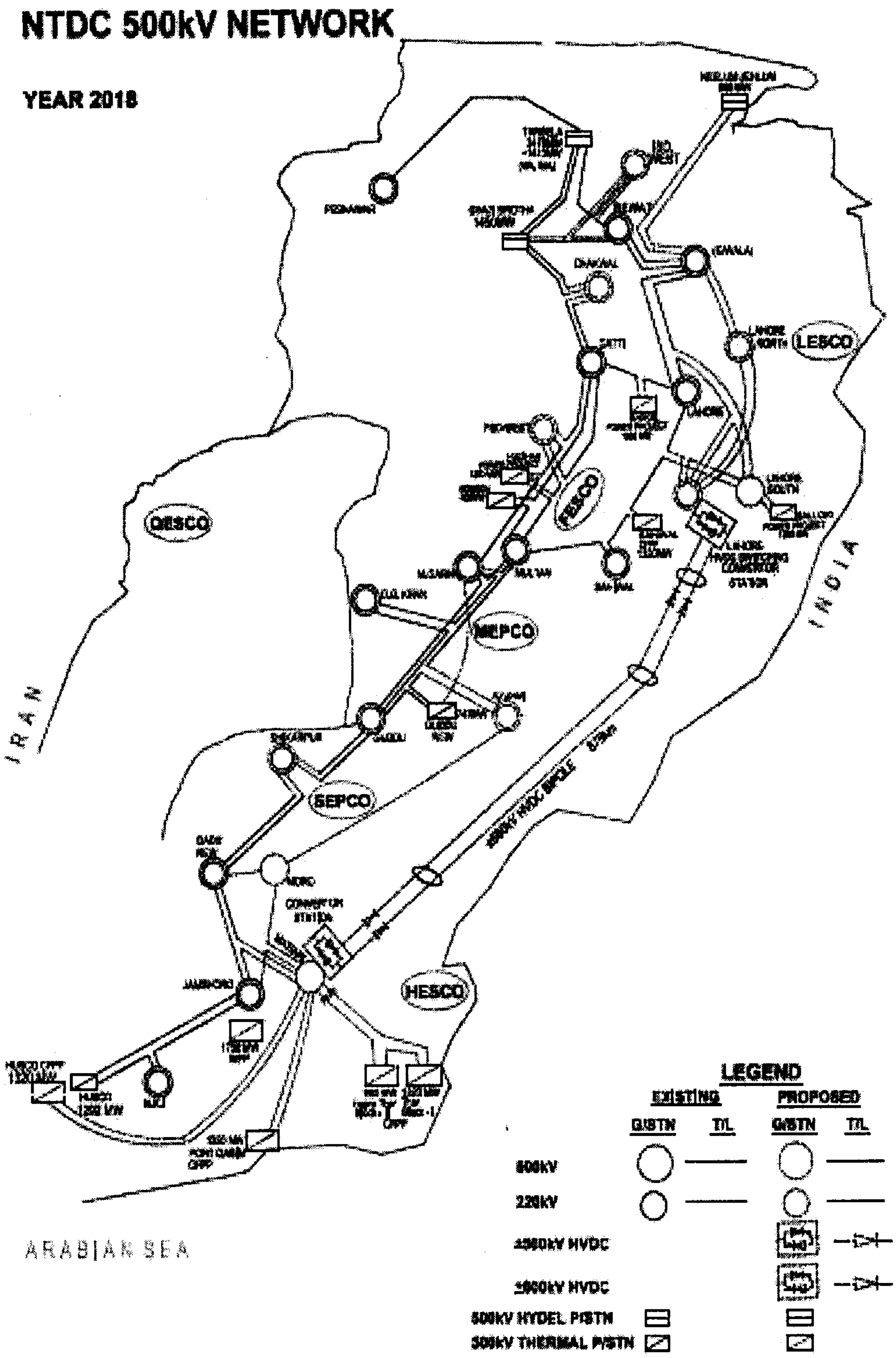

图 3-3　2018 年巴基斯坦 500 千伏电网规划图
Fig.3-3 2018 Planning Diagram for Pakistan Power Grid of 500kV

Pak Matiari Lahore Transmission Co. (Pvt) Ltd.

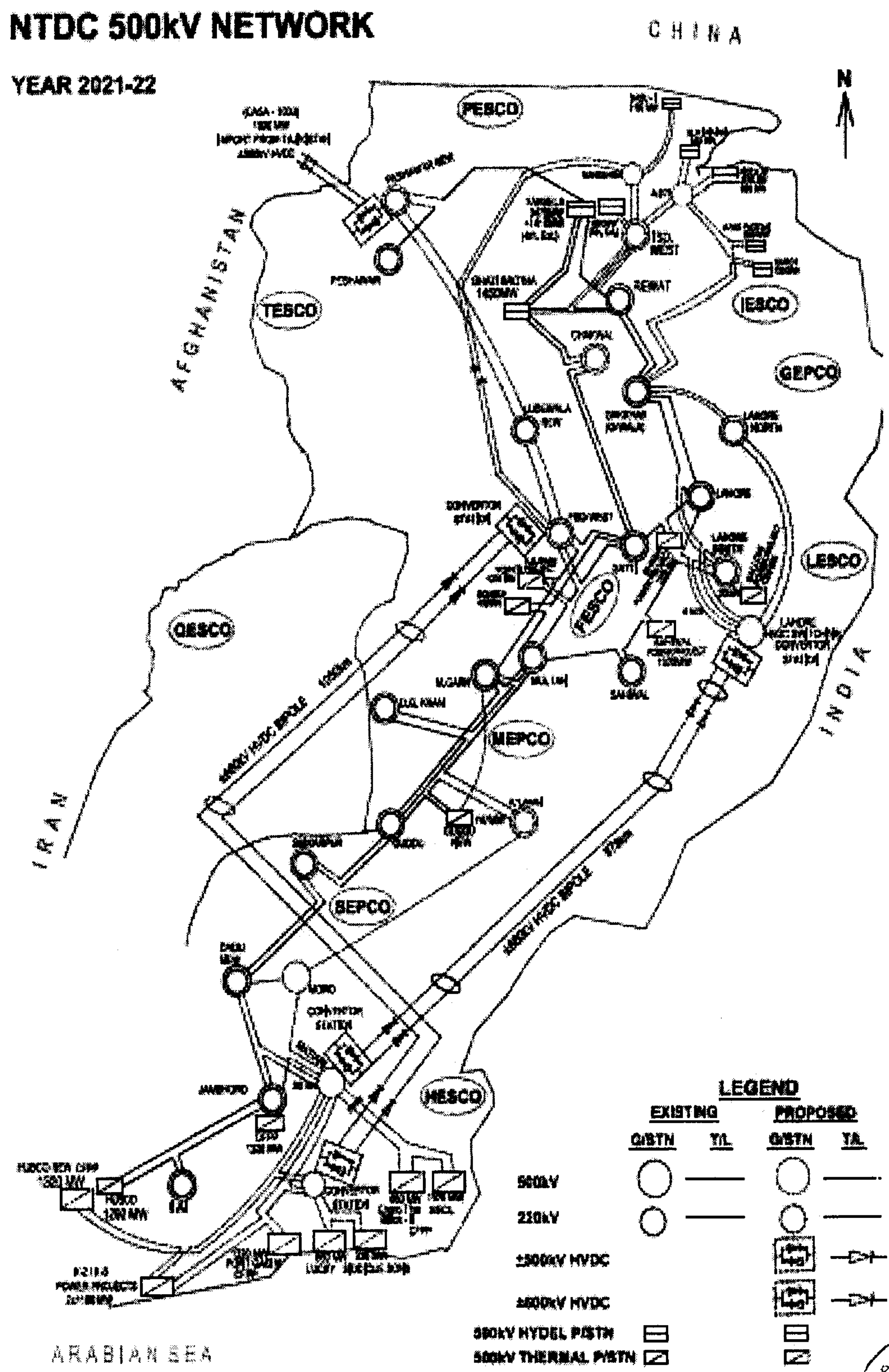

图 3-4　2022 年巴基斯坦 500kV 及以上电网规划图
Fig.3-4 2022 Planning Diagram for Pakistan Power Grid of 500kV and Above

Lahore Transmission Co. (Pvt) Ltd.

3.3 默蒂亚里～拉合尔直流规划设计概况
Overview of Matiari-Lahore HVDC Project

依据《中巴经济走廊能源规划报告》中关于巴基斯坦电源规划内容和巴基斯坦国家输电公司（NTDC）提供的《巴基斯坦电网发展规划（National Power System Expansion Plan）(2011 年版)报告》及后续调整资料，为促进信德省塔尔煤田及沿海煤电的开发外送，满足旁遮普省及伊斯兰堡地区用电负荷增长的需求，规划建设默蒂亚里～拉合尔±660kV 直流输电工程。工程起点巴基斯坦南部信德省默蒂亚里，途径信德、旁遮普 2 省，落点中部旁遮普省拉合尔地区，直流线路长度约 878km，输电容量 4000MW，规划 2018 年投产。

According to contents of power supply planning in *Energy Planning Report for China-Pakistan Economic Corridor* as well as National Power System Expansion Plan Report (2011 edition) and subsequent adjustment information provided by NTDC, to promote the development and delivery of coal fired power in Thar Coal Field and the coastal areas of Sindh and meet the increased load consumption requirements of Punjab and Islamabad Region, it is planned to construct Matiari-Lahore ±660kV HVDC Project. The project starts from Matiari in Sindh in South Pakistan, pass through Sindh and Punjab, and end at Lahore in Central Punjab, of which, the linear line length is about 878 km and the transmission capacity is 4000MW. It is planned to turn the project into operation in 2018.

3.3.1 配套电源概况
Overview of power supply projects

送端信德省配套电源考虑 2014 年 11 月《中华人民共和国政府与巴基斯坦伊斯兰共和国政府关于中巴经济走廊能源项目合作的协议》优先实施项目清单中的安格鲁燃煤电厂（2×330MW）、塔尔煤田一区块坑口燃煤电厂（2×660MW），卡西姆港燃煤电厂（2×660MW）；此外根据表 3-3 电源项目最新进展，考虑积极推动清单中胡布克扩建燃煤电厂（2×660MW）。配套电源总装机容量 4620MW，满足默蒂亚里～拉合尔直流工程送电需要。

Engro Coal Power Plant (2×330MW), SSRL Thar Coal Block I Mine Mouth Power Plant (2×660MW) and Port Qasim Coal Power Plant (2×660MW) in the List of Preferential Implementation Projects in the *Agreement between the People's Republic of China and the Islamic Republic of Pakistan on Cooperation on Energy Projects in China-Pakistan Economic Corridor* in November 2014 are considered as the Sindh supporting power supply projects; furthermore, according to the latest progress of power supply projects in table 3-3, it is considered to actively promote the construction of Hubco Coal Power Plant (2×660MW) in the List. The total installed capacity of the supporting projects will be 4620MW, and can meet the power transmission requirement of Matiari-Lahore HVDC Project.

（1）安格鲁燃煤电厂（Engro Thar Coal Power Plant)
Engro Thar Coal Power Plant

安格鲁燃煤电厂位于塔尔煤田区块 II，为坑口燃煤电厂，装机容量 2×330MW，业主为信德安格鲁煤炭公司，中国机械设备工程股份有限公司以 EPC 方式参与，已完成可研报告并通过巴方评审。

Locating in Thar Coal Field Block II, Engro Thar Coal Power Plant is a pithead coal power plant, and has an installed capacity of 2×330MW. Its Employer is Sindh Engro Coal Company, and China Machinery Engineering Co., Ltd. is going to participate in the project through EPC, for which, the feasibility study report has been reviewed and approved by the Pakistani side.

（2）塔尔煤田一区块坑口燃煤电厂（SSRL Thar Coal Block I Mine Mouth Power Plant）
SSRL Thar Coal Block I Mine Mouth Power Plant

塔尔煤田一区块坑口燃煤电厂位于塔尔煤田区块 I，装机容量 2×660MW，中国电力国际有限公司以 BOO 方式控股开发，目前已完成初可研审查并完成可研报告。

Locating in Thar Coal Field Block I, SSRL Thar Coal BlockI Mine Mouth Power Plant has an installed capacity of 2×660MW, and China Power International Development Limited is going to control the development of the project through BOO, for which, the preliminary feasibility study review and the feasibility study report have been completed.

（3）卡西姆港燃煤电厂（Port Qasim Coal Power Plant）
Port Qasim Coal Power Plant

卡西姆港燃煤电厂位于卡拉奇东南约 47km 的卡西姆港，为进口燃煤电厂，装机容量 2×660MW，中国电力建设股份有限公司以 BOOT 方式控股开发，目前已完成可研报告并通过中方评审。

Locating at Port Qasim about 47km to the southeast of Karachi, Port Qasim Coal Power Plant is an imported coal power plant, and has an installed capacity of 2×660MW, and PowerChina Limited is going to control the development of the project through BOOT, for which, the feasibility study report has been completed and reviewed and approved by the Chinese side.

（4）胡布克扩建燃煤电厂（Hubco Coal Power Plant）
Hubco Coal Power Plant

胡布克扩建燃煤电厂位于卡拉奇西北约 30km 的胡布港，为进口燃煤电厂，装机容量 2×660MW，业主为胡布电力公司，中国电力建设股份有限公司参与开发，目前已完成厂址总规划、接入系统规划和环评。

Locating at Port Hubco about 30km to the northwest of Karachi, Hubco Coal Power Plant is an imported coal power plant, and has an installed capacity of 2×660MW. Its Employer is Hubco Power Company, and PowerChina Limited is going to participate in the development of the project. The general planning of plant site, the planning of access system and the environmental impact assessment have been completed.

表 3-3　信德省主要火电项目前期工作情况
Table 3-3 Preliminary work of the main thermal power plant projects in Sindh

单位：10MW
Unit: 10MW

	项目名称 Project name	装机容量 Installed capacity	参与单位 Participating units	前期进度 Preliminary progress	投产时间 Production time
1	安格鲁燃煤电厂 Engro Coal Power Plant	2×330	业主为信德安格鲁煤炭公司，中国机械设备工程股份有限公司以EPC方式参与 With Sindh Engro Coal Company as the Employer, and China Machinery Engineering Corporation participating through EPC mode	完成可研报告 Feasibility study report completed	2019.6
2	塔尔煤田一区块坑口燃煤电厂 Thar Coal Field Block I Pithead Coal Power Plant	2×660	中国电力国际有限公司以BOO方式控股开发Held and developed by China Power International Development Limited through BOO mode	完成可研报告 Feasibility study report completed	2020.8
3	卡西姆港燃煤电厂 Port Qasim Coal Power Plant	2×660	中国电力建设股份有限公司以BOOT方式控股开发 Held and developed by Power Construction Corporation of China through BOOT mode	完成可研报告并通过中方评审Feasibility study report completed and Chinese party's review passed	2018.6
4	胡布克扩建燃煤电厂 Hubco Expanded Coal Power Plant	2×660	业主为胡布克电力公司，中国电力建设股份有限公司参与开发With Hubco Electric Power Company	正在开展可研 Feasibility study in progress	2020.3

Pak Matiari Lahore Transmission Co. (Pvt) Ltd.

			as the Employer, and Power Construction Corporation of China participating in the development		
	合计 Total	4620			

3.3.2 直流接入系统方案 HVDC access scheme

考虑本工程 2018 年建成投产，在现有网架基础上，送端地区 500kV 电网新建贾姆沙罗（Jamshoro）～摩洛（Moro）单回 500kV 线路、摩洛（Moro）～新大都（Dadu New）单回 500kV 线路、摩洛（Moro）～R.Y.汉（R.Y.KHAN）单回 500kV 线路，南电北送能力进一步增强。

By considering this project will be completed and put into service in 2018, Jamshoro-Moro single-circuit 500kV line, Moro-Dadu New single-circuit 500kV line and Moro -R.Y.Khan single-circuit 500kV line will be constructed in the 500kV grid of south area based on existing network, to further strengthen the capability of power transmission from south to north.

同时，如果为提高巴基斯坦电网稳定运行，减少严重故障下的措施量，可配套默蒂亚里～拉合尔±660kV 直流工程，建设 R.Y.汉～萨希瓦尔 1 回 500 千伏交流线路，并在摩洛～R.Y.汉 500 千伏线路加装 40%串补，如下图所示：

Meanwhile, in order to enhance the stable operation of the State Grid of Pakistan and reduce the measures for serious faults, R.Y.Khan-Sahiwal single-circuit 500kV AC line is suggested to be constructed to support Matiari-Lahore ±660kV HVDC project, with 40% series compensation in Moro-R.Y.Khan 500kV line, as shown in the figure below:

图 3-5 配套直流工程的 500kV 网架建议加强工程
Fig. 3-5 Suggested enhancement for 500kV network in supporting HVDC project

考虑信德省默蒂亚里及周边地区作为直流工程送端起点，提出以下送端换流站接入系统方案：

It is considered to take Matiari, Sindh and its surrounding areas as the starting point of the HVDC Project, and the following access scheme is proposed for the Matiari Converter Station:

直流送端换流站 π 入贾姆沙罗（Jamshoro）～摩洛（Moro）500kV 线路；π 入贾姆沙罗～新大都（Dadu New）500kV 线路。直流配套火电机组以 500kV 电压等级接入换流站。送端换流站形成 10 回出线，2 回至贾姆沙罗，1 回至摩洛，1 回至新大都，6 回至配套电源。默蒂亚里换流站无功补偿容量为 2610Mvar，分成 4 大组，16 小组，每组容量为 150～180Mvar。送端换流站接入方案如图 3-6 所示。

At the HVAC side of HVDC Matiari converter station, connect (π connection) to Jamshoro - Moro 500kV lines and connect (π connection) to Jamshoro - Dadu New 500kV lines. The HVDC thermal power generating unit is connected to the converter station at a voltage of 500kV. The Matiari converter station will have 10-circuit outgoing lines, with 2 to Jamshoro, 1 to Moro, 1 to Dadu New and 6 to the matching power supply. The reactive compensation capacity of Matiari Converter Station will be 2610Mvar, and will be divided into 16 subgroups under four groups. The capacity of each group will be 150-180Mvar. The access scheme for the Matiari Converter Station is as shown in Fig. 3-6.

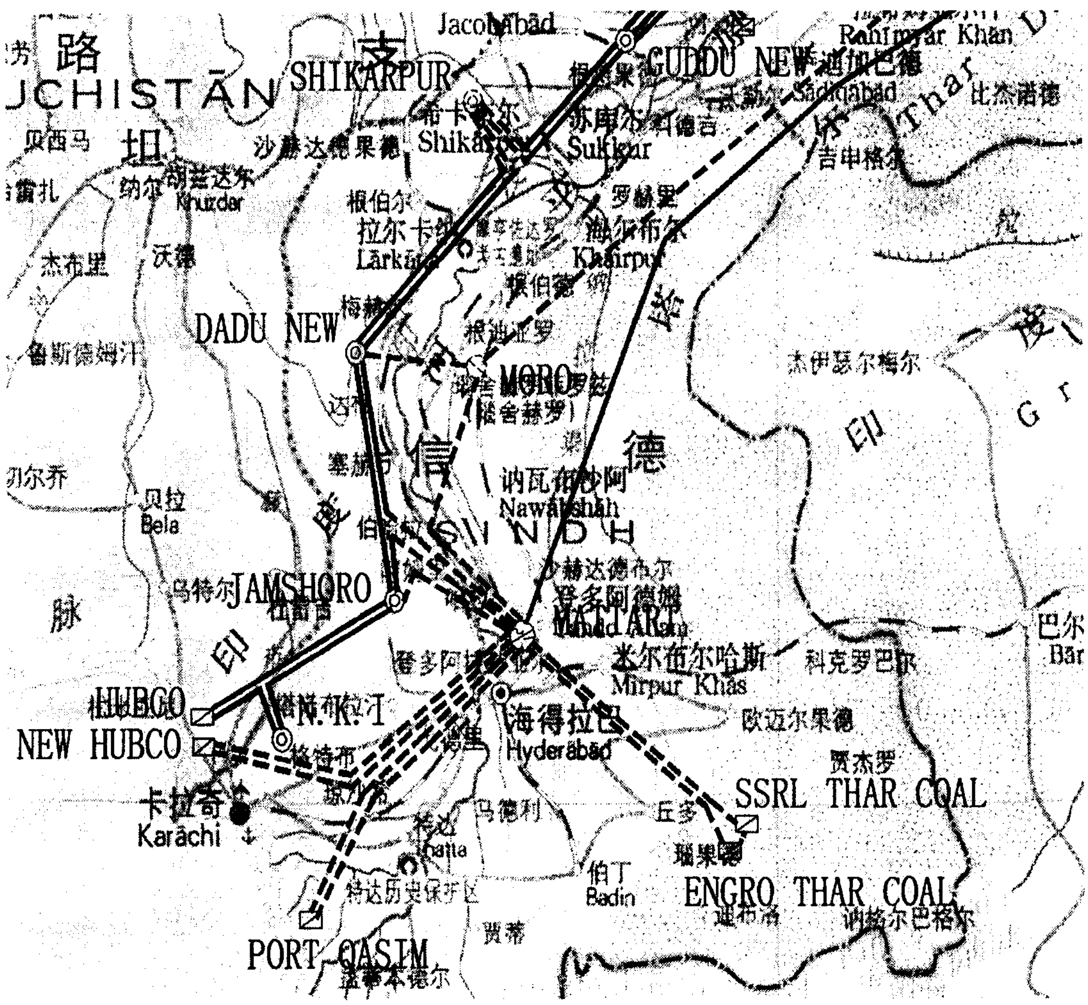

图 3-6 送端换流站接入方案

Fig. 3-6 Access scheme of Matiari Converter Station

考虑旁遮普省拉合尔南部地区作为直流工程受端落点，提出以下受端换流站接入系统方案：

It is considered to take Lahore South, Punjab as the end point of the HVDC Project, and the following access scheme is proposed for the Lahore Converter Station:

直流受端换流站交流侧电压采用 500kV，分别 π 入拉合尔（Lahore）～拉合尔南（Lahore South）双回

500kV 线路；建设受端换流站～拉合尔北（Lahore North）双回 500kV 线路。受端换流站形成 6 回出线，2 回至拉合尔，2 回至拉合尔南，2 回至拉合尔北。拉合尔换流站无功补偿容量为 2480Mvar，分成 4 大组，16 小组，每组容量为 150～160Mvar。受端换流站接入方案如图 3-7 所示。

Adopt 500kV voltage at the HVAC side of HVDC Lahore converter station and connect (π connection) the converter station to the Lahore-Lahore South double-circuit 500kV lines; build the receiving-end converter station-Lahore North double-circuit 500kV lines. The Lahore converter station will have 6-circuit outgoing lines, with 2 to Lahore, 2 to Lahore South and 2 to Lahore North. The reactive compensation capacity of Lahore Converter Station will be 2480Mvar, and will be divided into 16 subgroups under four groups. The capacity of each group will be 150-160Mvar. The access scheme for the Lahore Converter Station is as shown in Fig. 3-7.

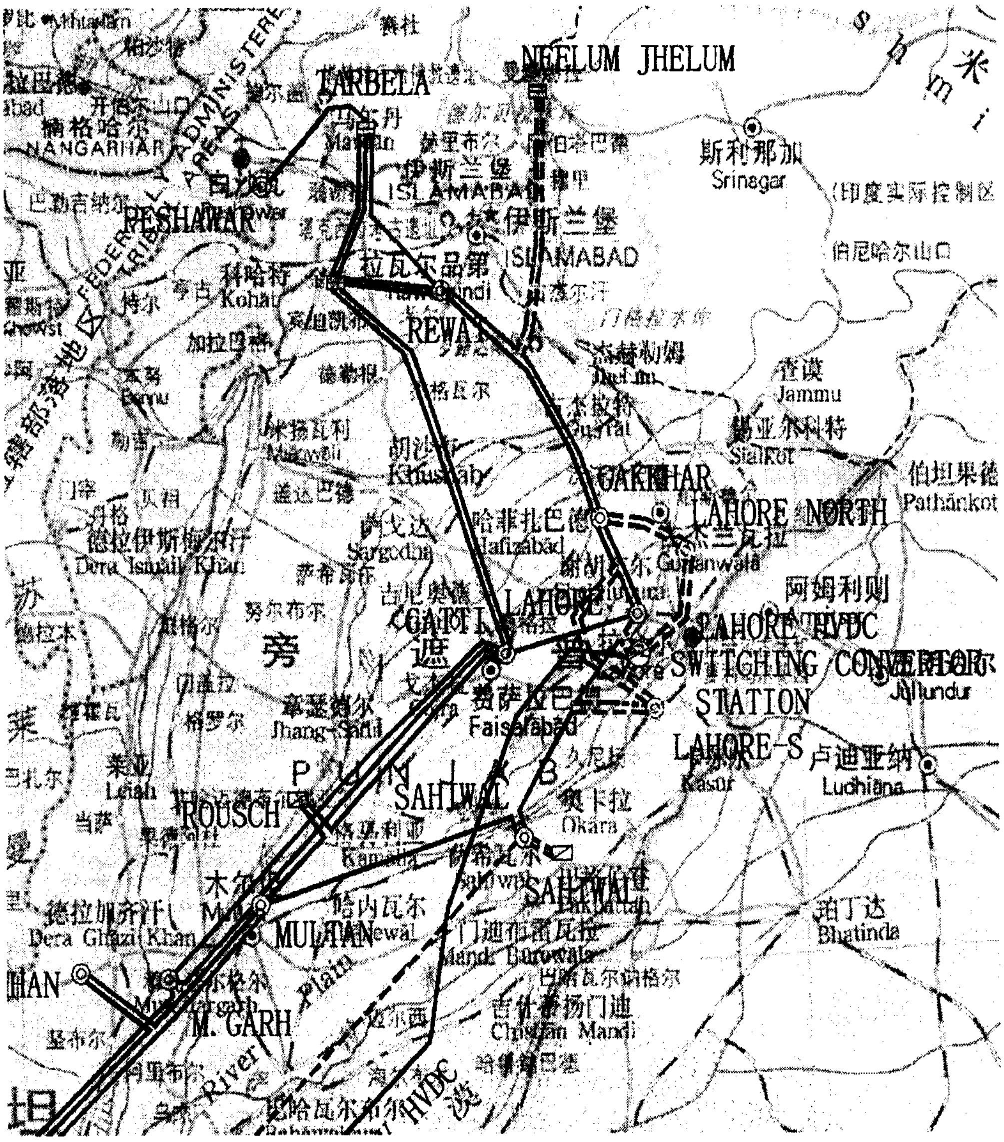

图 3-7 受端换流站接入方案

Fig. 3-7 Access scheme of Lahore Converter Station

3.4 潮流计算
Load flow calculation

计算采用巴基斯坦电网 2018 年夏大方式，根据巴基斯坦国家输电公司（NTDC）提供的《巴基斯坦电网发展规划（National Power System Expansion Plan）(2011 年版)报告》及后续调整资料中的电力平衡，2018 年，不考虑风电出力，南部电力盈余约 3800MW。根据巴方介绍，2018 年除中巴经济走廊项目外，

另新增风电 1410MW，加上中巴经济走廊项目 350MW 风电项目，总共 1760MW 风电，基于风电同时满发几率低，正常方式下 1760MW 风电出力按照 50%考虑，南部外送电力总共为 4600MW，默蒂亚里～拉合尔±660kV 直流工程从南部送电 4000MW 至中部负荷中心，南北 500kV 交流通道从南部外送约 690MW。旁遮普省新增 3 个燃气电厂出力 3000MW、Sahiwal 燃煤电厂出力 1200MW 同时关停负荷中心附近低电压等级机组，考虑 New Kotlakhpat 容量+450/-50MVar 的 SVC 正常运行且系统旋转备用取最大一台单机容量。

In calculation, 2018 summer maximum-load mode is used for the grid of Pakistan. According to power balance in *National Power System Expansion Plan Report (2011 edition)* and subsequent adjustment information provided by NTDC, the surplus electricity in the south in 2018 is about 3800MW without regard to wind power. As introduced by Pakistan side, in 2018 besides 350MW of wind power in the project of China-Pakistan Economic Corridor, 1410MW of wind power is newly added, so there is totally 1760MW of wind power; due to low rate of full capacity operation of wind power, under normal mode, the capacity of 1760MW of wind power is considered as 50% output, and the total power delivered from the south is 4600MW, MATIARI-Lahore ±660kV HVDC project delivers 4000MW of power from the south to central load center, and the south-to-north 500kV HVAC channel delivers about 690MW of power from the south. Three LNG units is added in Punjab with output of 3000MW、Sahiwal coal fire plant output 1200MW, meanwhile the generators connected to the lower voltage level are closed near load center. A SVC with capability of +450/-50MVar is provided in New Kotlakhpat, and one maximum unit installed capacity is considered as the spinning reserve of whole system.

潮流计算表明，送、受端系统潮流分布均匀、电压水平满足要求。与直流并列运行的交流通道 DADU-NEW～SHIKARPUR 和 MORO～R.Y.KHAN 交流送出断面潮流较轻为 290MW。通道 JAMSHORO～DADU-NEW、MATIARI～DADU-NEW 和 MATIARI～MORO 交流送出断面潮流较轻为 690MW。默蒂亚里～拉合尔直流电力主要通过换流站～拉合尔南、换流站～拉合尔、换流站～拉合尔北 3 个通道送出，3 个通道潮流分别为 1234MW、1860MW、802MW。正常方式潮流分布如图 3-8 所示。

The load flow calculation indicates that the load flows of Matiari and Lahore areas are distributed evenly, their voltage levels can meet the requirements. On the HVAC outlet cross sections of JAMSHORO-DADU-NEW and MATIARI-MORO HVAC channels operating in parallel with the HVDC line, the load flow is 290MW, which is light. On the HVAC outlet cross sections of JAMSHORO-DADU-NEW and MATIARI-MORO channels, the load flow is 690MW, which is also light. Matiari-Lahore HVDC power is mainly transmitted through three channels, Lahore South - Converter Station, Lahore - Converter Station and Lahore North - Converter Station, of which, the load flows is 1234MW, 1860MW and 802MW respectively. The load flow distribution under normal mode is as shown in Fig. 3-8.

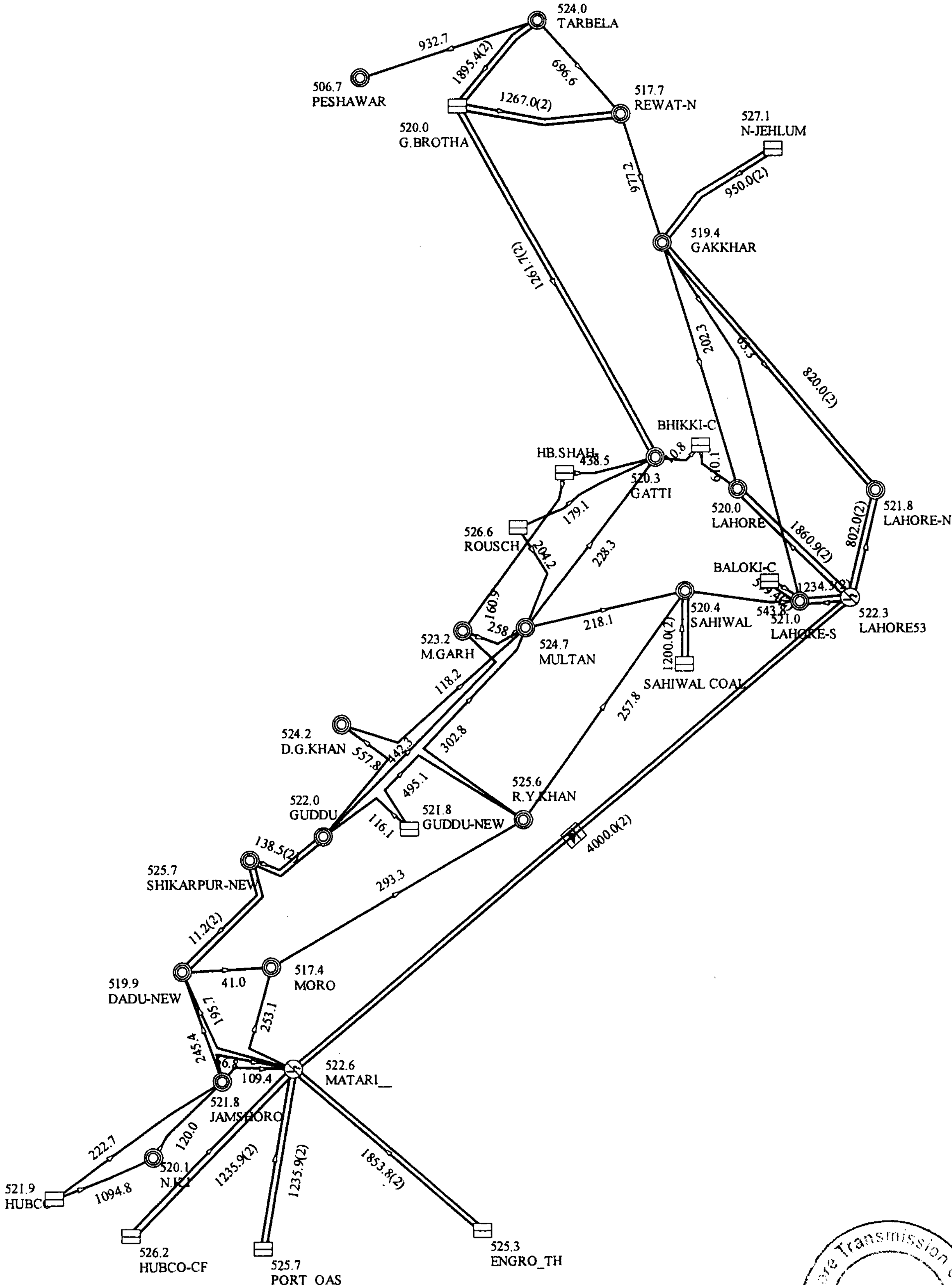

图 3-8 2018 年夏大方式潮流图

Fig. 3-8 Load flow under 2018 summer maximum-load mode

3.5 交流故障对系统的影响
Impacts of AC fault on system

3.5.1 系统运行电压
Operating voltage of system

在保证发电机组运行在较合理的功率因数，并考虑卡拉奇地区 500kV 变电所内配置适当的低压无功补偿容量后，可将换流站的 500kV 母线电压基本控制在合理范围之间。

When it is ensured that the generator unit operates in reasonable power factor and given that appropriate LV reactive compensation capacity is allocated in the Karachi region substations, the 500kV bus voltage of converter stations can be controlled within the reasonable range.

对于推荐的接入方案，根据《巴基斯坦电力监管局并网准则（NEPRA Grid Code）》及 2015 年 7 月 2 号中巴双方专家会议纪要，明确换流站 500kV 的正常电压取 475～540kV，换流站交流侧 500kV 母线额定电压取 500kV，事故后电压取 450～550kV。

For the recommended access scheme, according to *NEPRA Grid Code* and the minutes in China-Pakistan Expert Meeting on July 2, 2015, it is definite that the normal voltage of converter station 500 kV bus is between 475 and 540kV, and the rated voltage of converter station HVAC side 500kV bus is 500kV, and voltage after fault is 450kV - 550kV.

3.5.2 系统频率
System frequency

根据实际系统实际运行情况、《巴基斯坦电力监管局并网准则（NEPRA Grid Code）》及 2015 年 7 月 2 号中巴双方专家会议纪要，明确换流站母线频率正常波动为 50±0.1Hz，当系统发生事故后频率范围暂定为 49.4～50.5Hz，故障清除平稳后波动范围为 50±0.2Hz。

According to actual system operation situations, *NEPRA Grid Code* and the minutes in China-Pakistan Expert Meeting on July 2, 2015, it is definite that the normal fluctuation of the converter station bus frequency is 50±0.1Hz. In case of occurrence of system fault, the frequency range is provisionally determined to be 49.4 - 50.5Hz, and the fluctuation is 50±0.2Hz after the fault is removed.

3.5.3 稳定计算
Stability calculation

直流接入的情况下，相关线路三永故障，保护装置正确动作，系统均可保持稳定，结果如表 3-4 所示。

In case of HVDC access, relevant lines will incur permanent three-phase ground fault. In this case, efforts shall be done to ensure the units to operate properly, thus enabling the system to keep stability. See Table 3-7 for the calculation results.

表 3-4 电网稳定计算结果表
Table 3-4 Stability Calculation Results

线路名称 Name of line	故障类型 Fault type	稳定计算结果 Stability calculation result
MATIARI～MORO	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～JAMSHORO	三永 Permanent three-phase ground fault	稳定 Stable
MORO～DADU-NEW	三永 Permanent three-phase ground fault	稳定 Stable
MORO～R.Y.KHAN	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～THAR COAL PLANT	三永 Permanent three-phase ground fault	稳定 Stable

MATIARI～QASIM COAL PLANT	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～NEW HUBCO COAL PLANT	三永 Permanent three-phase ground fault	稳定 Stable
LAHORE 换流站～LAHORE SOUTH LAHORE Converter station～LAHORE SOUTH	三永 Permanent three-phase ground fault	稳定 Stable
LAHORE 换流站～LAHORE LAHORE Converter station～LAHORE	三永 Permanent three-phase ground fault	稳定 Stable
换流站～LAHORE NORTH LAHORE Converter station～LAHORE NORTH	三永 Permanent three-phase ground fault	稳定 Stable
LAHORE NORTH～GAKKHAR	三永 Permanent three-phase ground fault	稳定 Stable
GAKKHAR～LAHORE SOUTH	三永 Permanent three-phase ground fault	稳定 Stable
GAKKHAR～LAHORE	三永 Permanent three-phase ground fault	稳定 Stable
SAHIWAL～LAHORE SOUTH	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～THAR COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 1000MW 负荷 1000MW load shedding
MATIARI～QASIM COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 400MW 负荷 400MW load shedding
MATIARI～NEW HUBCO COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 400MW 负荷 400MW load shedding
LAHORE 换流站～LAHORE SOUTH LAHORE Converter station～LAHORE SOUTH	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
LAHORE 换流站～LAHORE LAHORE Converter station～LAHORE	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
LAHORE 换流站～LAHORE NORTH LAHORE Converter station～LAHORE NORTH	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
LAHORE NORTH～GAKKHAR	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable

1）选取潮流最重的 Moro～R.Y. KHAN 线路三永 N-1，对应的系统响应曲线为：

1）where, permanent three-phase ground fault N-1 for Moro-R.Y.KHAN line whose load is heavest, the corresponding system response curve is as follows:

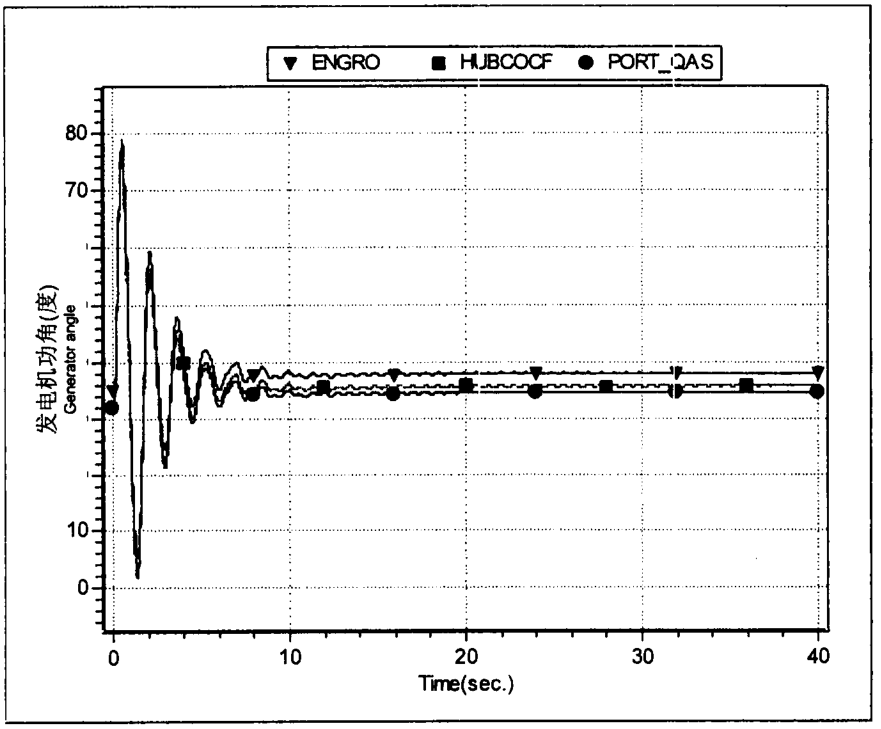

图 3-9 Moro～R.Y.KHAN 线路三永 N-1 故障南部机组相对北部 G.BROTH 机组功角差
Fig.3-9 Moro-R.Y.KHAN Line Permanent Three-phase Ground N-1 Fault-related south generator angle differences to G.BROTH generator angle

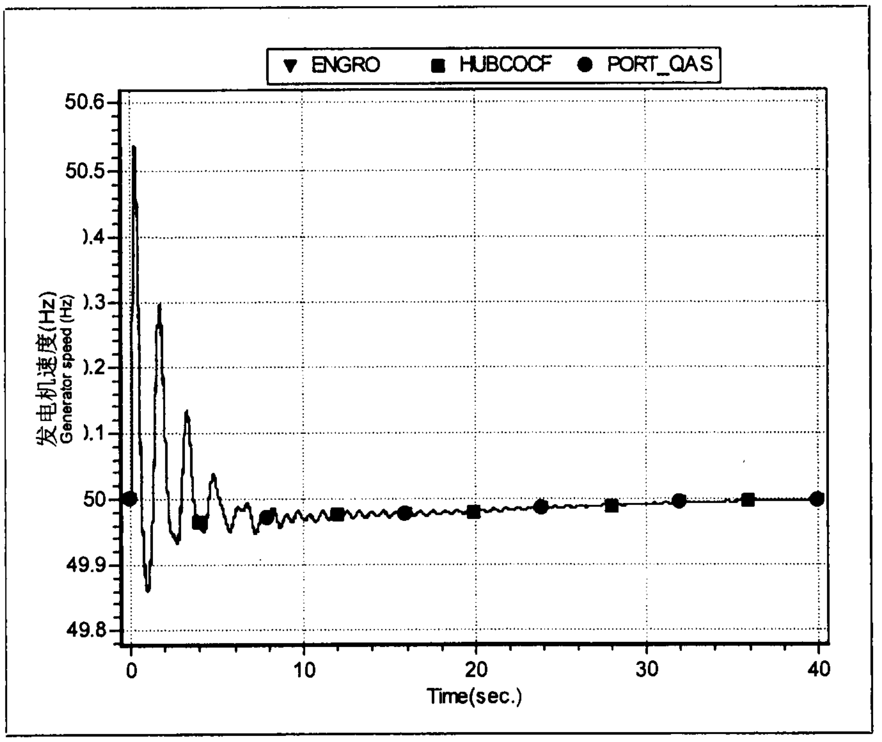

图 3-10 Moro～R.Y.KHAN 线路三永 N-1 故障南部机组发电机速度
Fig.3-10 Moro-R.Y.KHAN Line Permanent Three-phase Ground N-1 Fault-related south generator speed

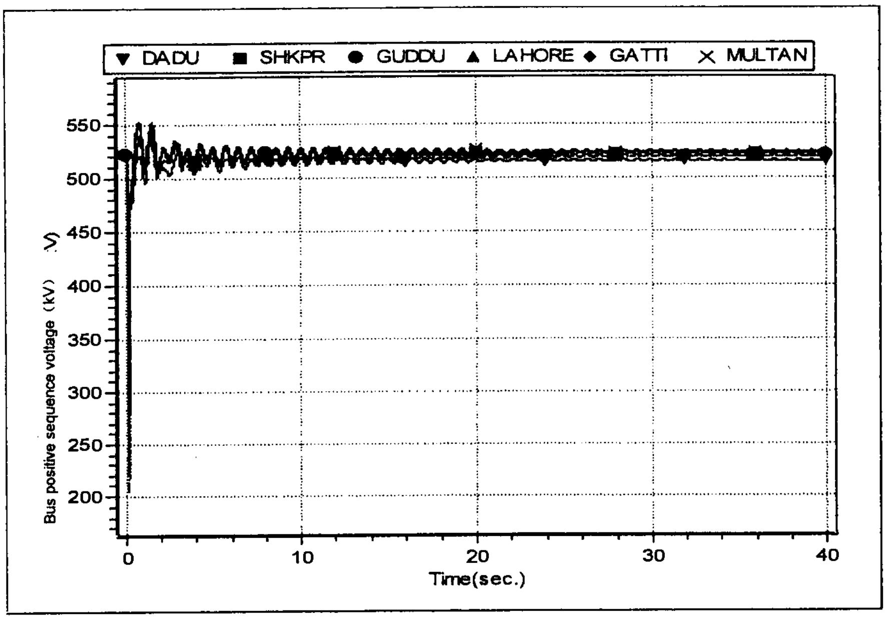

图 3-11　Moro～R.Y.KHAN 线路三永 N-1 故障相关母线电压图

Fig.3-11 Moro-R.Y.KHAN Line Permanent Three-phase Ground N-1 Fault-related Bus Voltage Graph

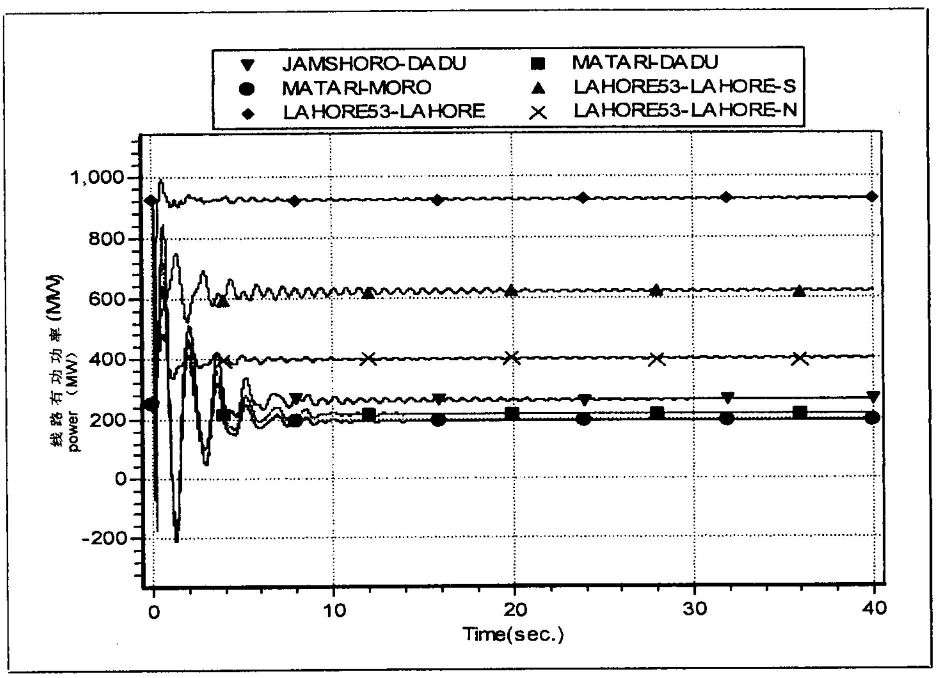

图 3-12　Moro～R.Y.KHAN 线路三永 N-1 故障交流线路功率曲线图

Fig.3-12 Moro～R.Y.KHAN Line Permanent Three-phase Ground N-1 Fault AC Power Curve

Moro～R.Y.KHAN 线路三永 N-1 故障后，南北机组功角差第一摆约 80 度，功角稳定，由于交流通道潮流较轻,交流三永 N-1 故障对影响较小，送受端相关母线电压可恢复到合理范围内。Moro～R.Y. KHAN 500kV 线路上的 293MW 潮流大部分通过 MORO～DADU-NEW 500kV 线路转移。

When there is a three-phase permanent ground N-1 fault in Moro～R.Y.KHAN line, the first swing of south generator angle difference with north generator is about 80 degrees. The generator is not step-out and the power angle is stable. Due to low load flow in AC channel, AC permanent three-phase ground N-1 fault has little influence on system, and the voltage can restore to the reasonable range. Most power of 293MW load flow in MORO-R.Y. KHAN 500kV line is transferred through MORO-DADU-NEW 500kV line.

2）LAHORE 换流站～LAHORE 线路三永 N-1，对应的系统响应曲线为：

2）Where, LAHORE Converter station～LAHORE Line occurs permanent three-phase ground N-1 fault, corresponding to the following system response curve:

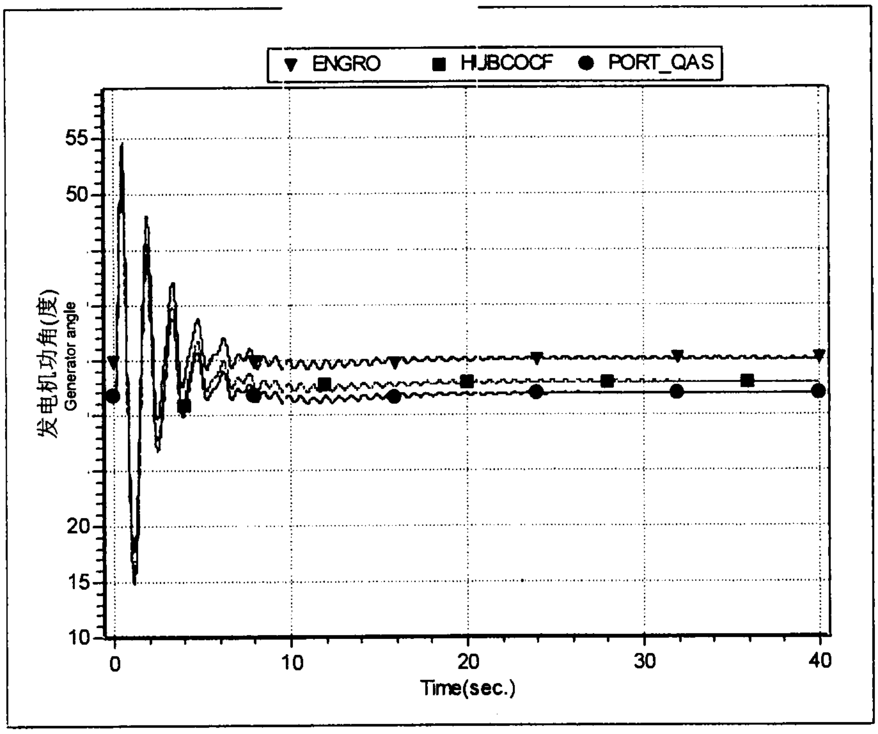

图 3-13　LAHORE Converter station～LAHORE 线路三永 N-1 故障南部机组相对北部 G.BROTH 机组功角差
Fig.3-13 LAHORE Converter station～LAHORE Line Permanent Three-phase Ground N-1 Fault-related south generator angle differences to G.BROTH generator angle

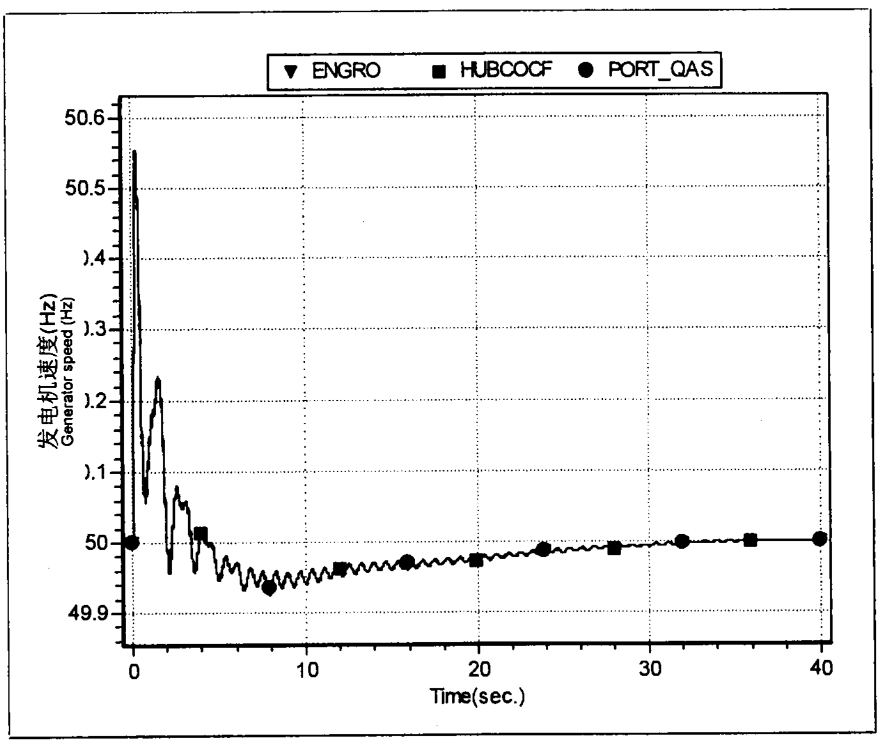

图 3-14　LAHORE Converter station～LAHORE 线路三永 N-1 故障南部机组发电机速度
Fig.3-14 LAHORE Converter station～LAHORE Line Permanent Three-phase Ground N-1 Fault-related south generator

speed

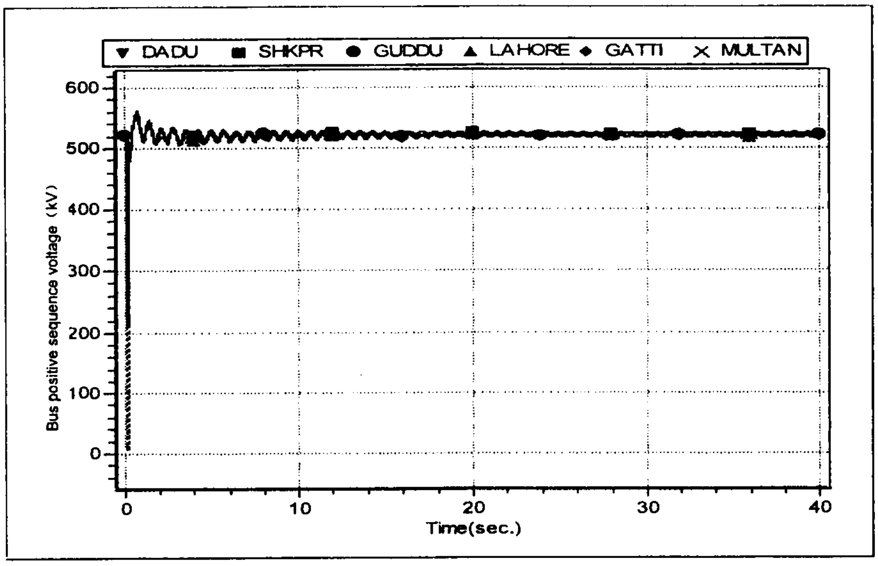

图 3-15 LAHORE Converter station～LAHORE 线路三永 N-1 故障相关母线电压图
Fig.3-15 LAHORE Converter station～LAHORE Line Permanent Three-phase Ground N-1 Fault-related Bus Voltage Graph

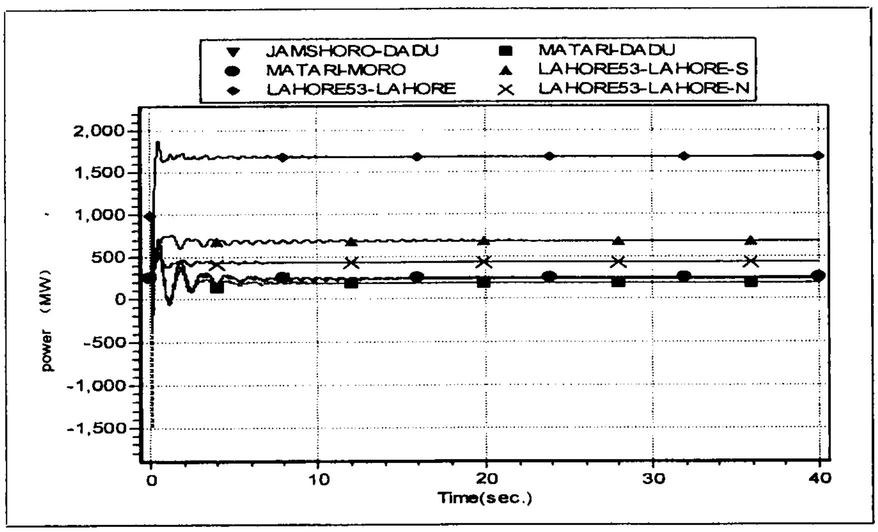

图 3-16 LAHORE Converter station～LAHORE 线路三永 N-1 故障交流线路功率曲线图
Fig.3-16 LAHORE Converter station～LAHORE Line Permanent Three-phase Ground N-1 Fault AC Power Curve

LAHORE 换流站～LAHORE 线路三永 N-1 故障后，南部机组相对北部机组功角差约 40 度，功角稳定。相关母线电压可恢复到合理范围内。LAHORE 换流站～LAHORE 500kV 双回线路上的 1860MW 潮流通过剩余一回线路转移 1670MW，LAHORE 换流站～LAHORE-N 双回线路潮流从 802MW 增加到 860MW，LAHORE 换流站～LAHORE-S 双回线路潮流从 1234MW 增加到 1348MW。由于 LAHORE 端负荷中心网架较强，交流线路三永 N-1 故障对系统影响较小。

When there is a permanent three-phase ground N-1 fault in LAHORE converter station-LAHORE line, the first swing of power angle difference between south generator and north generator is about 40 degrees and the power angle is stable. The related bus voltage can return to the reasonable range. 1860MW load flow in LAHORE converter station-LAHORE double-circuit 500kV line is transferred through surplus single-circuit line by 1670MW, the load flow of LAHORE converter station-LAHORE-N double-circuit line is increased from 802MW to 860MW, and that of LAHORE converter station-LAHORE-S double-circuit line is increased from 1234MW to 1348MW. Due to the strong network of load center, AC line permanent three-phase ground N-1 fault has little influence on system.

3）MATIARI～THAR COAL PLANT 线路三永 N-2，对应的系统响应曲线为：

3）For MATIARI～THAR COAL PLANT line permanent three-phase ground N-2, the corresponding system response curve is as follows:

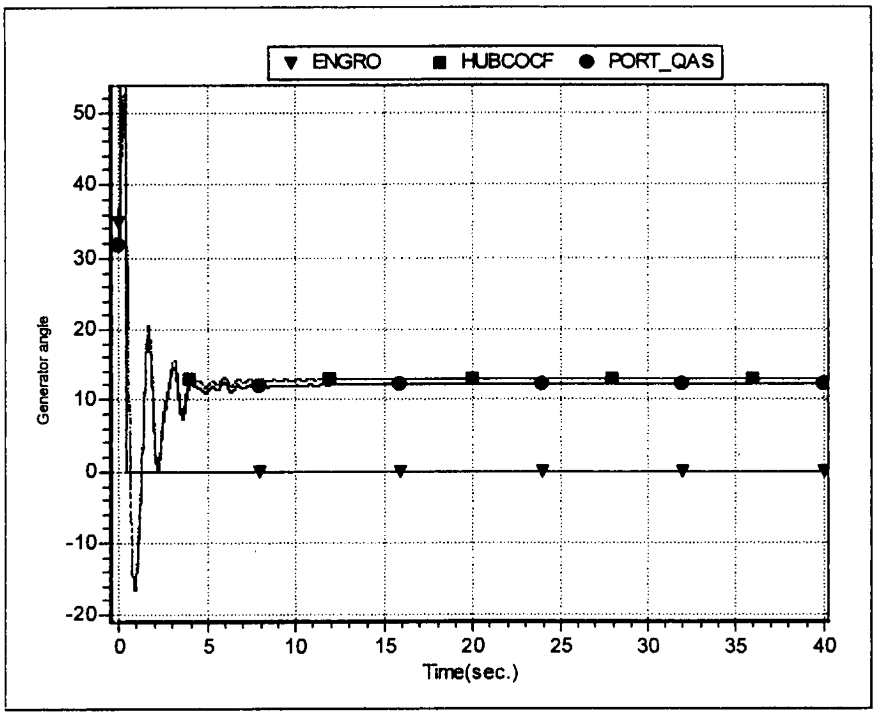

图 3-17 MATIARI～THAR COAL PLANT 线路三永 N-2 故障南部机组相对北部 G.BROTH 机组功角差
Fig.3-17 MATIARI～THAR COAL PLANT Line Permanent Three-phase Ground N-2 Fault -related south generator angle differences to G.BROTH generator angle

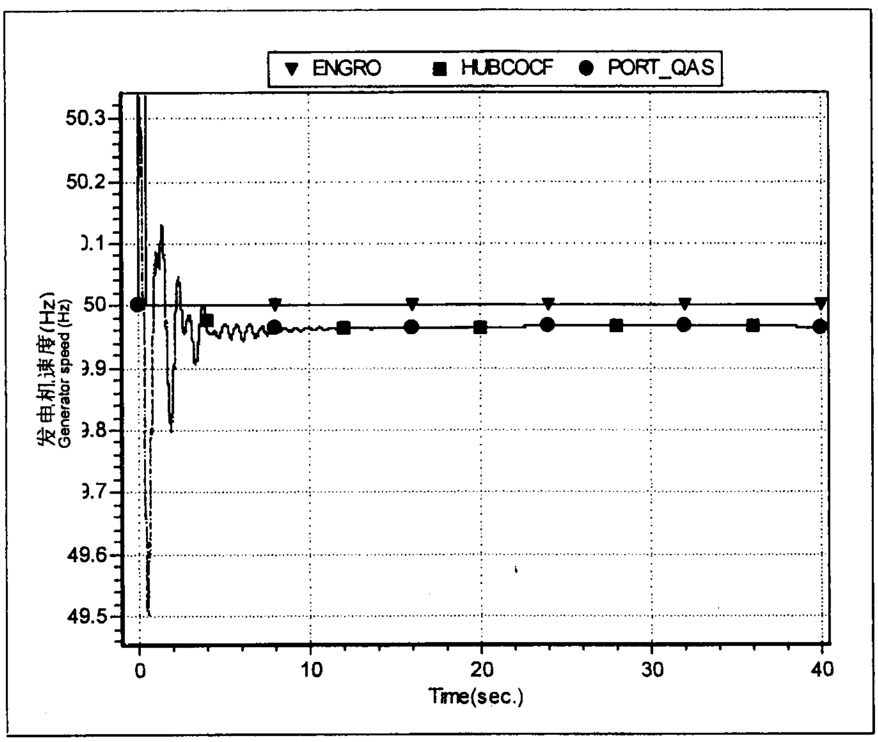

图 3-18 MATIARI～THAR COAL PLANT 线路三永 N-2 故障故障南部机组发电机速度
Fig.3-18 MATIARI～THAR COAL PLANT Line Permanent Three-phase Ground N-2 Fault -related south

generator speed

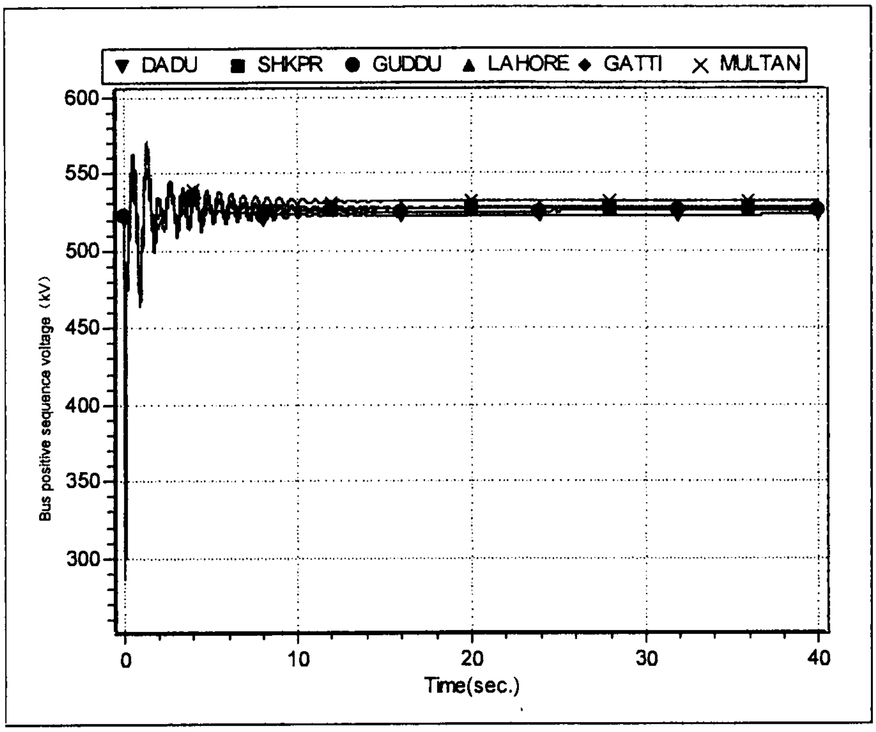

图 3-19　MATIARI～THAR COAL PLANT 线路三永 N-2 故障相关母线电压图

Fig.3-19 MATIARI～THAR COAL PLANT Line Permanent Three-phase Ground N-2 Fault-related Bus Voltage Graph

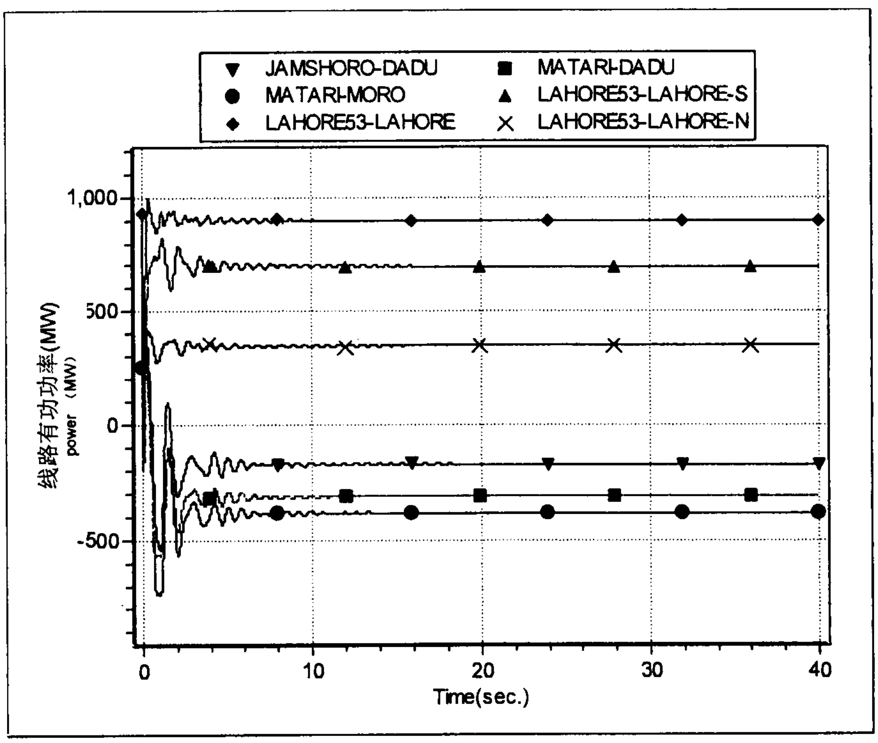

图 3-20　MATIARI～THAR COAL PLANT 线路三永 N-2 故障交流线路功率曲线图

Fig.3-20 MATIARI～THAR COAL PLANT Line Permanent Three-phase Ground N-2 Fault AC Power Curve

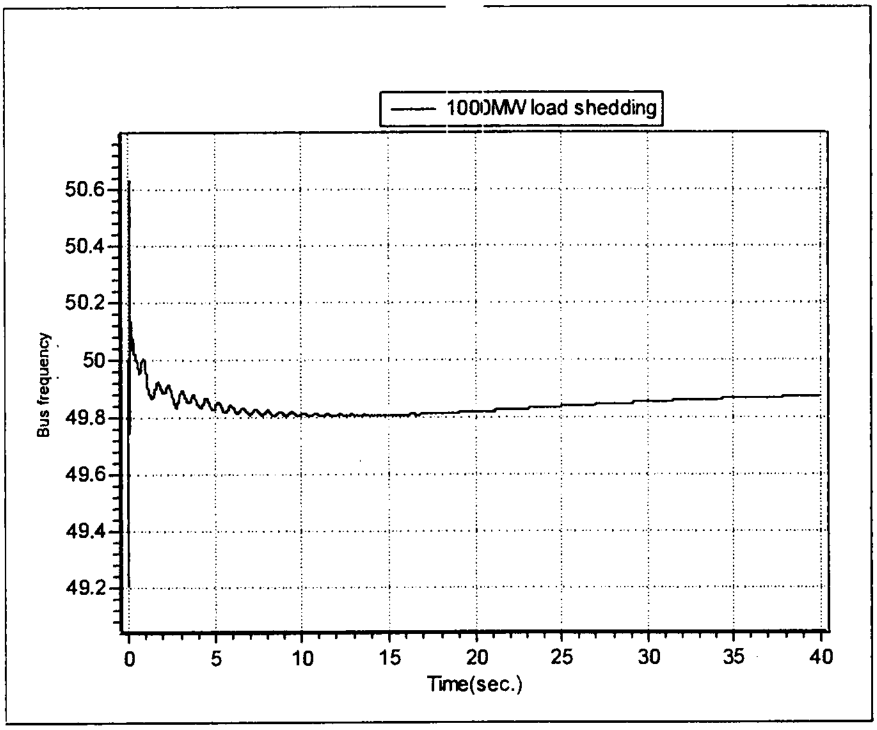

图 3-21 MATIARI～THAR COAL PLANT 线路三永 N-2 故障母线频率曲线图
Fig.3-21 MATIARI～THAR COAL PLANT Line Permanent Three-phase Ground N-2 Fault Bus Frequency Curve

MATIARI～THAR COAL PLANT 线路三永 N-2 故障后，送端损失 1800MW 功率，频率最低为 48.9Hz，切除 1000MW 负荷后，频率可恢复到允许范围内。MATIARI～QASIM COAL PLANT 和 MATIARI～NEW HUBCO COAL PLANT 发生线路三永 N-2 故障，分别切除 400MW 负荷，系统频率可恢复到允许范围。

When there is a three-phase permanent ground N-2 fault in MATIARI～THAR COAL PLANT line, the sending-end will lose the power of 1800MW and the lowest frequency will be 48.9Hz, but after the 1000MW load shedding, the frequency can return to allowable range. When there is a three-phase permanent ground N-2 fault in MATIARI～QASIM COAL PLANT line and MATIARI～NEW HUBCO COAL PLANT line, with 400MW load shedding respectively from each line, the system frequency can restore to allowable range.

3.6 直流故障对系统的影响
Impacts of DC fault on system

3.6.1 直流闭锁对系统的影响
Impacts of DC block on system

对直流计算单、双极闭锁故障，稳定计算结果表明，默蒂亚里～拉合尔直流工程发生单极闭锁故障，不需要采取措施,系统保持稳定运行；发生双极闭锁故障，需要分别采取送端切机 2640MW、受端切负荷 1700MW 的措施，占全网负荷比例 6%，采取措施后系统恢复稳定运行。

Calculate HVDC monopole and bipolar block faults. Stability calculation result shows that, when Matiari-Lahore HVDC Project encounters monopole block fault, no load shedding is required and the system maintains stable operation. When Matiari-Lahore HVDC Project encounters bipolar block fault, 2640MW units require to be switched off and load shedding of 1700MW is required, accounting for 6% of the loads of the whole grid; after taking these measures, the system resumes stable operation.

1）单极闭锁故障，系统相关曲线如下图：

1）In a monopole block fault, the relevant curve of system is indicated below:

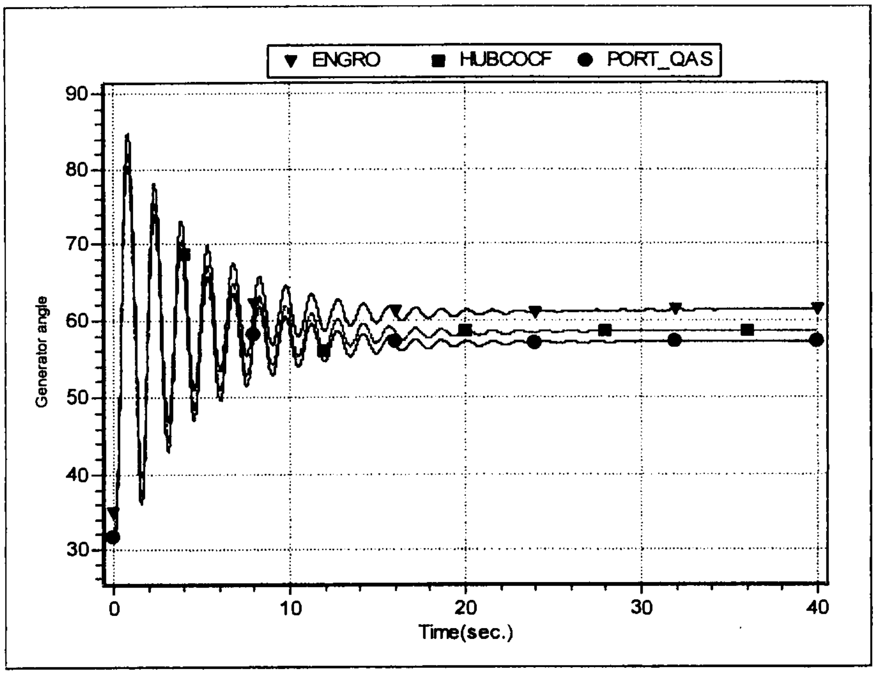

图 3-22 直流单极闭锁故障南部机组相对北部 G.BROTH 机组功角差
Fig.3-22 HVDC Monopole Block Fault-related south generator angle differences to G.BROTH generator angle

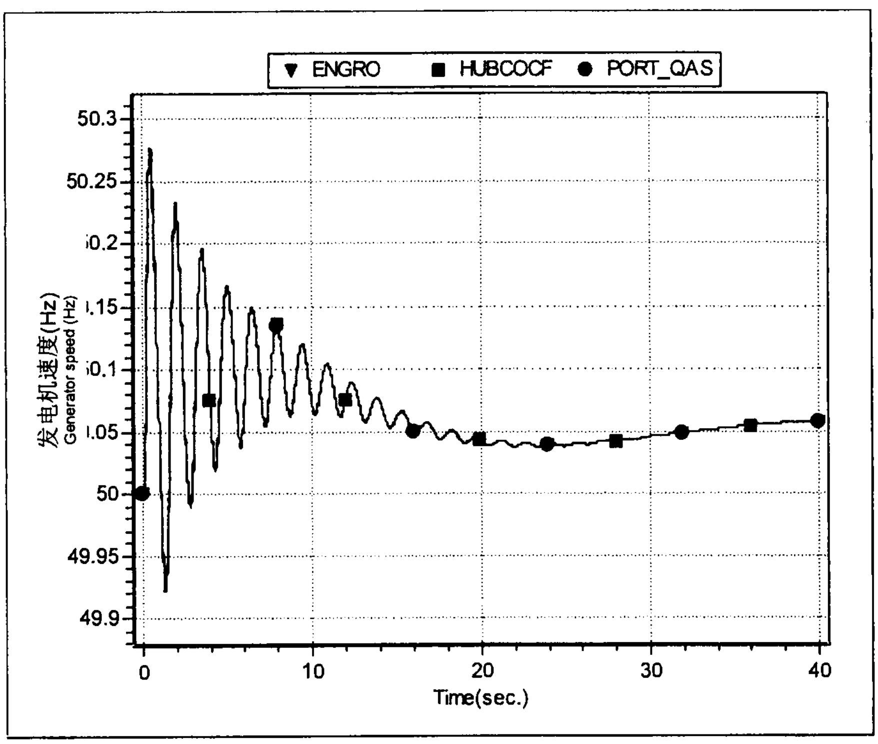

图 3-23 直流单极闭锁故障故障南部机组发电机速度
Fig.3-23 HVDC Monopole Block Fault -related south generator speed

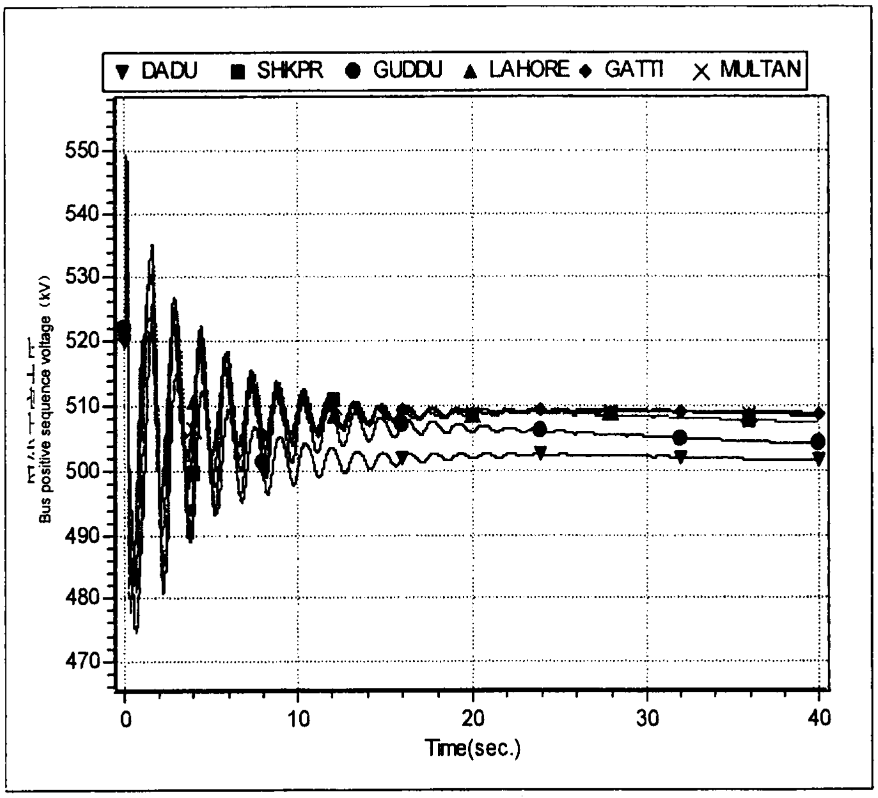

图 3-24 直流单极闭锁故障相关母线电压图
Fig.3-24 HVDC Monopole Block Fault -related Bus Voltage Graph

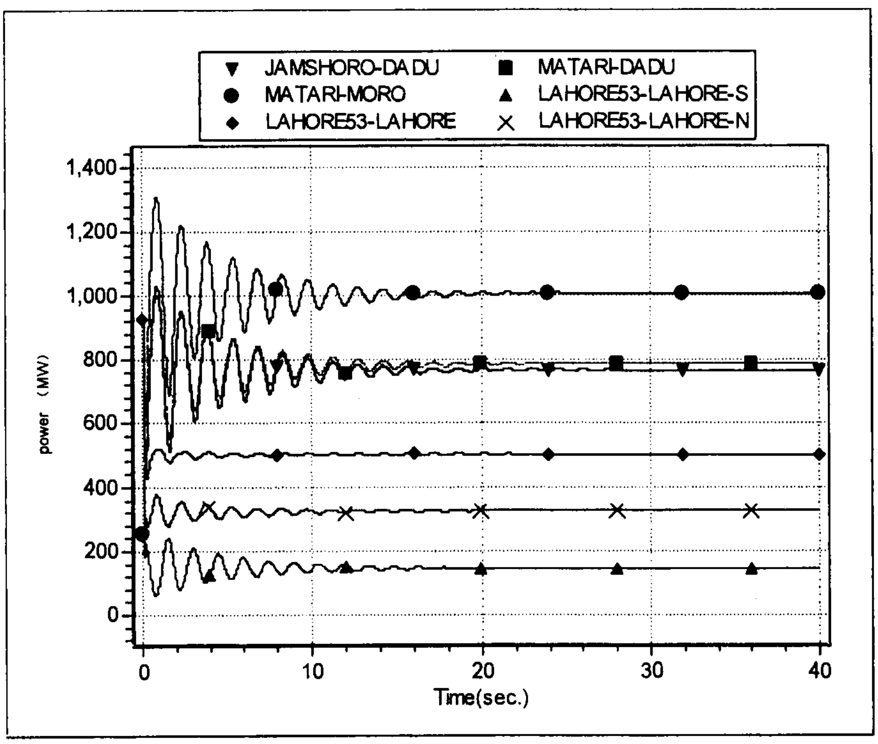

图 3-25 直流单极闭锁故障交流线路功率曲线图
Fig.3-25 HVDC Monopole Block Fault AC Power Curve

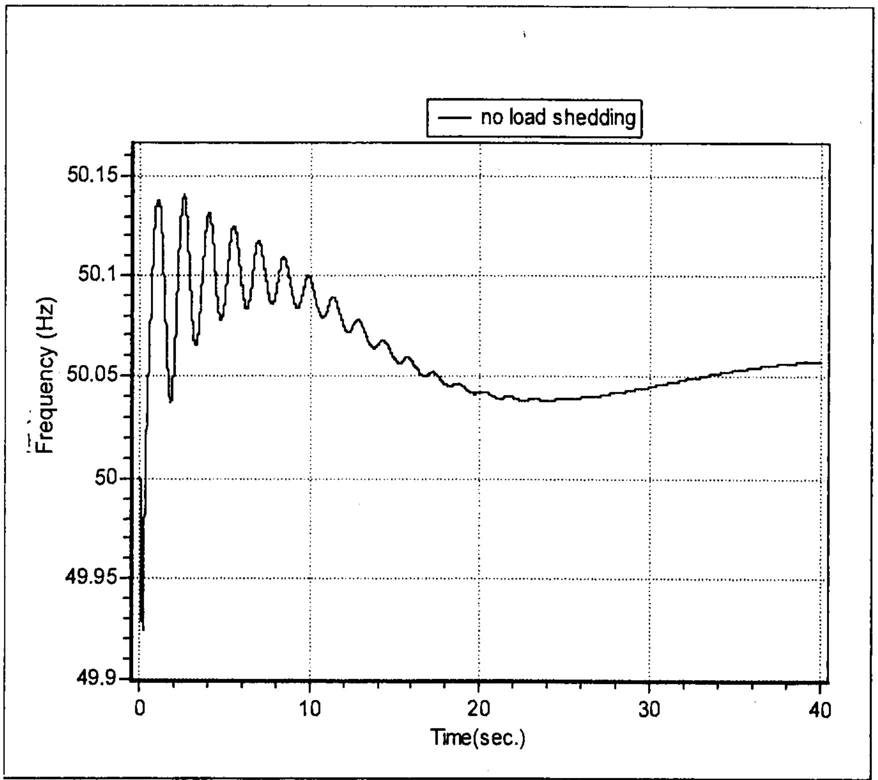

图 3-26 直流单极闭锁故障系统频率曲线图
Fig. 3-26 HVDC Monopole Block Fault System Frequency Curve

可以看出，直流单极闭锁后，盈余功率转移到并列运行的交流通道上，交流系统能够承受。故障后第一摆南北机组功角差约 50 度，功角稳定。故障后电压可恢复到合理范围，系统频率最低约为 49.9Hz，系统频率稳定。

It can be seen that, after HVDC monopole block occurs, the power surplus shifts to the HVAC channel in parallel operation, and the AC system can withstand it. The first swing of power angle difference between south and north generator is about 50 degrees and power angle is stable. The voltage can return to allowable range. The frequency of the system is stable, with the lowest frequency at approximately 49.9Hz.

2）双极闭锁故障不采取措施系统失稳，系统相关曲线如下图：

2）In a bipolar block fault without control measures the system is unstable, the relevant curve of system is indicated below:

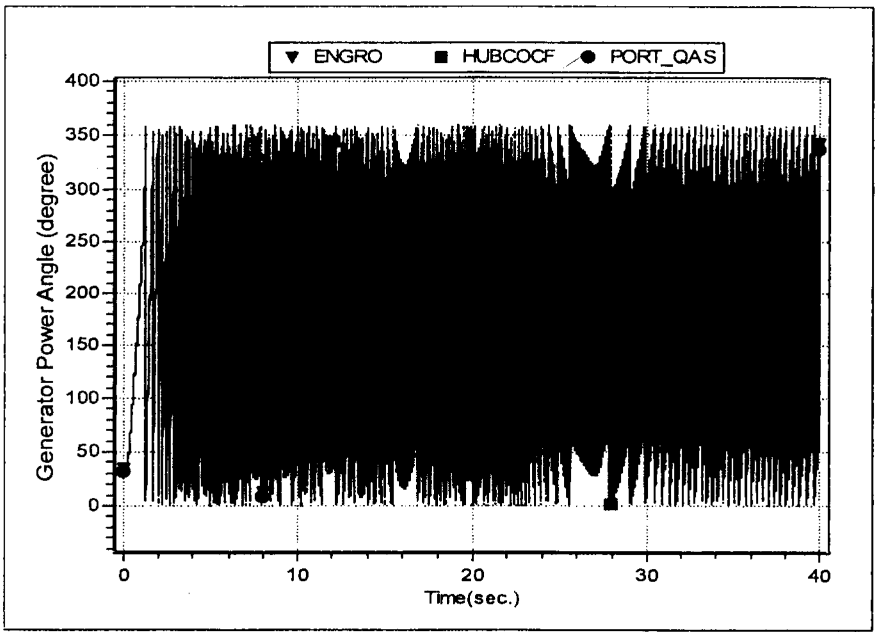

图 3-27 直流双极闭锁故障送端机组功角曲线图
Fig.3-27 HVDC Bipolar Block Fault Power Angle Graph

双极闭锁故障后，采取切除送端 2640MW 机组，受端 1700MW 负荷，系统可保持稳定。系统相关曲线如下图：

In case of bipolar block fault, 2640MW units require to be switched off and load shedding of 1700MW is required, and after taking these measures, the system resumes stable operation. The relevant curve of system is indicated below:

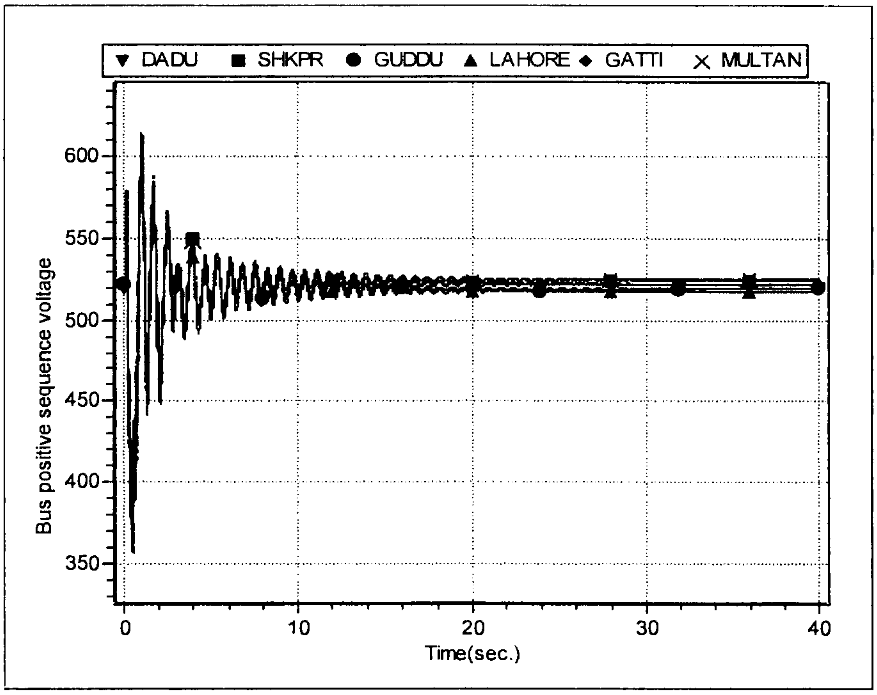

图 3-28 直流双极闭锁故障相关母线电压图
Fig. 3-28 HVDC Bipolar Block Fault-related Bus Voltage Graph

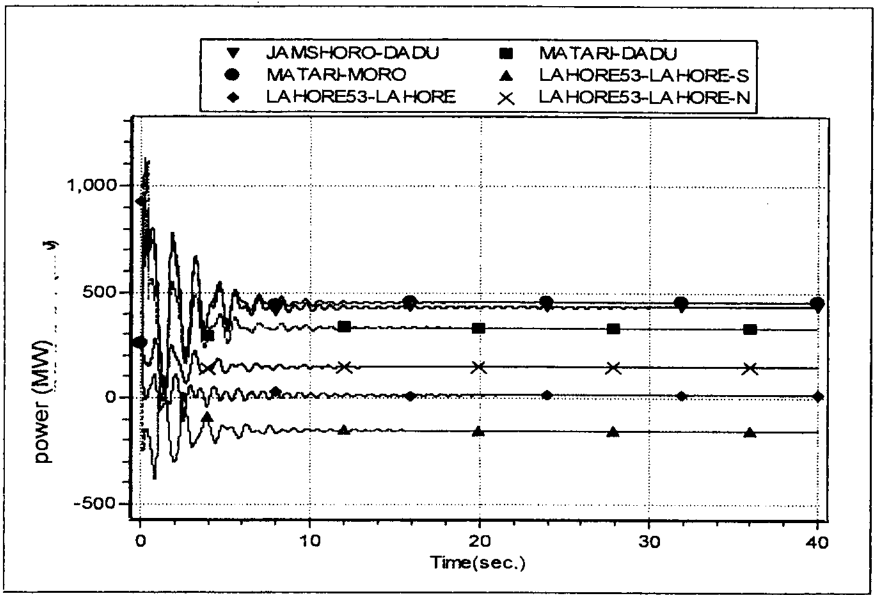

图 3-29 直流双极闭锁故障交流线路功率曲线图
Fig. 3-29 HVDC Bipolar Block Fault AC Power Curve

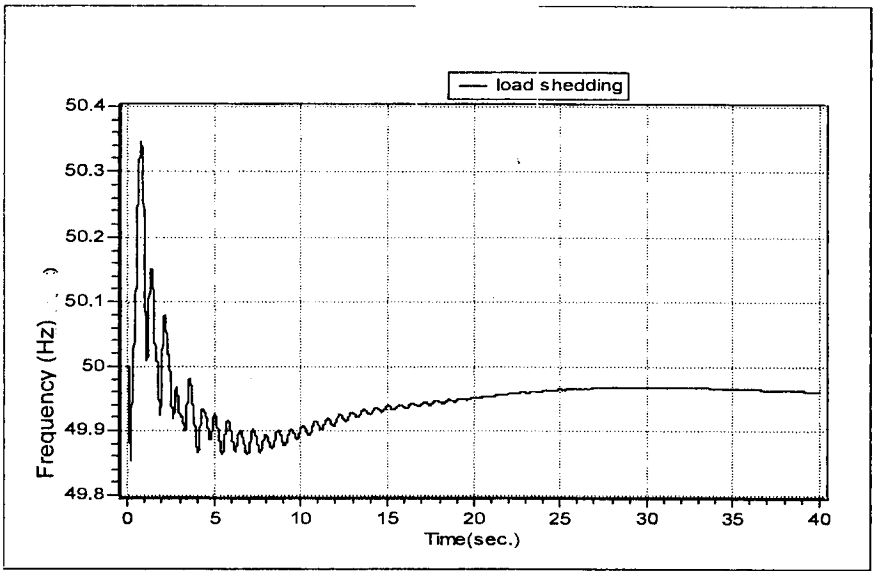

图 3-30 直流双极闭锁故障系统频率曲线图
Fig. 3-30 HVDC Bipolar Block Fault System Frequency Curve

以直流单极闭锁为例，分析直流闭锁对换流母线以及网内相关母线电压的影响：滤波器未切除期间，母线电压升高，最高约 1.10p.u.（550kV）左右；滤波器切除后，各母线电压均有所下降，电压最低降至约 0.96p.u.(480kV)左右。电压下降的主要原因是直流闭锁后的过剩功率将由南往北向交流网内涌动，从而带来沿途电压下降，并未影响系统的正常运行。如果双极闭锁后采取送端切机 2640MW、受端切负荷 1700MW 的措施，降低沿途电压在可接受范围内，系统频率不失稳。

Taking HVDC monopole block fault as an example, analyze the impacts of HVDC block on voltages of converting bus and related buses within the grid. Before switching off filter, the bus voltage increases, up to about 1.10p.u. (550kV); after switching off filter, every bus voltage decreases, and the voltage is reduced at the lowest to about 0.96p.u.(480kV). The main cause for voltage drop is the shift of power surplus to the AC grid from south to north after HVDC block, leading to voltage drop along the line, yet the normal system operation is not influenced. If after bipolar block, 2640MW units are switched off and 1700MW loads are shedded, so as to reduce the voltage along the line to an acceptable range, the system frequency does not lose its stability.

3.6.2 直流换相失败对系统的影响
Impacts of DC commutation failure on system

直流受端网内逆变站出口处发生三相短路故障（0.1 秒～0.2 秒），将导致直流发生换相失败，相关曲线如下图所示：

When three-phase short-circuit fault (0.1s – 0.2s) occurs at the outlet of the inversion station within the grid at HVDC Lahore side, the DC commutation is fail, with the relevant curve indicated below:

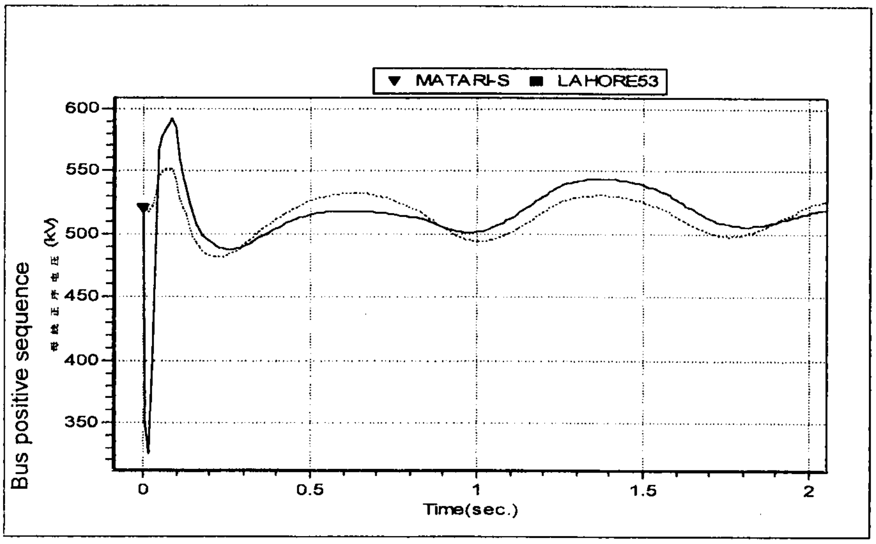

图 3-31　直流换相失败故障相关母线电压图
Fig. 3-31 HVDC Commutation Failure-related Bus Voltage Graph

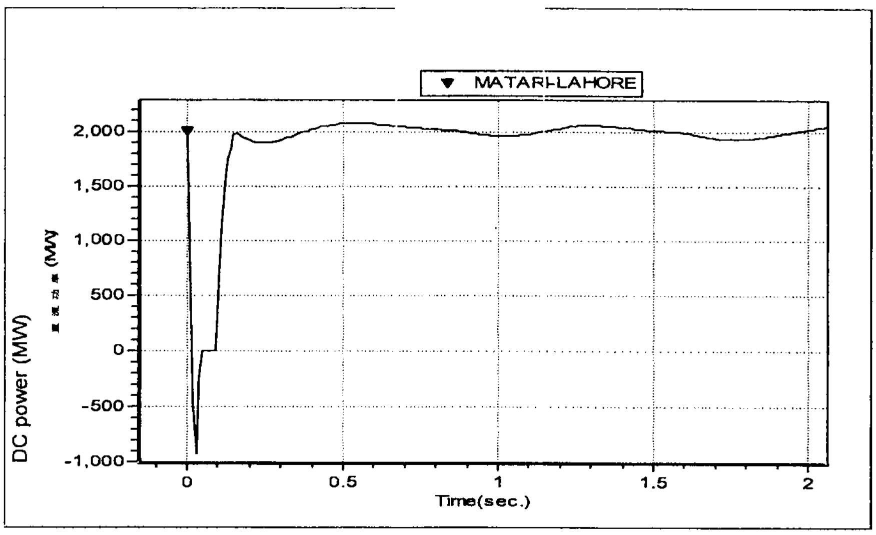

图 3-32　直流换相失败故障直流线路功率曲线图
Fig. 3-32 DC Commutation Failure DC Power Curve

可以看出，直流一次换相失败时，直流功率受阻约 0.2 秒，将导致送端换流站及附近母线电压先降后升，最高约 1.18 p.u.（588kV）左右，在机组可承受范围内，随着直流功率的恢复，母线电压经过波动后也逐渐恢复至初始水平。

It can be seen that, in a HVDC primary commutation failure, the DC power is obstructed 0.2s approximately, leading to voltage decreasing first and then rising at the Matiari converter station and bus nearby, reaching the highest voltage of about 1.18 p.u. (588kV), which is under the bearable range of unit. With the recovery of HVDC power, the bus voltage will be restored to the original level after fluctuation.

3.6.3 直流再启动对系统的影响
Impacts of DC restart on system

直流单极再启动故障下，相关曲线如下所示：

In a HVDC monopole restart fault, the relevant curve is indicated below:

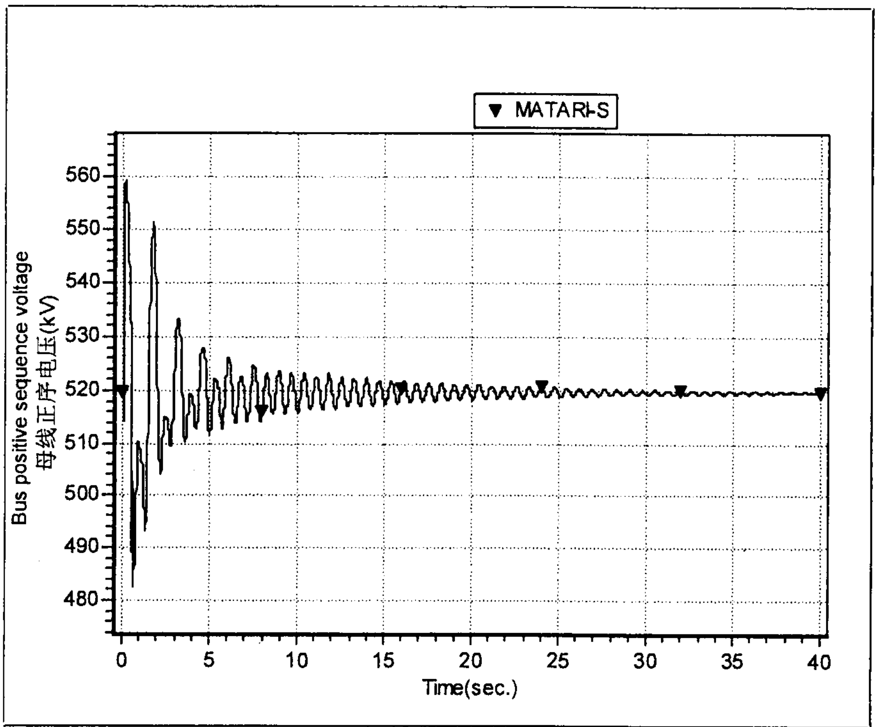

图 3-33　直流单极再启动故障换流站母线电压图
Fig. 3-33 HVDC Monopole Restart Fault Converter Station Bus Voltage Graph

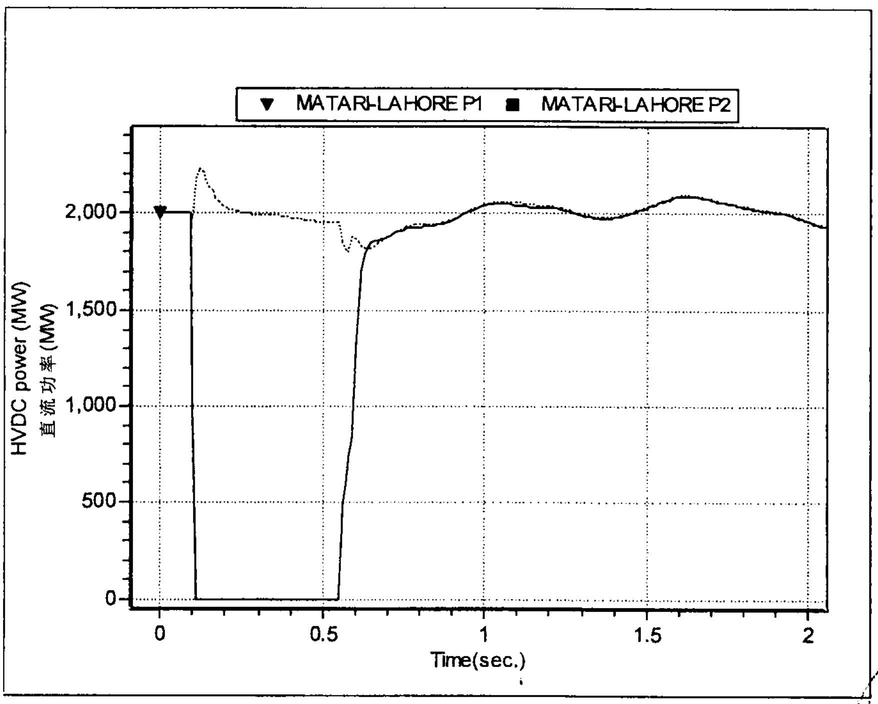

图 3-34 直流单极再启动故障直流线路功率曲线图
Fig. 3-34 HVDC Monopole Restart Fault DC Power Curve

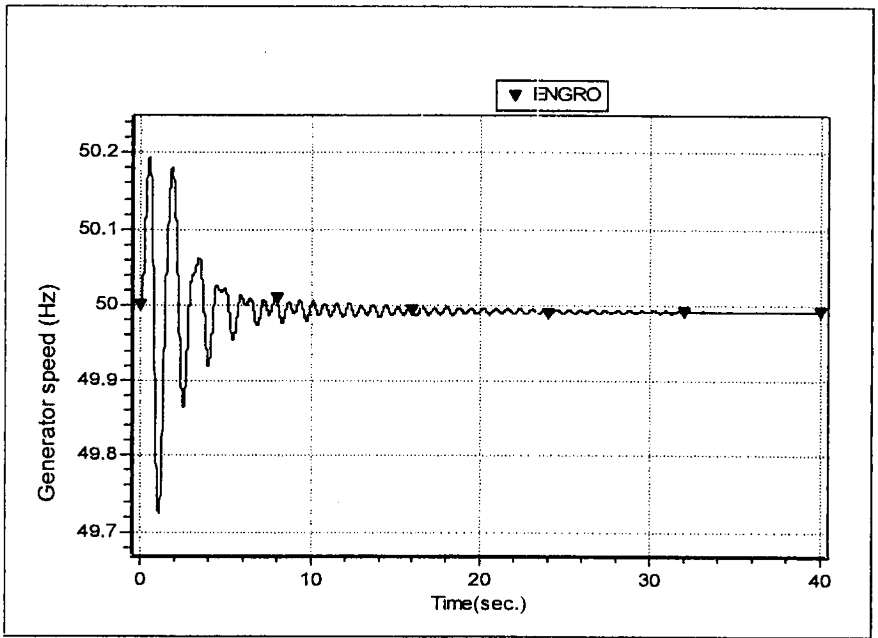

图 3-35 直流单极再启动故障送端机组频率曲线图
Fig. 3-35 HVDC Monopole Restart Fault Sending-end Unit Frequency Curve

可以看出，直流故障后，经过 0.15 秒去游离过程，直流再启动成功，将导致换流站及附近母线电压先升后降，最高约 1.11 p.u.（559kV）左右，随着直流再启动成功后功率的恢复，母线电压经过波动后也逐渐恢复至初始水平，送端机组频率在安全范围内。

It can be seen that, when a HVDC fault occurs, after a 0.15s process of deionization, HVDC restart succeeds, leading to voltage rising first and then decreasing at the converter station and bus nearby, reaching the highest voltage of about 1.11 p.u.(559kV). With the recovery of power after HVDC restart succeeds, the bus voltage is gradually restored to the original level after fluctuation, and the south generation unit frequency is within the safe range.

3.6.4 考虑直流过负荷能力
Consideration of DC overloading capacity

直流输电系统一般运行在连续额定功率状态，但从设备的设计裕度、环境温度变化等因素考虑，直流系统都具有一定的过负荷能力。直流的过负荷能力可按过负荷时间长短分为暂时过负荷能力和短期过负荷能力。

DC power transmission system generally operates at continuous rated power. But considering the design allowance of equipment and change of environmental temperature, all DC systems have a certain overloading capacity. The DC overloading capacity may be divided into transient overloading capacity and short-time overloading capacity according to the length of duration of overloading time.

直流暂态过负荷能力越强，对提高系统的暂态稳定水平越有利。直流短时过负荷能力的主要作用是在交、直流设备因故退出运行后，利用运行的直流设备的过负荷能力多送电，以便减少对电网运行的影响。

The stronger the DC transient overloading capacity is, the more contribution is made to improvement of transient stability level of system. The main benefit of DC short-time overloading capacity lies in that, after operation suspension of AC/CD equipment for some reasons, more power is transmitted by the overloading capacity of the operating DC equipment, so as to reduce the impact to the grid.

根据宁东直流设计标准，在不额外增加换流设备投资的原则下，直流系统 3 秒钟暂时过负荷能力暂按额定输送容量的 1.2 倍考虑，直流系统 2 小时直流过负荷能力暂按额定输送容量的 1.1 倍考虑。

According to the design standards of Ning-Dong HVDC Project, under the principle that no extra investment is made to converting equipment, the 3s transient overloading capacity of HVDC system is temporarily decided to be 1.2 times the rated transmission capacity, and the 2h short-time overloading capacity of DC system is temporarily decided to be 1.1 times the rated transmission capacity.

直流发生单极闭锁故障时，稳定计算时考虑直流 3 秒钟 1.2 倍的过负荷能力，3 秒后考虑 1.1 倍 2 小时的过负荷能力，单极闭锁稳定，不需要采取切机切负荷的措施，相关曲线如下图所示：

At a HVDC monopole block fault, the stability calculation considers the HVDC 3s overloading capacity at 1.2 times the rated transmission capacity and the 2h short-time overloading capacity at 1.1 times the rated transmission capacity after the first 3s. The monopole block is stable, no switching off or load shedding is required, with the related curve indicated below:

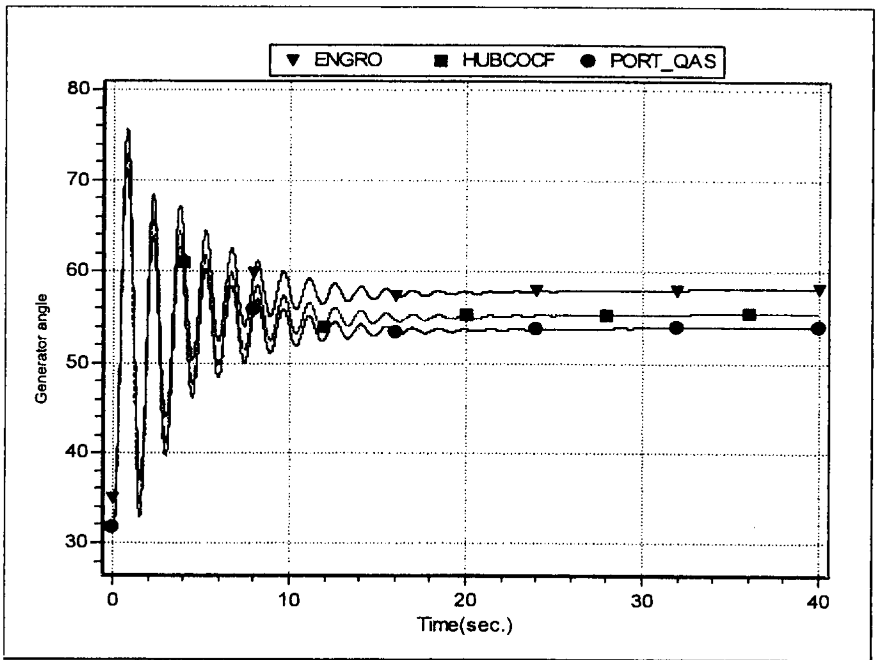

图 3-36 直流单极闭锁故障南部机组相对北部 G.BROTH 机组功角差
Fig.3-36 HVDC Monopole Block Fault-related south generator angle differences to G.BROTH generator angle

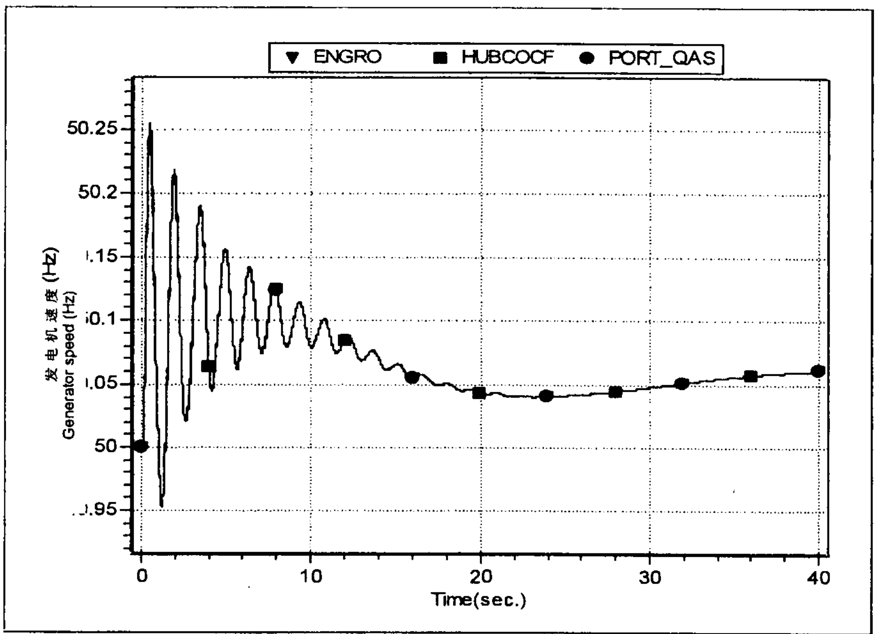

图 3-37 直流单极闭锁故障故障南部机组发电机速度
Fig.3-37 HVDC Monopole Block Fault -related south generator speed

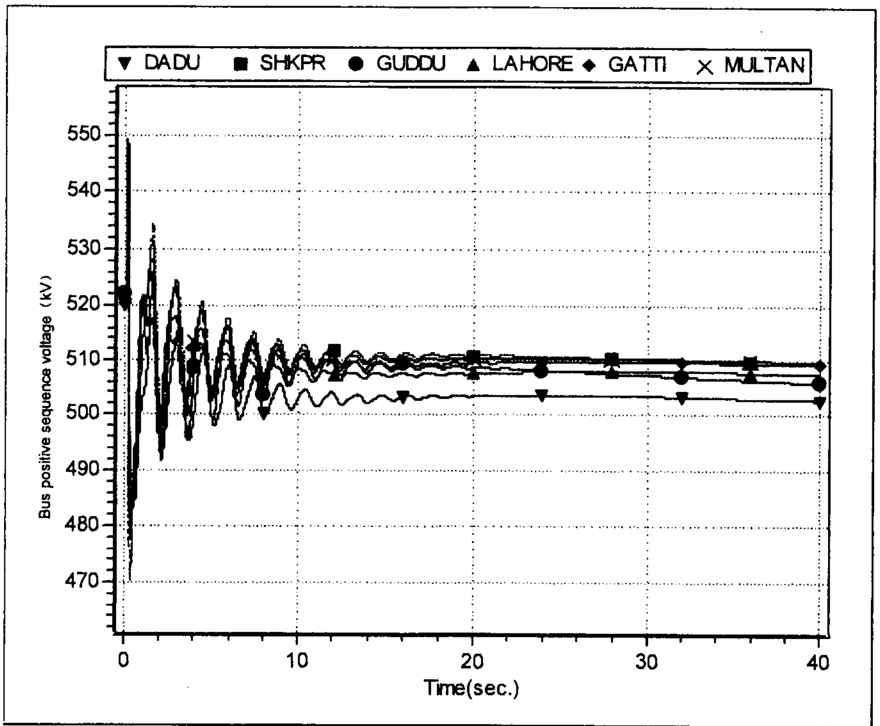

图 3-38 直流单极闭锁故障相关母线电压图
Fig.3-38 HVDC Monopole Block Fault -related Bus Voltage Graph

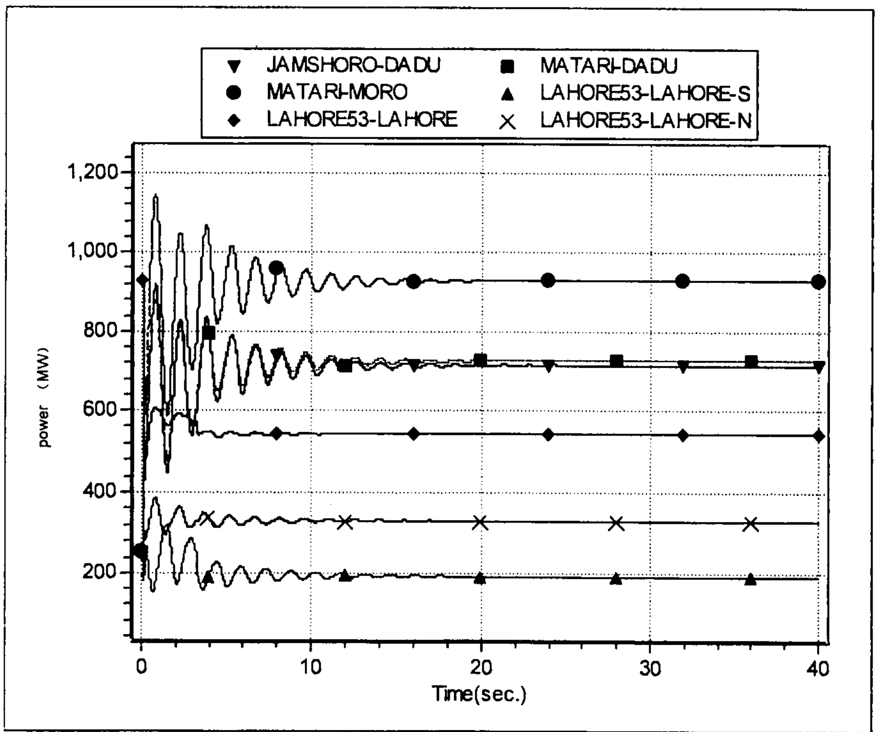

图 3-39 直流单极闭锁故障交流线路功率曲线图
Fig.3-39 HVDC Monopole Block Fault AC Power Curve

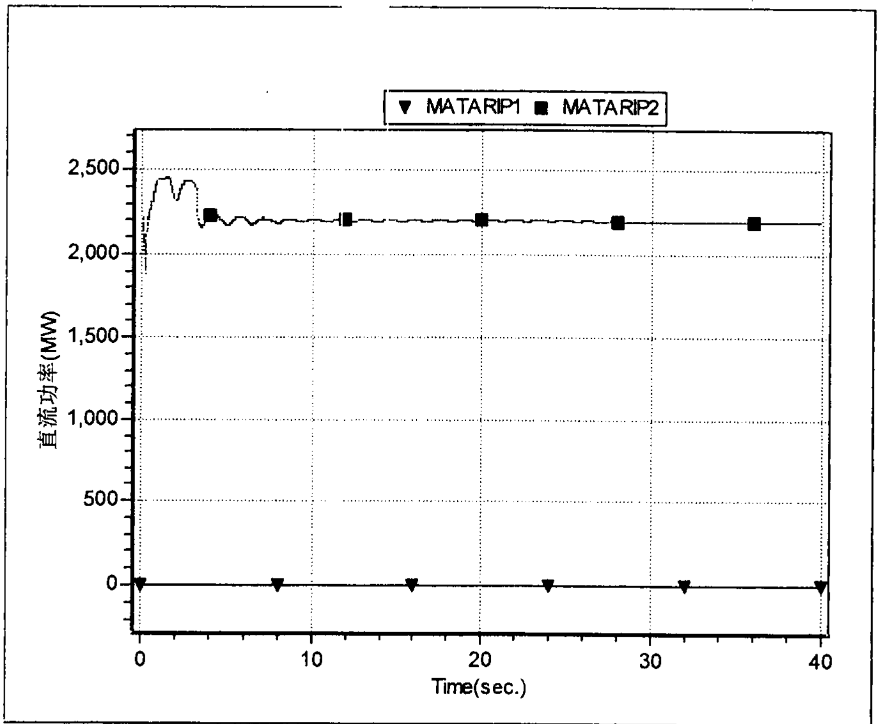

图 3-40　直流单极闭锁故障直流线路功率曲线图
Fig.3-40 HVDC Monopole Block Fault DC Power Curve

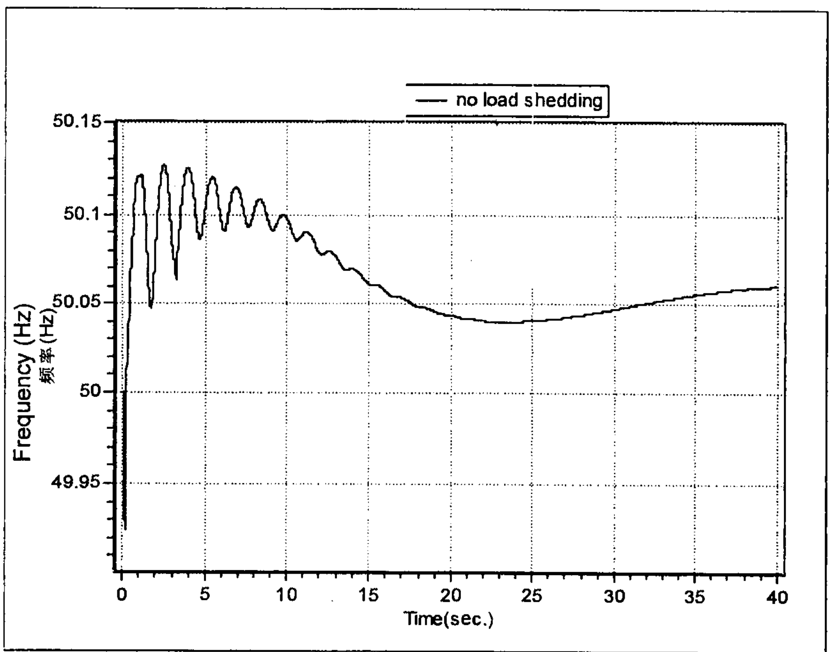

图 3-41 直流单极闭锁故障系统频率曲线图
Fig. 3-41 HVDC Monopole Block Fault System Frequency Curve

可以看出，直流单极闭锁后利用直流另一极 3 秒钟 1.2 倍的过负荷能力，3 秒后考虑 1.1 倍 2 小时的过负荷能力，功率转移到并列运行的交流通道上，交流系统能够承受，系统频率稳定。

It can be seen that, when HVDC monopole block occurs, the 3s overloading capacity of the other pole at 1.2 times the rated transmission capacity and the 2h short-time overloading capacity at 1.1 times the rated transmission capacity after the first 3s are considered. The power shifts to the AC channel in parallel operation, and the AC system can withstand it. The system frequency is stable.

3.7 考虑交流补强网架不建设
Without MORO～R.Y.KHAN series compensation, R.Y.KHAN～SAHIWAL 500kV line

3.7.1 潮流计算
Load flow calculation

考虑默蒂亚里～拉合尔±660kV 直流工程送电 4000MW，交流补强网架（MORO～R.Y.KHAN 串补，R.Y.KHAN～SAHIWAL500kV 线路）不建设，南北 500kV 交流通道潮流为 690MW，通过 JAMSHORO～DADU-NEW、MATIARI～MORO 和 MATIARI～DADU-NEW 外送，南北潮流与基础方式比较无变化。

The calculation adopts Matiari-Lahore ±660kV HVDC Project with 4000MW power transmission, and it is considered the AC compensating network (MORO～R.Y.KHAN series compensation, R.Y.KHAN～SAHIWAL500kV line) can't be put into service. The load flow in south-to-north 500kV AC channel is 690MW, and transmitted outwards through JAMSHORO～DADU-NEW, MATIARI～MORO and MATIARI～DADU-NEW, and the south-to-north load flow has no change through comparison with basic mode.

潮流计算表明，送受端系统潮流分布均匀、电压水平满足要求。不建设补强交流网架方式潮流分布如图 3-42 所示。

The load flow calculation shows that, at the receiving end, distribution of system load flow is uniform and voltage level meets requirements. When the AC compensating network cannot be put into service, the load flow distribution is illustrated in Fig. 3-42.

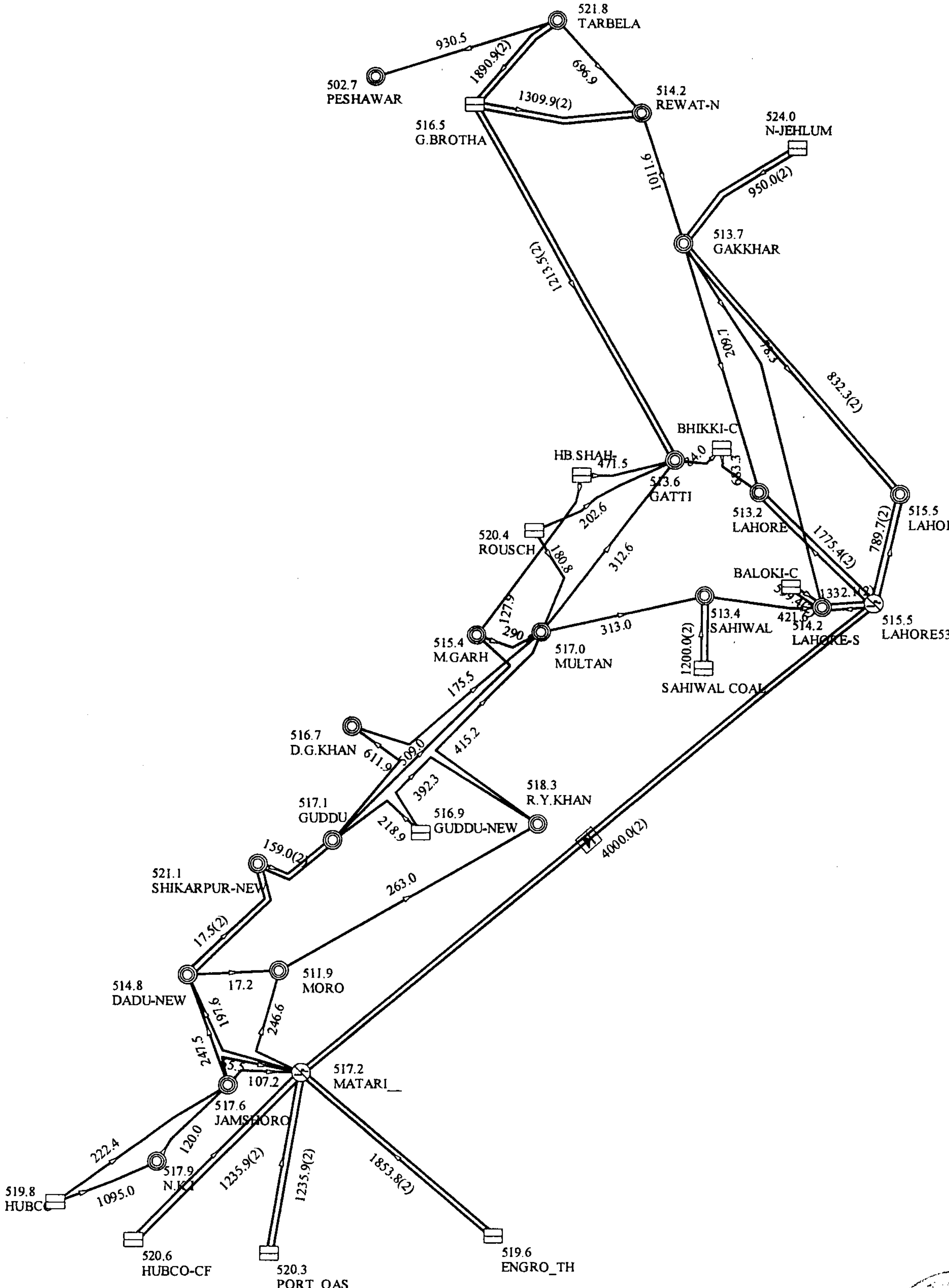

图 3-42 交流补强网架不能投产方式潮流图

Fig. 3-42 Load Flow Diagram for Failure to Put into Service of the AC compensating network

3.7.2 稳定计算
Stability calculation

考虑交流补强网架（MORO～R.Y.KHAN 串补，R.Y.KHAN～SAHIWAL500kV 线路）不建设的情况下，稳定计算结果表明，500kV 主干网架线路发生单一故障系统均可保持安全稳定运行,送端电厂送出线路 N-2 需采取切负荷措施使系统频率恢复允许范围。直流单极闭锁故障，系统可保持稳定，不需要采取措施。直流双极闭锁故障，系统失稳，需采取切除送端共 3960MW 机组，同时切除 3000MW 负荷，占全网负荷比例 12%，系统可保持稳定。稳定计算结果如表 3-5 所示:

Considering that the AC compensating network (MORO～R.Y.KHAN series compensation, R.Y.KHAN～SAHIWAL 500kV line) cannot be put into service, the stability calculation result shows that, when a single fault occurs in 500kV main network line, the system can maintain safe and stable operation, and in case of N-2 fault in outgoing circuit of power plant at Matiari side, load shedding measure needs to be taken to restore the system frequency to allowable range. The system can keep stable with no measure taken, in case of the HVDC monopole block fault. The system becomes unstable when the HVDC bipolar block fault, and the Matiari 3960MW unit switch-off and 3000MW load (12% of load of the whole grid) shedding is performed to make the system maintain stable. The stability calculation results are shown in Table 3-5:

表 3-5 电网稳定计算结果表

Table 3-5 Grid Stability Calculation Results

线路名称 **Name of line**	故障类型 **Fault type**	稳定计算结果 **Stability result**
送端交流故障 Matiari side AC fault		
MATIARI～JAMSHORO	三永 Permanent three-phase ground fault	稳定 Stable
DADU-NEW～JAMSHORO	三永 Permanent three-phase ground fault t	稳定 Stable
MATIARI～DADU-NEW	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～MORO	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～THAR COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 1000MW 负荷 1000MW load shedding
MATIARI～QASIM COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 400MW 负荷 400MW load shedding
MATIARI～NEW HUBCO COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 400MW 负荷 400MW load shedding
受端交流故障 Lahore side AC fault		
换流站～LAHORE SOUTH LAHORE Converter station-LAHORE SOUTH	三永 Permanent three-phase ground fault	稳定 Stable
换流站～LAHORE LAHORE Converter station-	三永 Permanent three-phase ground fault	稳定 Stable

LAHORE		
换流站～LAHORE NORTH LAHORE Converter station-LAHORE NORTH	三永 Permanent three-phase ground fault	稳定 Stable
换流站～LAHORE SOUTH LAHORE Converter station-LAHORE SOUTH	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
换流站～LAHORE LAHORE Converter station-LAHORE	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
换流站～LAHORE NORTH LAHORE Converter station-LAHORE NORTH	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
直流故障 HVDC Fault		
MATIARI～LAHORE 直流 MATIARI～LAHORE HVDC	单极闭锁 Monopole block fault	稳定 Stable
MATIARI～LAHORE 直流 MATIARI～LAHORE HVDC	双极闭锁 Bipolar block fault	切除 3960MW 机组，同时切除 3000MW 负荷后系统恢复稳定 The system restores to the stable state after 3960MW unit switch-off and 3000MW load shedding.

其中：

1）选取潮流最重的 Moro～R.Y. KHAN 线路三永 N-1，对应的系统响应曲线为：

1）where, permanent three-phase ground fault N-1 for Moro-R.Y.KHAN line whose load is heavest, the corresponding system response curve is as follows:

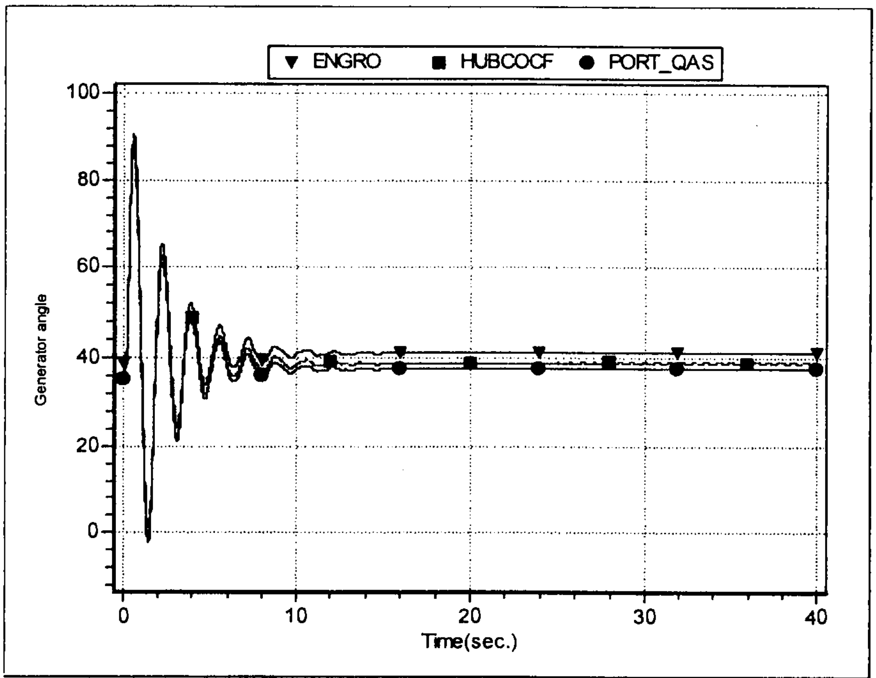

图 3-43 Moro～R.Y.KHAN 线路三永 N-1 故障南部机组相对北部 G.BROTH 机组功角差
Fig.3-43 Moro-R.Y.KHAN Line Permanent Three-phase Ground N-1 Fault-related south generator angle differences to G.BROTH generator angle

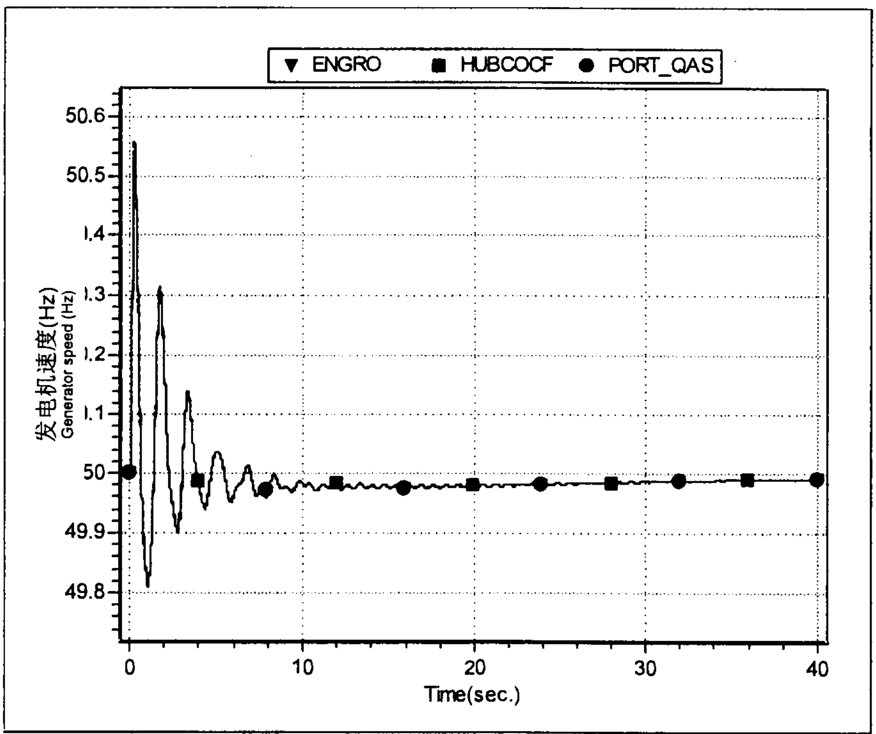

图 3-44 Moro～R.Y.KHAN 线路三永 N-1 故障南部机组发电机速度
Fig.3-44 Moro-R.Y.KHAN Line Permanent Three-phase Ground N-1 Fault-related south generator speed

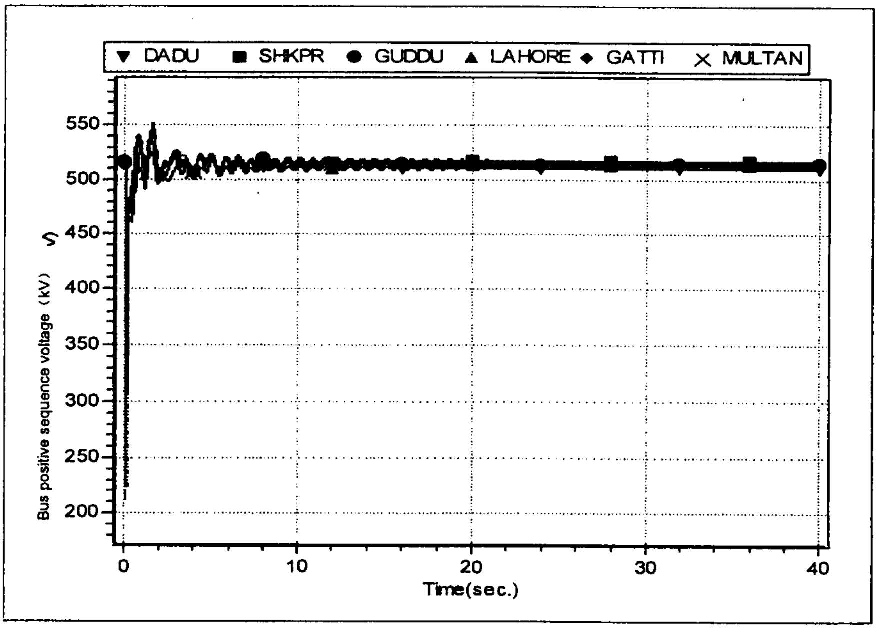

图 3-45 Moro～R.Y.KHAN 线路三永 N-1 故障相关母线电压图
Fig.3-45 Moro-R.Y.KHAN Line Permanent Three-phase Ground N-1 Fault-related Bus Voltage Graph

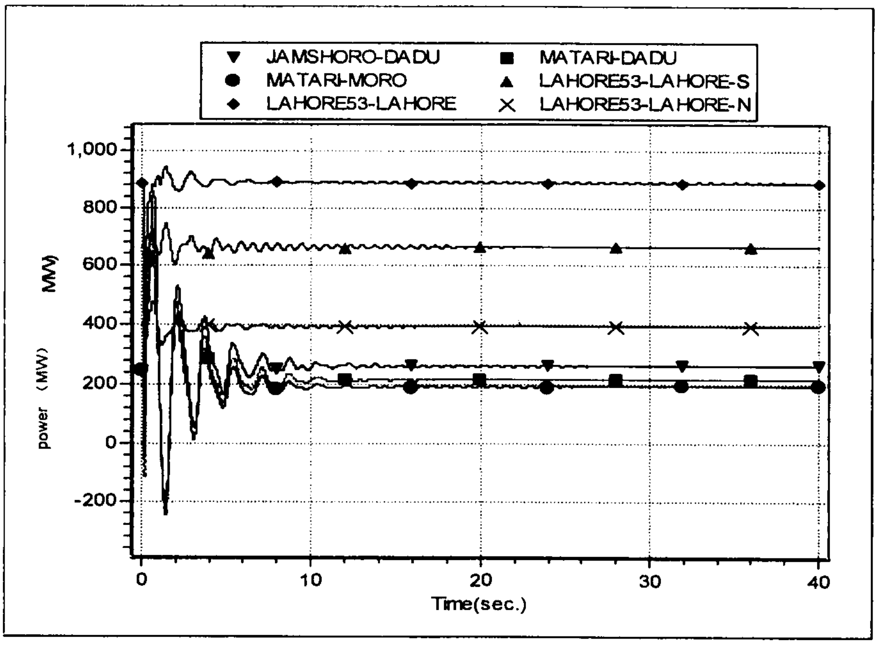

图 3-46 Moro～R.Y.KHAN 线路三永 N-1 故障交流线路功率曲线图
Fig.3-46 Moro～R.Y.KHAN Line Permanent Three-phase Ground N-1 Fault AC Power Curve

Moro～R.Y.KHAN 线路三永 N-1 故障后，南北机组功角差第一摆约 90 度，功角稳定，由于交流通道潮流较轻,交流三永 N-1 故障对影响较小，送受端相关母线电压可恢复到合理范围内。Moro～R.Y. KHAN 500kV 线路上的 263MW 潮流大部分通过 MORO～DADU-NEW 500kV 线路转移。

When there is a three-phase permanent ground N-1 fault in Moro～R.Y.KHAN line, the first swing of south generator angle difference with north generator is about 90 degrees. The generator is not step-out and the power angle is stable. Due to low load flow in AC channel, AC permanent three-phase ground N-1 fault has little influence on system, and the voltage can restore to the reasonable range. Most power of 263MW load flow in MORO-R.Y. KHAN 500kV line is transferred through MORO-DADU-NEW 500kV line.

2）LAHORE 换流站～LAHORE 线路三永 N-1，对应的系统响应曲线为：

2）Where, LAHORE Converter station～LAHORE Line occurs permanent three-phase ground N-1 fault, corresponding to the following system response curve:

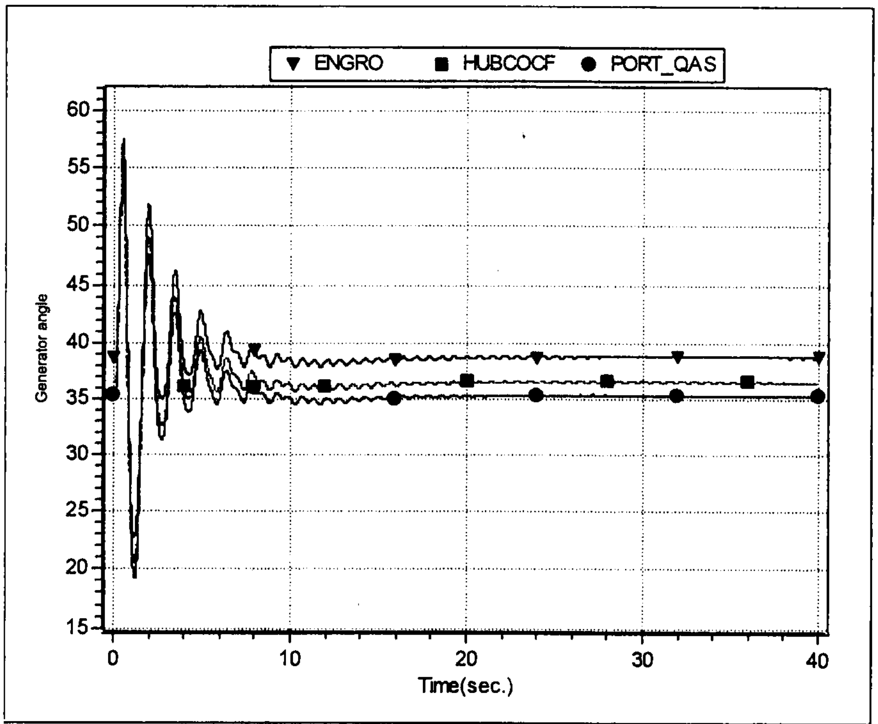

图 3-47 LAHORE Converter station～LAHORE 线路三永 N-1 故障南部机组相对北部 G.BROTH 机组功角差
Fig.3-47 LAHORE Converter station～LAHORE Line Permanent Three-phase Ground N-1 Fault-related south generator angle differences to G.BROTH generator angle

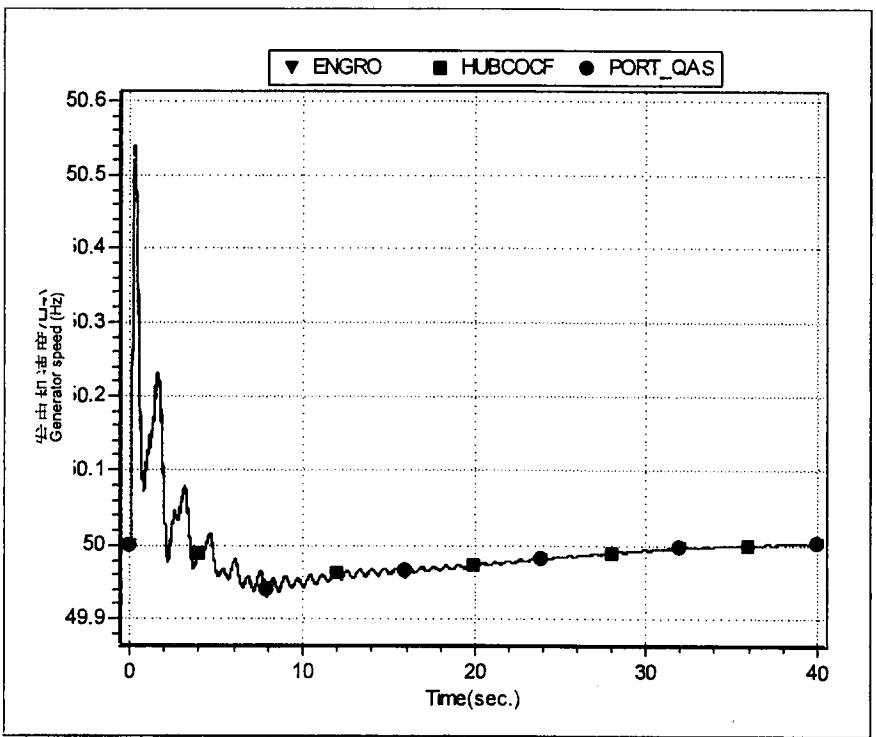

图 3-48 LAHORE Converter station～LAHORE 线路三永 N-1 故障南部机组发电机速度
Fig.3-48 LAHORE Converter station～LAHORE Line Permanent Three-phase Ground N-1 Fault-related south generator

speed

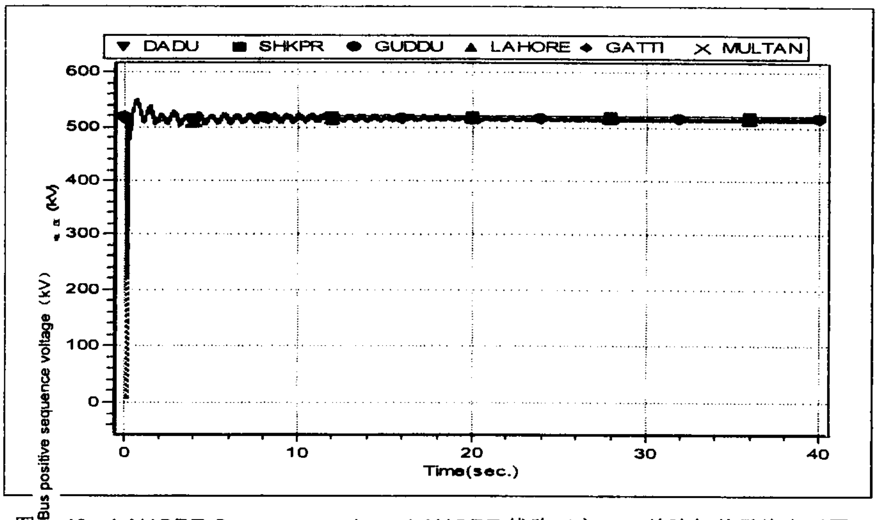

图 -49 LAHORE Converter station～LAHORE 线路三永 N-1 故障相关母线电压图

Fig.3-49 LAHORE Converter station～LAHORE Line Permanent Three-phase Ground N-1 Fault-related Bus Voltage Graph

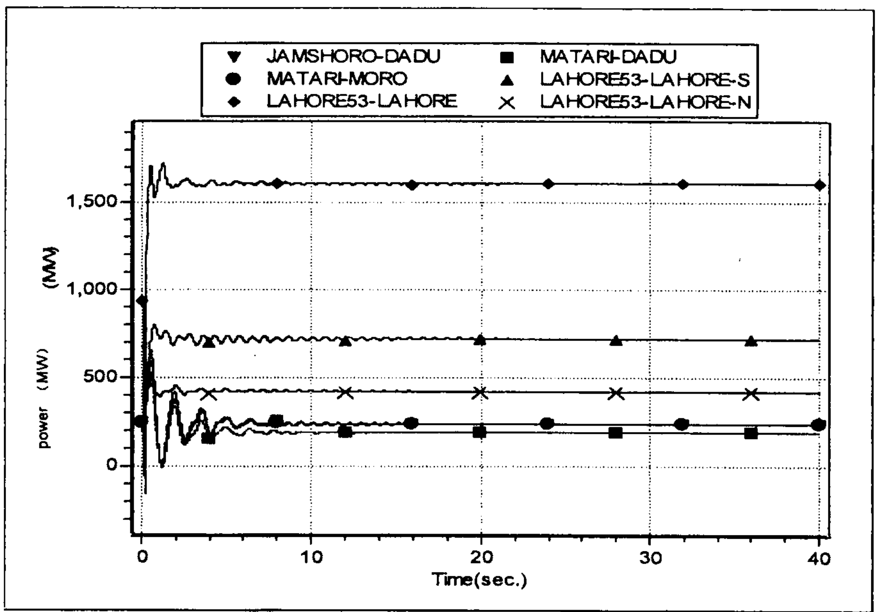

图 3-50 LAHORE Converter station～LAHORE 线路三永 N-1 故障交流线路功率曲线图

Fig.3-50 LAHORE Converter station～LAHORE Line Permanent Three-phase Ground N-1 Fault AC Power Curve

LAHORE 换流站～LAHORE 线路三永 N-1 故障后，南部机组相对北部机组功角差约 30 度，功角稳定。相关母线电压可恢复到合理范围内。LAHORE 换流站～LAHORE 500kV 双回线路上的 1775MW 潮流通过剩余一回线路转移 1600MW，LAHORE 换流站～LAHORE-N 双回线路潮流从 790MW 增加到 840MW，LAHORE 换流站～LAHORE-S 双回线路潮流从 1332MW 增加到 1450MW。由于 LAHORE 端负荷中心网架较强，交流线路三永 N-1 故障对系统影响较小。

When there is a permanent three-phase ground N-1 fault in LAHORE converter station-LAHORE line, the first swing of power angle difference between south generator and north generator is about 30 degrees and the power angle is stable. The related bus voltage can return to the reasonable range. 1775MW load flow in LAHORE converter station-LAHORE double-circuit 500kV line is transferred through surplus single-circuit line by 1600MW, the load flow of LAHORE converter station-LAHORE-N double-circuit line is increased from 790MW to 840MW, and that of LAHORE converter station-LAHORE-S double-circuit line is increased from 1332MW to 1450MW. Due to the strong network of load center, AC line permanent three-phase ground N-1 fault has little influence on system.

3）MATIARI～THAR COAL PLANT 线路三永 N-2，对应的系统响应曲线为:

3）For MATIARI～THAR COAL PLANT line permanent three-phase ground N-2, the corresponding system response curve is as follows:

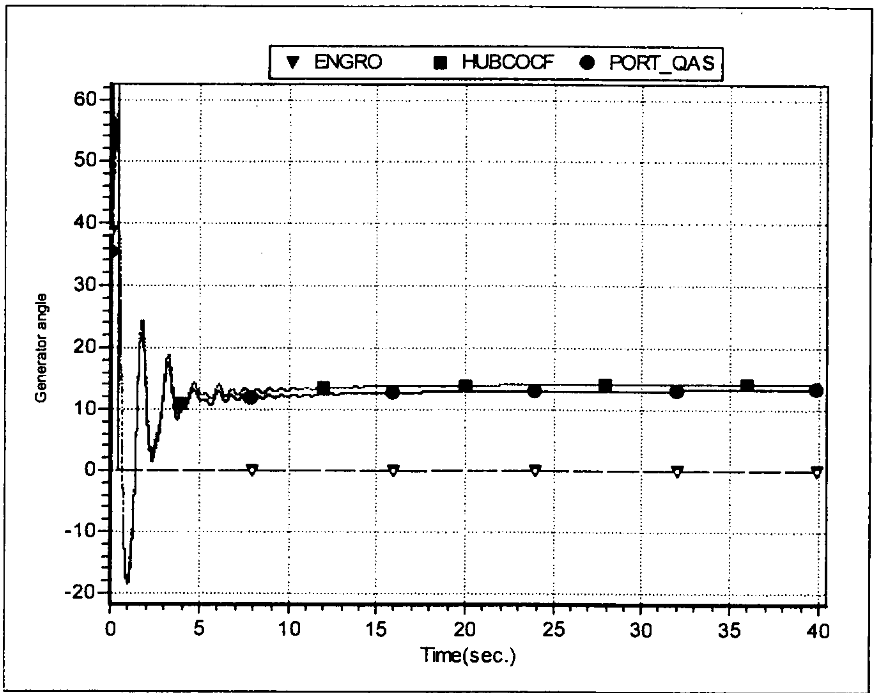

图 3-51 MATIARI～THAR COAL PLANT 线路三永 N-2 故障南部机组相对北部 G.BROTH 机组功角差
Fig.3-51 MATIARI～THAR COAL PLANT Line Permanent Three-phase Ground N-2 Fault -related south generator angle differences to G.BROTH generator angle

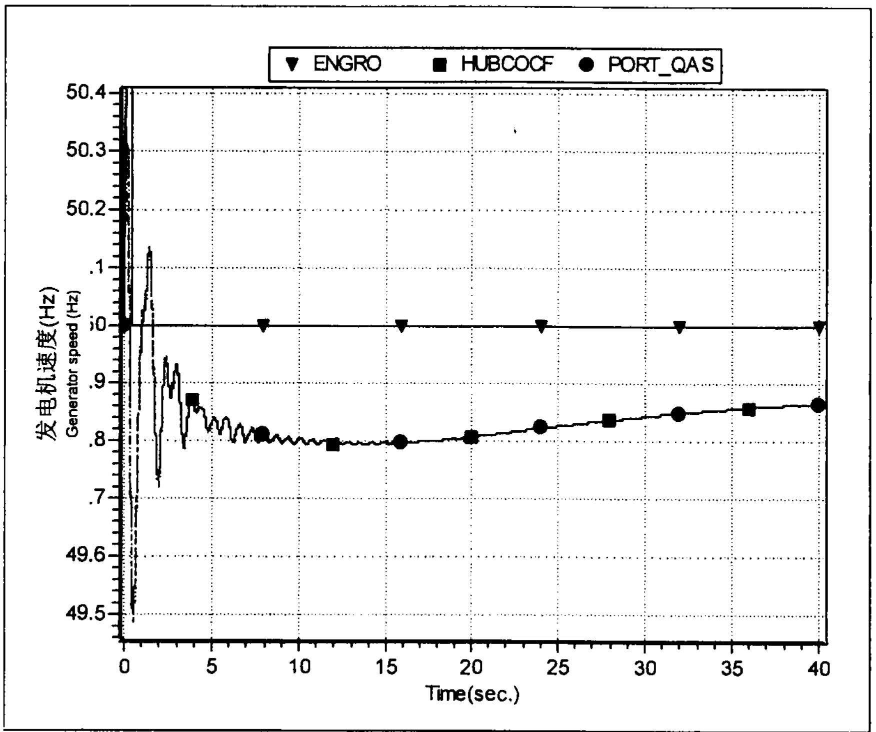

图 3-52 MATIARI～THAR COAL PLANT 线路三永 N-2 故障故障南部机组发电机速度
Fig.3-52 MATIARI～THAR COAL PLANT Line Permanent Three-phase Ground N-2 Fault -related south

generator speed

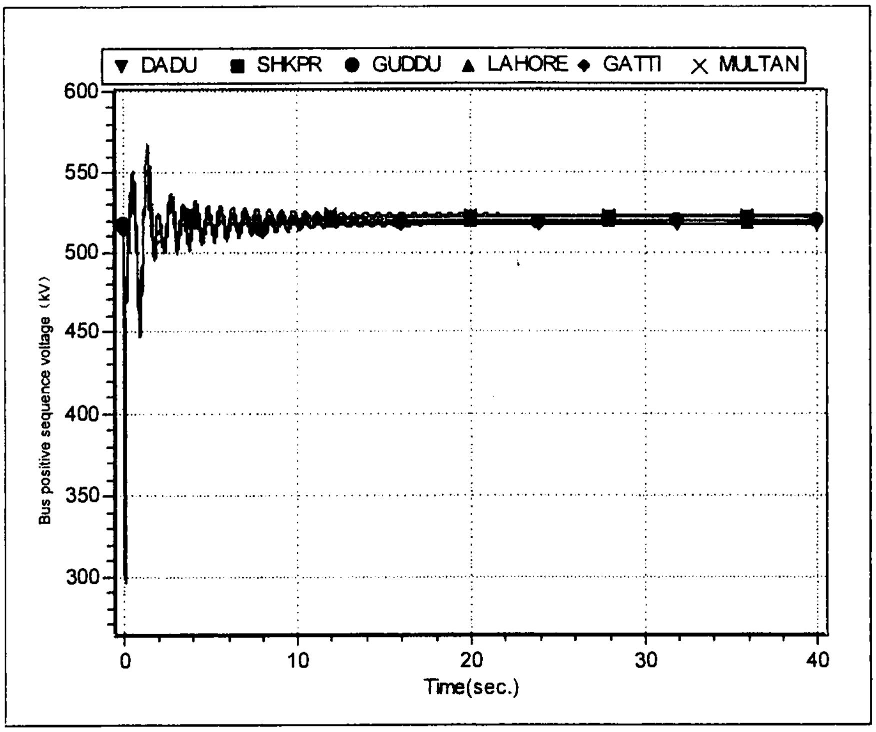

图 3-53 MATIARI~THAR COAL PLANT 线路三永 N-2 故障相关母线电压图
Fig.3-53 MATIARI~THAR COAL PLANT Line Permanent Three-phase Ground N-2 Fault-related Bus Voltage Graph

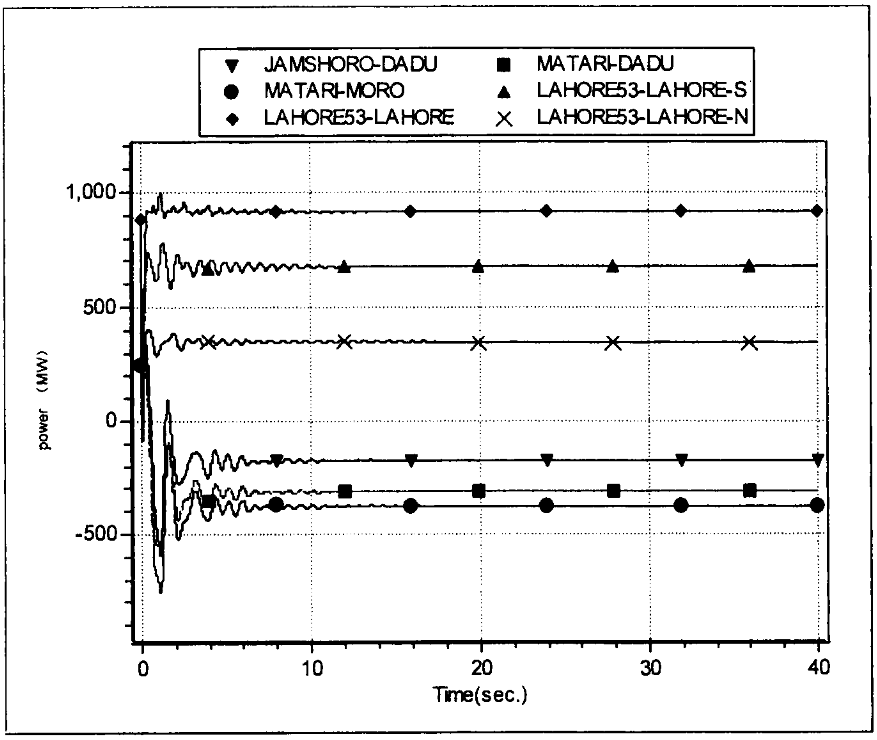

图 3-54 MATIARI~THAR COAL PLANT 线路三永 N-2 故障交流线路功率曲线图
Fig.3-54 MATIARI~THAR COAL PLANT Line Permanent Three-phase Ground N-2 Fault AC Power Curve

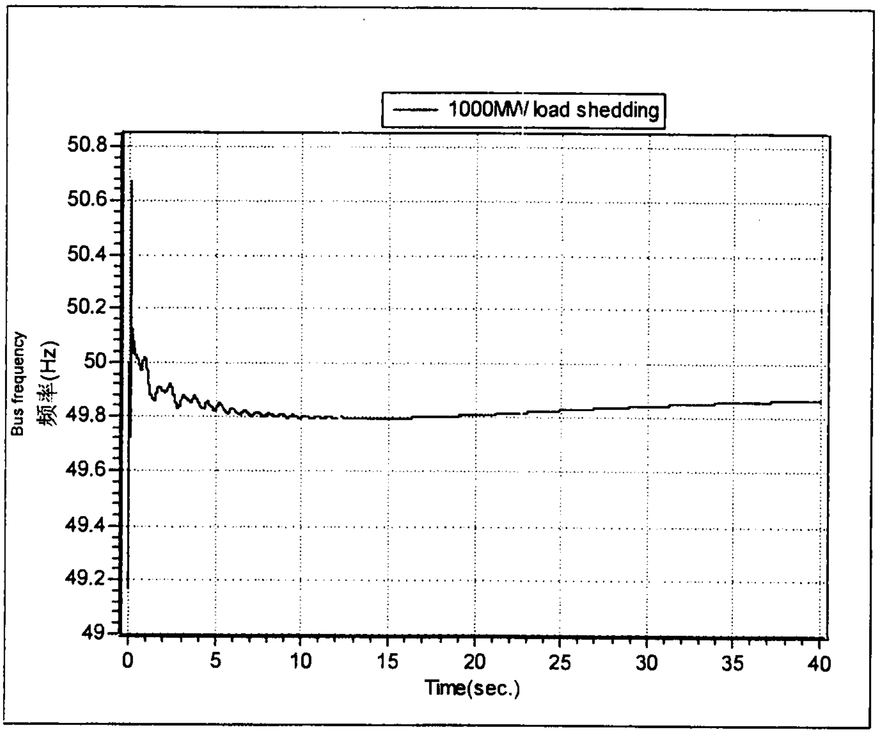

图 3-55 MATIARI～THAR COAL PLANT 线路三永 N-2 故障母线频率曲线图
Fig.3-55 MATIARI～THAR COAL PLANT Line Permanent Three-phase Ground N-2 Fault Bus Frequency Curve

MATIARI～THAR COAL PLANT 线路三永 N-2 故障后，送端损失 1800MW 功率，频率最低为 49.2Hz，切除 1000MW 负荷后，频率可恢复到允许范围内。MATIARI～QASIM COAL PLANT 和 MATIARI～NEW HUBCO COAL PLANT 发生线路三永 N-2 故障，分别切除 400MW 负荷，系统频率可恢复到允许范围。

When there is a three-phase permanent ground N-2 fault in MATIARI～THAR COAL PLANT line, the sending-end will lose the power of 1800MW and the lowest frequency will be 49.2Hz, but after the 1000MW load shedding, the frequency can return to allowable range. When there is a three-phase permanent ground N-2 fault in MATIARI～QASIM COAL PLANT line and MATIARI～NEW HUBCO COAL PLANT line, with 400MW load shedding respectively from each line, the system frequency can restore to allowable range.

4）单极闭锁故障，系统相关曲线如下图：

4）In a monopole block fault, the relevant curve of system is indicated below:

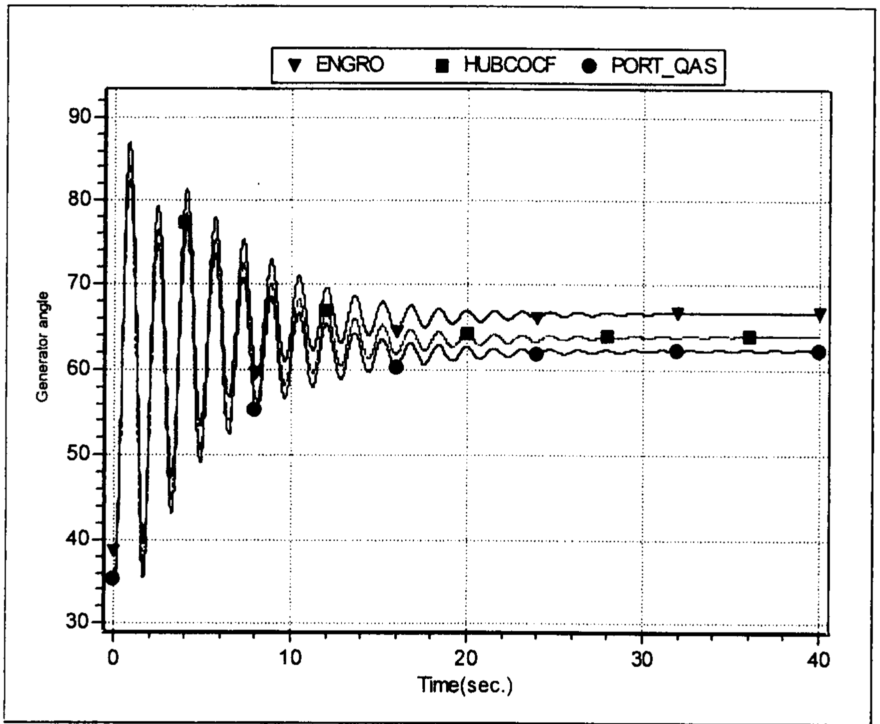

图 3-56　直流单极闭锁故障南部机组相对北部 G.BROTH 机组功角差
Fig.3-56 HVDC Monopole Block Fault-related south generator angle differences to G.BROTH generator angle

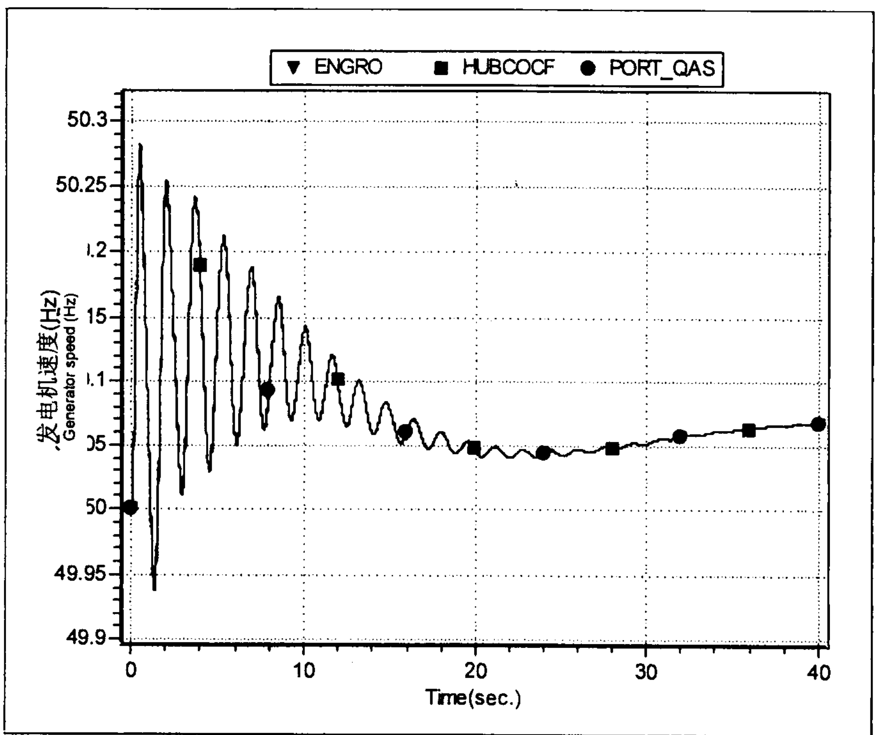

图 3-57　直流单极闭锁故障故障南部机组发电机速度
Fig.3-57 HVDC Monopole Block Fault -related south generator speed

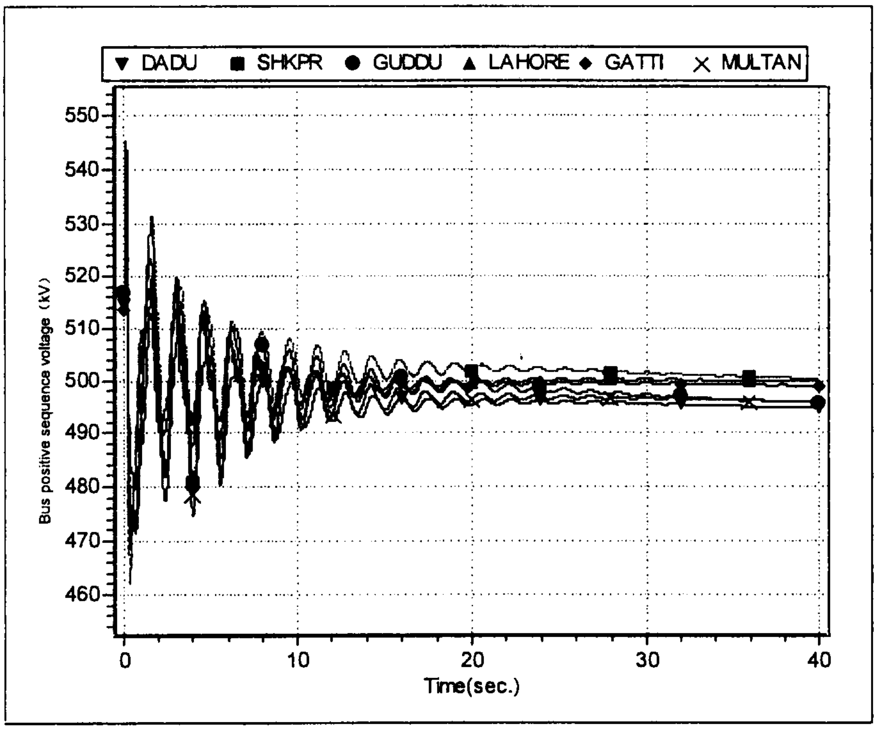

图 3-58　直流单极闭锁故障相关母线电压图
Fig.3-58 HVDC Monopole Block Fault -related Bus Voltage Graph

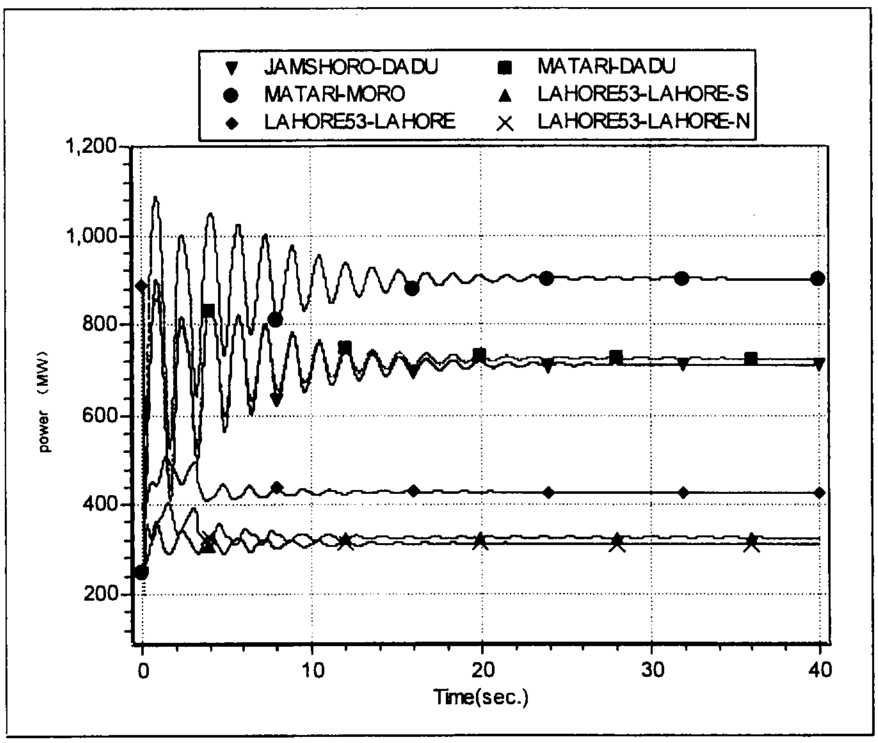

图 3-59　直流单极闭锁故障交流线路功率曲线图
Fig.3-59 HVDC Monopole Block Fault AC Power Curve

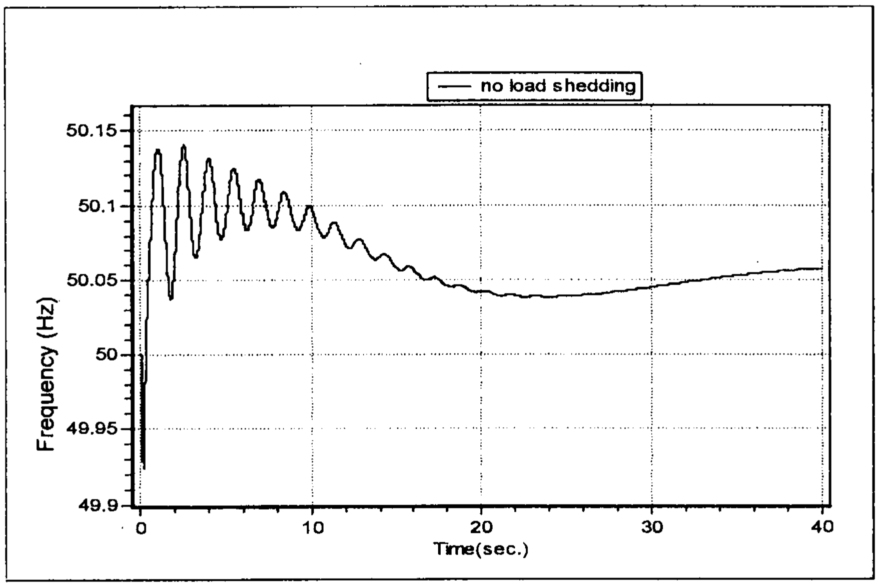

图 3-60 直流单极闭锁故障系统频率曲线图
Fig. 3-60 HVDC Monopole Block Fault System Frequency Curve

可以看出，直流单极闭锁后，盈余功率转移到并列运行的交流通道上，交流系统能够承受。故障后第一摆南北机组功角差约 50 度，功角稳定。故障后电压可恢复到合理范围，系统频率最低约为 49.9Hz，系统频率稳定。

It can be seen that, after HVDC monopole block occurs, the power surplus shifts to the HVAC channel in parallel operation, and the AC system can withstand it. The first swing of power angle difference between south and north generator is about 50 degrees and power angle is stable. The voltage can return to allowable range. The frequency of the system is stable, with the lowest frequency at approximately 49.9Hz.

5）双极闭锁故障不采取措施系统失稳，系统相关曲线如下图：

5）In a bipolar block fault without control measures the system is unstable, the relevant curve of system is indicated below:

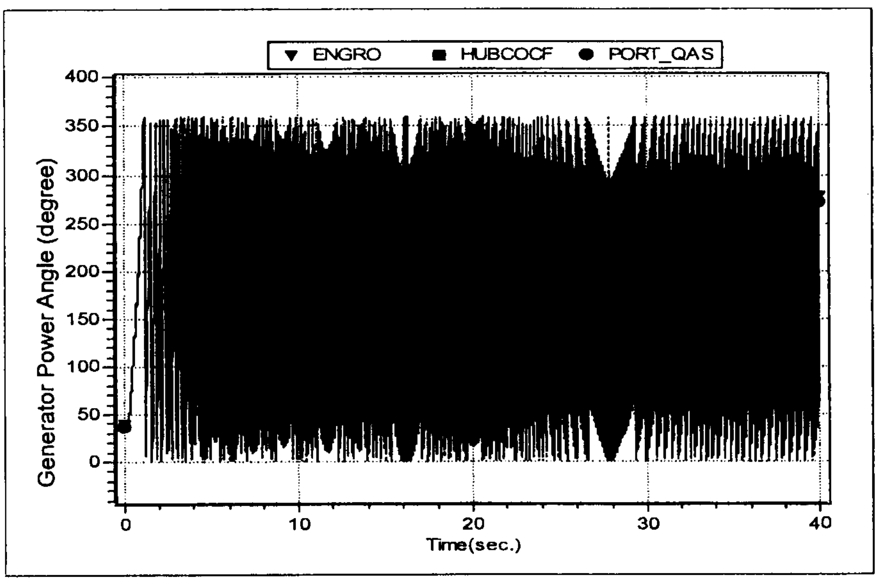

图 3-61 直流双极闭锁故障送端机组功角曲线图
Fig.3-61 HVDC Bipolar Block Fault Power Angle Graph

6）双极闭锁故障后，采取切除送端 3960MW 机组，受端 3000MW 负荷，系统可保持稳定。系统相关曲线如下图：

6）In case of bipolar block fault, 3960MW units require to be switched off and load shedding of 3000MW is required, and after taking these measures, the system resumes stable operation. The relevant curve of system is indicated below:

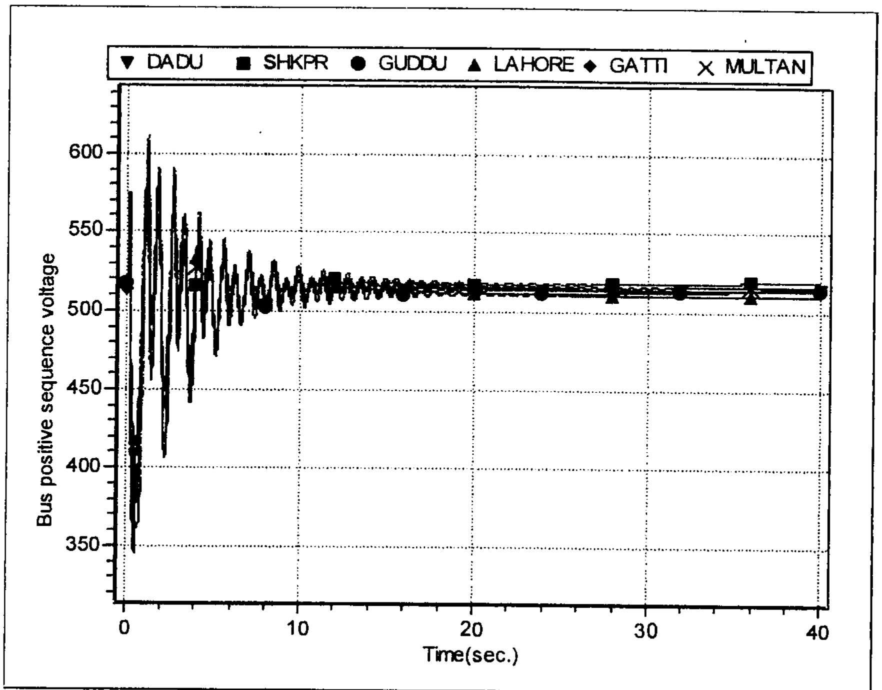

图 3-62 直流双极闭锁故障相关母线电压图
Fig. 3-62 HVDC Bipolar Block Fault-related Bus Voltage Graph

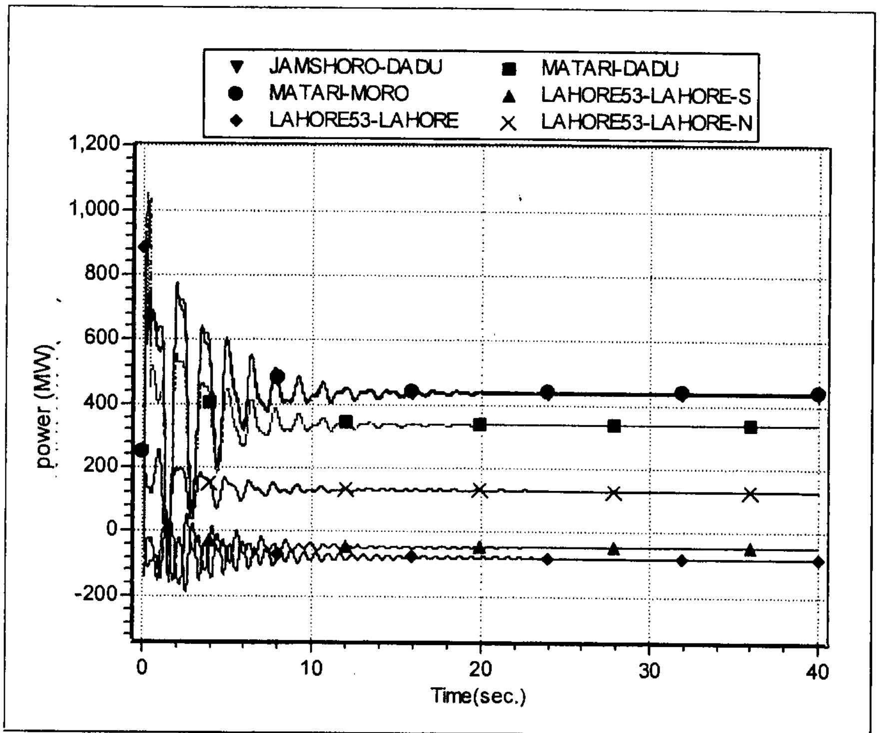

图 3-63 直流双极闭锁故障交流线路功率曲线图
Fig. 3-63 HVDC Bipolar Block Fault AC Power Curve

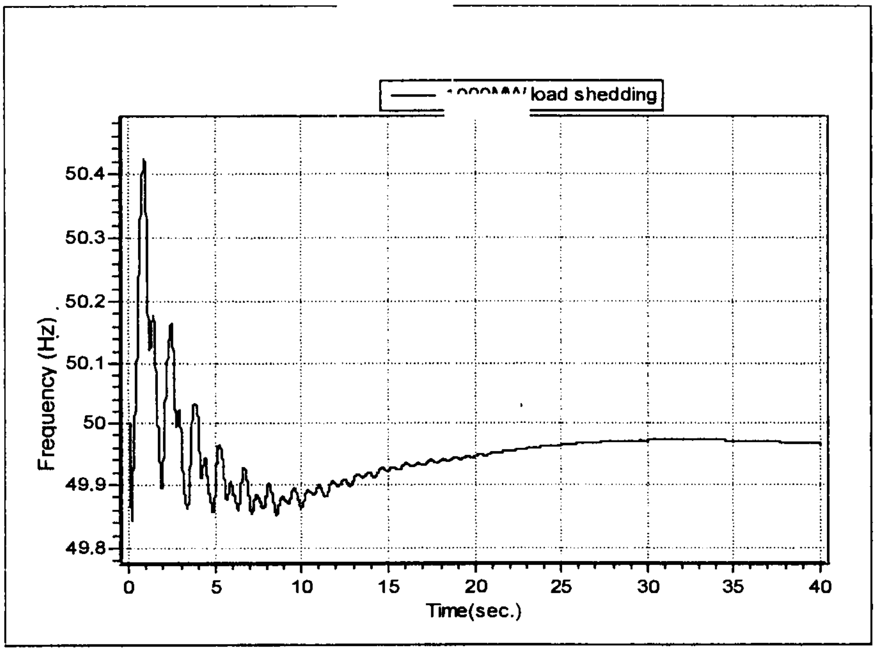

图 3-64 直流双极闭锁故障系统频率曲线图
Fig. 3-64 HVDC Bipolar Block Fault System Frequency Curve

如果双极闭锁后采取送端切机 3960MW、受端切负荷 3000MW 的措施，降低沿途电压下降的幅度，系统电压和频率不失稳，与基础方案相比需要多切除 1300MW 负荷。

If 3960MW unit switch-off and 3000MW load shedding are performed after a bipolar block fault, amplitude of voltage drop is reduced along the line to make system frequency not lose stability, and extra 1300MW load is shedded compared with the basic scheme.

3.8 交流网架不补强，直流满送，南电北送断面潮流 5400MW，南部机组最小出力方式 Worst case that without MORO~R.Y.KHAN series compensation, R.Y.KHAN~SAHIWAL 500kV line, 5400MW maximum power from south, minimum generation in north

3.8.1 潮流计算 Load flow calculation

巴基斯坦信德省规划的风电项目 2018 年的发电容量将达到 1756MW，根据巴基斯坦输电公司（NTDC）规划人员提出，风电场考虑同时率及厂用电，出力最大 0.91p.u.。考虑到风电项目实际的最大发电量和南部其它的电源项目，南部到北部的输电容量在风电大发方式下将达到 5400MW。
The generating capacity of the wind power project planned by Sindh Province of Pakistan will reach 1756MW in 2018. The planners of NTDC point out that the wind farm takes account of load simultaneity factor and auxiliary power and its maximum output is 0.91p.u.. Considering the actual maximum generating capacity of the power project and other power projects in the south, the transmission capacity from the south to the north will reach 5400MW in the maximum wind power generation mode.

计算采用巴基斯坦电网 2018 年夏大方式，考虑风电大发南电北送 5400MW，北部最小开机，同时交流补强网架（MORO~R.Y.KHAN 串补, R.Y.KHAN~SAHIWAL 500kV 一回线）不建设。潮流计算表明，送受端系统潮流分布均匀、电压水平满足要求。风电大发南电北送 5400MW 方式潮流分布如图 3-65 所示。
The load flow calculation of the Pakistan Grid is carried out based on summer maximum-load mode in 2018, and 5400MW maximum wind power transmission from the south, minimum generation in north without MORO~R.Y.KHAN series compensation, R.Y.KHAN~SAHIWAL 500kV line is considered. Load flow calculation shows that, at the both side, distribution of system load flow is uniform and voltage level meets requirements. The load flow distribution in 5400MW maximum wind power transmission from the south to the north is illustrated in Fig. 3-65.

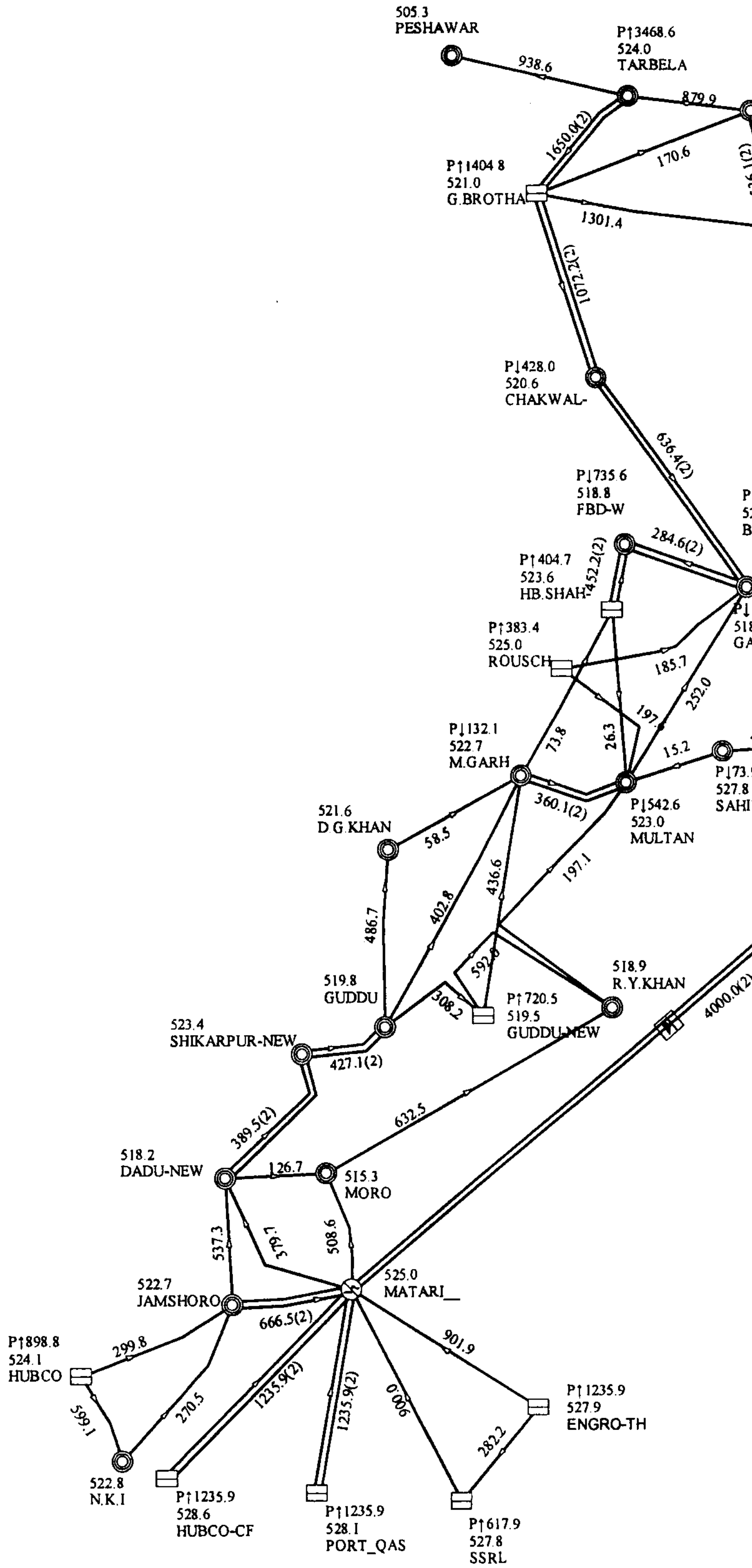

图 3-65 风电大发南电北送 5400MW 方式潮流图

Fig. 3-65 Load Flow Diagram of 5400MW Maximum Power Transmission from South to North

3.8.2 稳定计算
Stability calculation

考虑风电大发南电北送 5400MW 方式，稳定计算结果表明，500kV 主干网架线路发生单一故障系统均可保持安全稳定运行,送端电厂送出线路 N-2 需采取切负荷措施使系统频率恢复允许范围。直流单极闭锁故障，考虑直流过负荷能力，系统可保持稳定。直流双极闭锁故障，系统失稳，需采取切除送端 3960MW 机组，同时切除 3000MW 负荷，占全网负荷比例 11%，系统可保持稳定。稳定计算结果如表 3-6 所示:
When the power of south-north power transmission is considered to be 5400MW, the stability calculation result shows that, when a single fault occurs in 500kV main network line, the system can maintain safe and stable operation, and the load shedding measures for outgoing line N-2 of power plant are taken to make system frequency recover its allowable scope. If the system becomes unstable because of the HVDC monopole block fault, the system can maintain stable considering HVDC overloading capacity. If the system becomes unstable because of the HVDC bipolar block fault, the 3960MW unit switch-off and 3000MW load (11% of load of the whole grid) shedding should be performed to make the system maintain stable. The stability calculation results are shown in Table 3-6:

表 3-6 电网稳定计算结果表

Table 3-6 Grid Stability Calculation Results

线路名称 **Name of line**	**故障类型** **Faulty type**	**稳定计算结果** **Stability calculation result**
送端交流故障 **Matiari side AC fault**		
MATIARI～JAMSHORO	三永 Permanent three-phase ground fault	稳定 Stable
DADU-NEW～JAMSHORO	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～DADU-NEW	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～MORO	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～THAR COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 1000MW 负荷 1000MW load shedding
MATIARI～QASIM COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 400MW 负荷 400MW load shedding
MATIARI～NEW HUBCO COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 400MW 负荷 400MW load shedding
受端交流故障 **Lahore side AC fault**		
LAHORE 换流站～LAHORE SOUTH LAHORE Converter station-LAHORE SOUTH	三永 Permanent three-phase ground fault	稳定 Stable
LAHORE 换流站～LAHORE LAHORE Converter station-LAHORE	三永 Permanent three-phase ground fault	稳定 Stable

LAHORE 换流站～LAHORE NORTH LAHORE Converter station-LAHORE NORTH	三永 Permanent three-phase ground fault	稳定 Stable
LAHORE 换流站～LAHORE SOUTH LAHORE Converter station-LAHORE SOUTH	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
LAHORE 换流站～LAHORE LAHORE Converter station-LAHORE	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
LAHORE 换流站～LAHORE NORTH LAHORE Converter station-LAHORE NORTH	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
	直流故障 **HVDC fault**	
MATIARI～LAHORE 直流 MATIARI-LAHORE HVDC	单极闭锁 Monopole block fault	稳定 stable
MATIARI～LAHORE 直流 MATIARI-LAHORE HVDC	双极闭锁 Bipolar block fault	切除 3960MW 机组，同时切除 3000MW 负荷后系统恢复稳定 The system restores to the stable state after 3960MW unit switch-off and 3000MW load shedding.

其中：

1）选取潮流最重的 Moro～R.Y. KHAN 线路三永 N-1，对应的系统响应曲线为：

1）where, permanent three-phase ground fault N-1 for Moro-R.Y.KHAN line whose load is heavest, the corresponding system response curve is as follows:

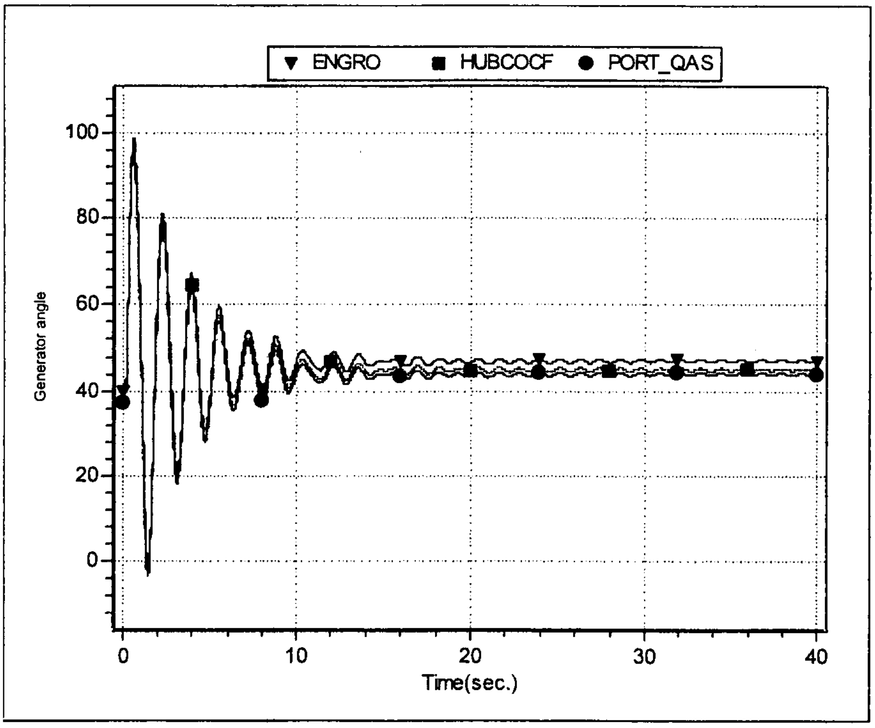

图 3-66 Moro～R.Y.KHAN 线路三永 N-1 故障南部机组相对北部 G.BROTH 机组功角差

Fig.3-66 Moro-R.Y.KHAN Line Permanent Three-phase Ground N-1 Fault-related south generator angle differences to G.BROTH generator angle

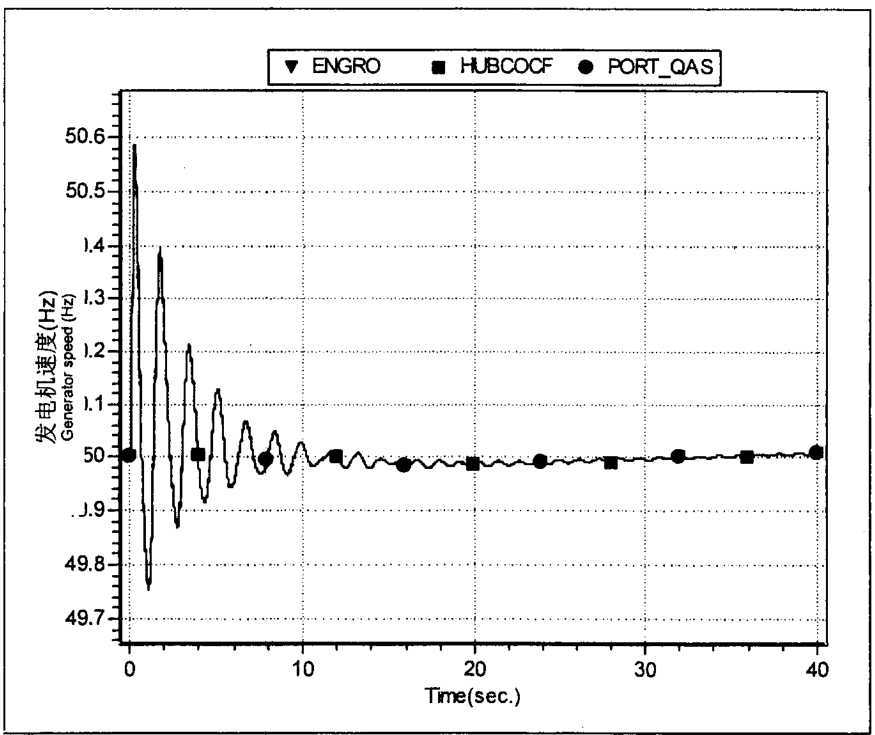

图 3-67 Moro～R.Y.KHAN 线路三永 N-1 故障南部机组发电机速度

Fig.3-67 Moro-R.Y.KHAN Line Permanent Three-phase Ground N-1 Fault-related south generator speed

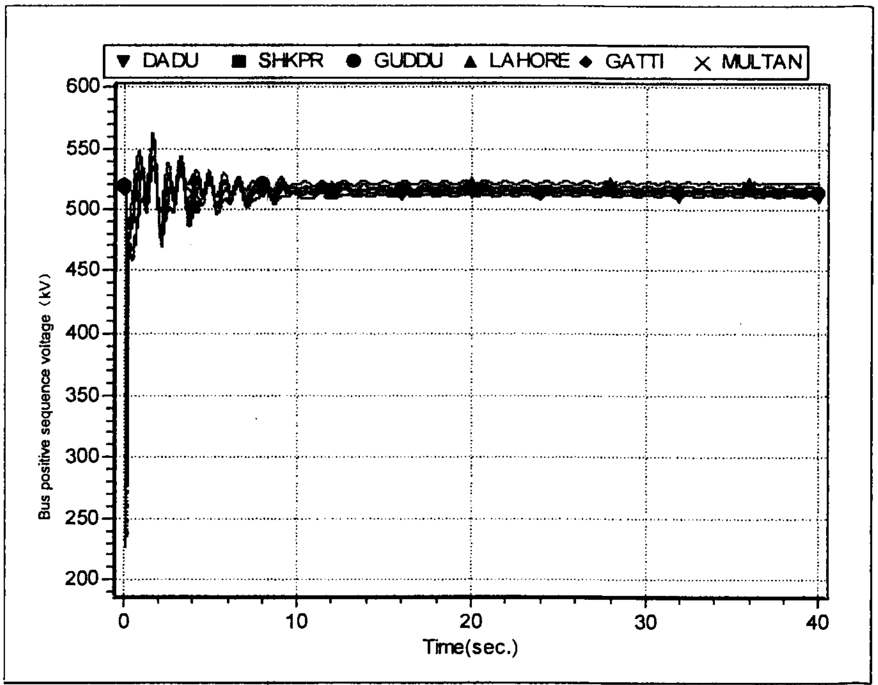

图 3-68　Moro～R.Y.KHAN 线路三永 N-1 故障相关母线电压图
Fig.3-68 Moro-R.Y.KHAN Line Permanent Three-phase Ground N-1 Fault-related Bus Voltage Graph

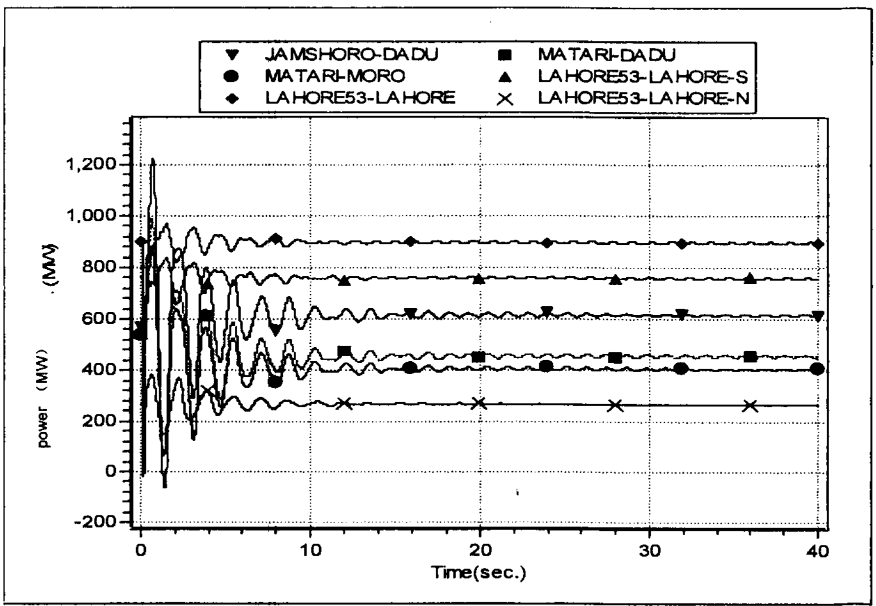

图 3-69　Moro～R.Y.KHAN 线路三永 N-1 故障交流线路功率曲线图
Fig.3-69 Moro～R.Y.KHAN Line Permanent Three-phase Ground N-1 Fault AC Power Curve

Moro～R.Y.KHAN 线路三永 N-1 故障后，南北机组功角差第一摆约 90 度，功角稳定，由于交流通道潮流较轻,交流三永 N-1 故障对影响较小，送受端相关母线电压可恢复到合理范围内。Moro～R.Y. KHAN 500kV 线路上的 667MW 潮流大部分通过 MORO～DADU-NEW 500kV 线路转移。

When there is a three-phase permanent ground N-1 fault in Moro～R.Y.KHAN line, the first swing of south generator angle difference with north generator is about 90 degrees. The generator is not step-out and the power angle is stable. Due to low load flow in AC channel, AC permanent three-phase ground N-1 fault has little influence on system, and the voltage can restore to the reasonable range. Most power of 667MW load flow in MORO-R.Y. KHAN 500kV line is transferred through MORO-DADU-NEW 500kV line.

2）LAHORE 换流站～LAHORE 线路三永 N-1，对应的系统响应曲线为：

2）Where, LAHORE Converter station～LAHORE Line occurs permanent three-phase ground N-1 fault, corresponding to the following system response curve:

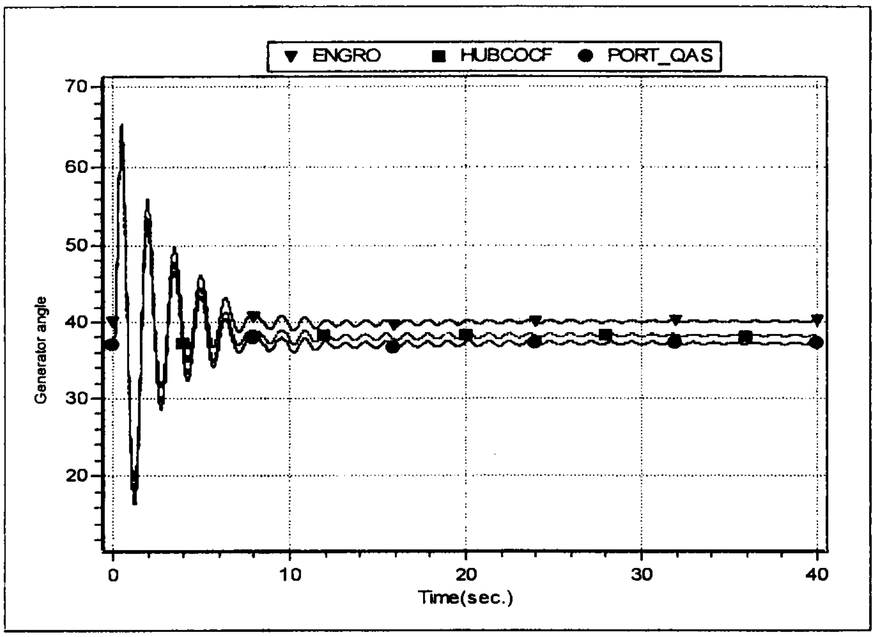

图 3-70　LAHORE Converter station～LAHORE 线路三永 N-1 故障南部机组相对北部 G.BROTH 机组功角差
Fig.3-70 LAHORE Converter station～LAHORE Line Permanent Three-phase Ground N-1 Fault-related south generator angle differences to G.BROTH generator angle

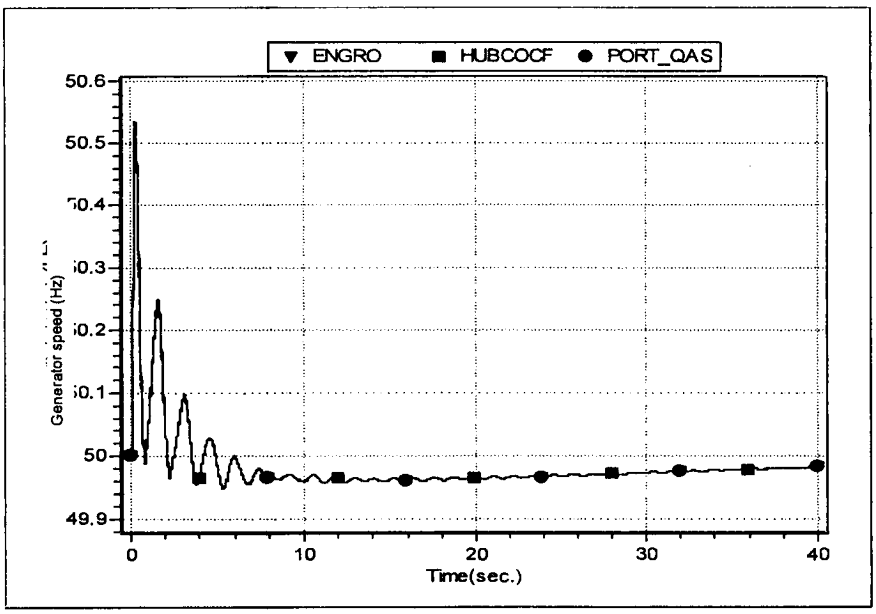

图 3-71　LAHORE Converter station～LAHORE 线路三永 N-1 故障南部机组发电机速度
Fig.3-71 LAHORE Converter station～LAHORE Line Permanent Three-phase Ground N-1 Fault-related south generator speed

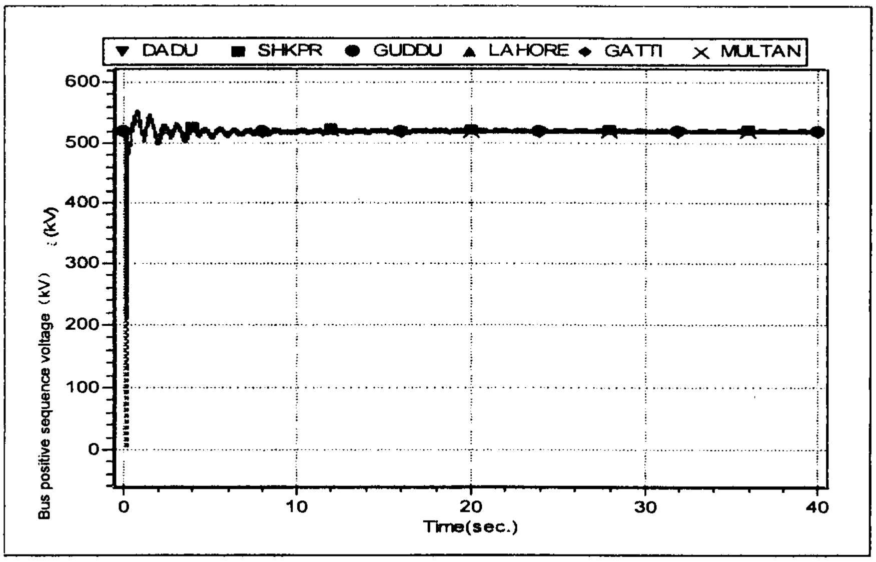

图 3-72 LAHORE Converter station～LAHORE 线路三永 N-1 故障相关母线电压图
Fig.3-72 LAHORE Converter station～LAHORE Line Permanent Three-phase Ground N-1 Fault-related Bus Voltage Graph

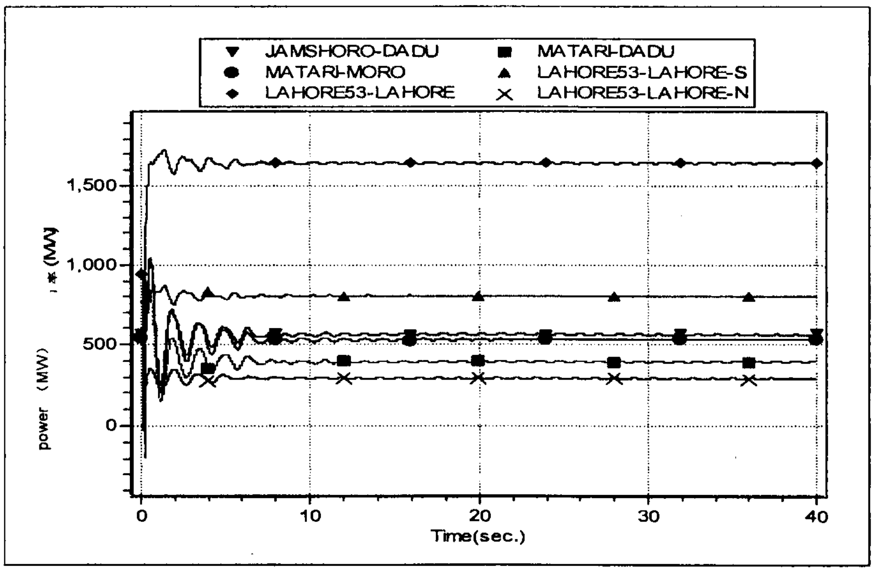

图 3-73 LAHORE Converter station～LAHORE 线路三永 N-1 故障交流线路功率曲线图
Fig.3-73 LAHORE Converter station～LAHORE Line Permanent Three-phase Ground N-1 Fault AC Power Curve

LAHORE 换流站～LAHORE 线路三永 N-1 故障后，南部机组相对北部机组功角差约 50 度，功角稳定。相关母线电压可恢复到合理范围内。LAHORE 换流站～LAHORE 500kV 双回线路上的 1794MW 潮流通过剩余一回线路转移 1670MW，LAHORE 换流站～LAHORE-N 双回线路潮流从 530MW 增加到 600MW，LAHORE 换流站～LAHORE-S 双回线路潮流从 1522MW 增加到 1600MW。由于 LAHORE 端负荷中心网架较强，交流线路三永 N-1 故障对系统影响较小。

When there is a permanent three-phase ground N-1 fault in LAHORE converter station-LAHORE line, the first swing of power angle difference between south generator and north generator is about 50 degrees and the power angle is stable. The related bus voltage can return to the reasonable range. 1794MW load flow in LAHORE converter station-LAHORE double-circuit 500kV line is transferred through surplus single-circuit line by 1670MW, the load flow of LAHORE converter station-LAHORE-N double-circuit line is increased from 530MW to 600MW, and that of LAHORE converter station-LAHORE-S double-circuit line is increased from 1522MW to 1600MW. Due to the strong network of load center, AC line permanent three-phase ground N-1 fault has little influence on system.

3）直流单极闭锁，另一极考虑 3 秒钟 1.2 倍的过负荷能力，3 秒后 1.1 倍 2 小时的过负荷能力，系统保持稳定，相关曲线如下图所示：

3）When a HVDC monopole block fault occurs, the 1.2 times of three-second overloading capacity and 1.1 times of two-hour overloading capacity after three seconds are considered, the system keeps stable. The relevant curves are as follows:

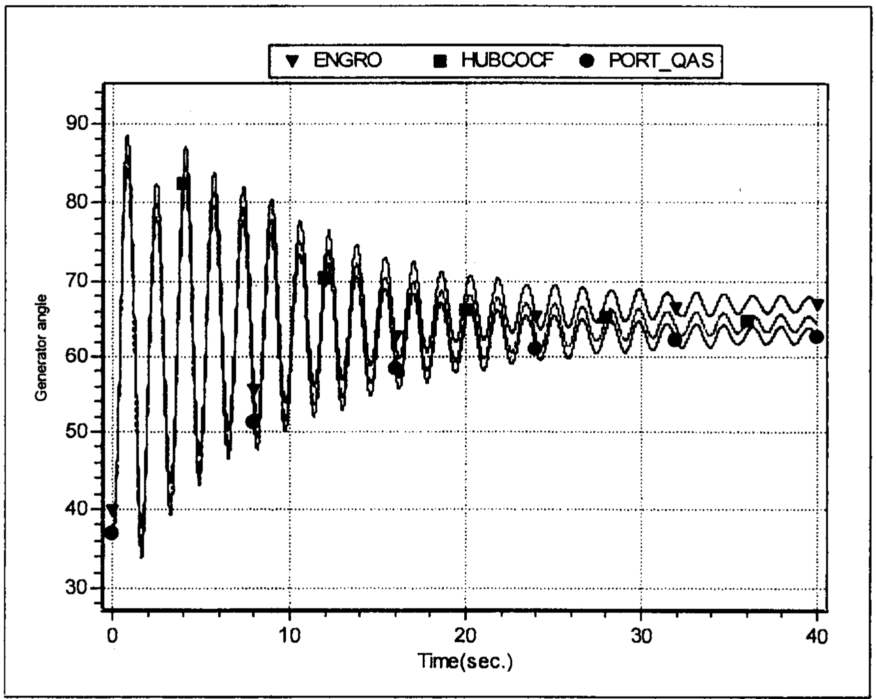

图 3-74　直流单极闭锁故障南部机组相对北部 G.BROTH 机组功角差
Fig.3-74 HVDC Monopole Block Fault-related south generator angle differences to G.BROTH generator angle

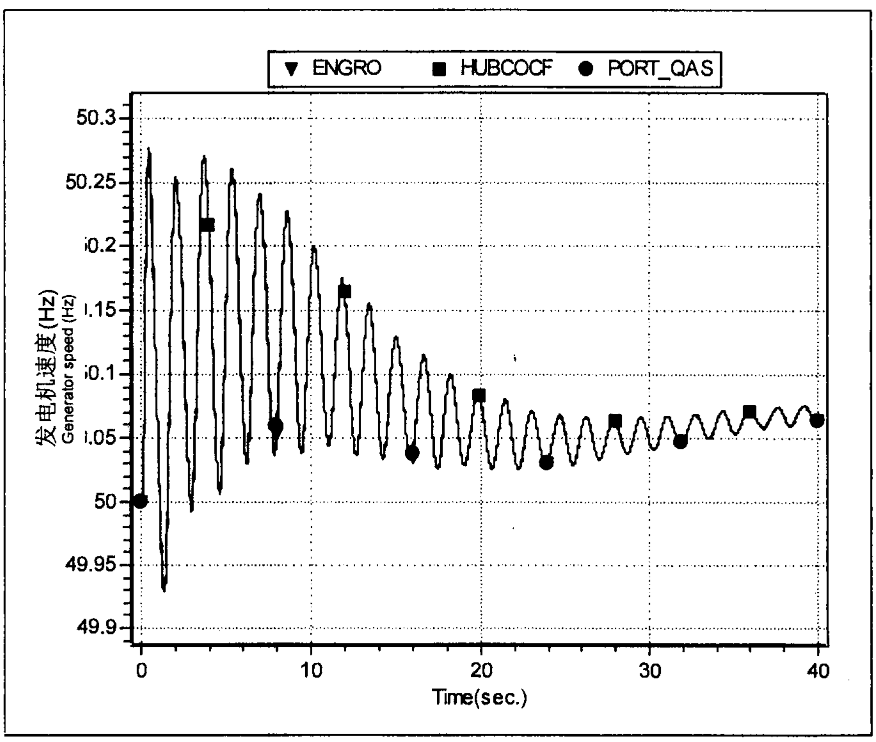

图 3-75　直流单极闭锁故障故障南部机组发电机速度
Fig.3-75 HVDC Monopole Block Fault -related south generator speed

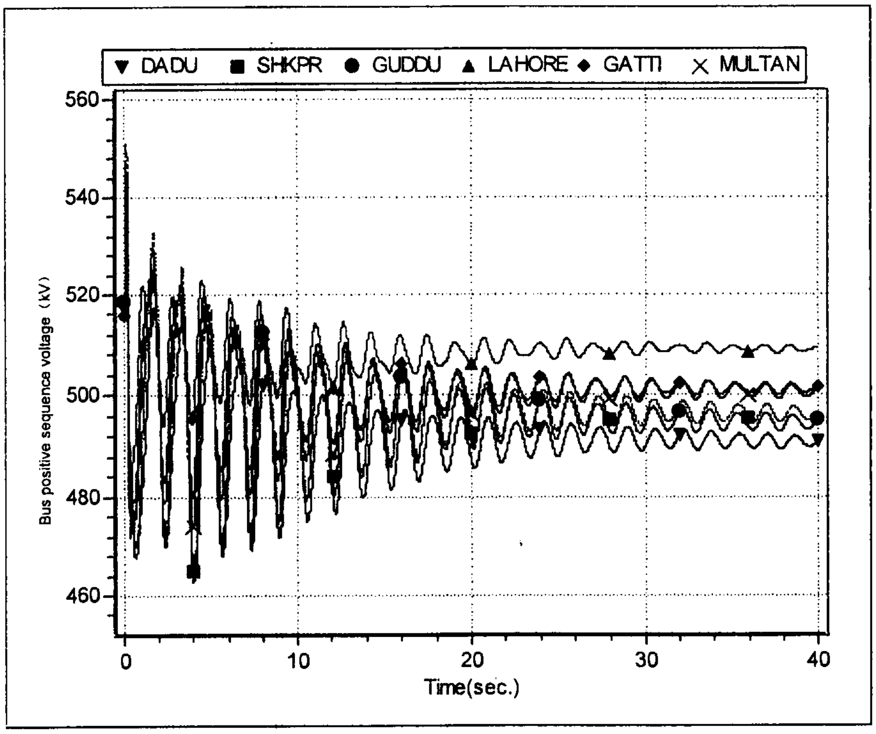

图 3-76 直流单极闭锁故障相关母线电压图
Fig.3-76 HVDC Monopole Block Fault -related Bus Voltage Graph

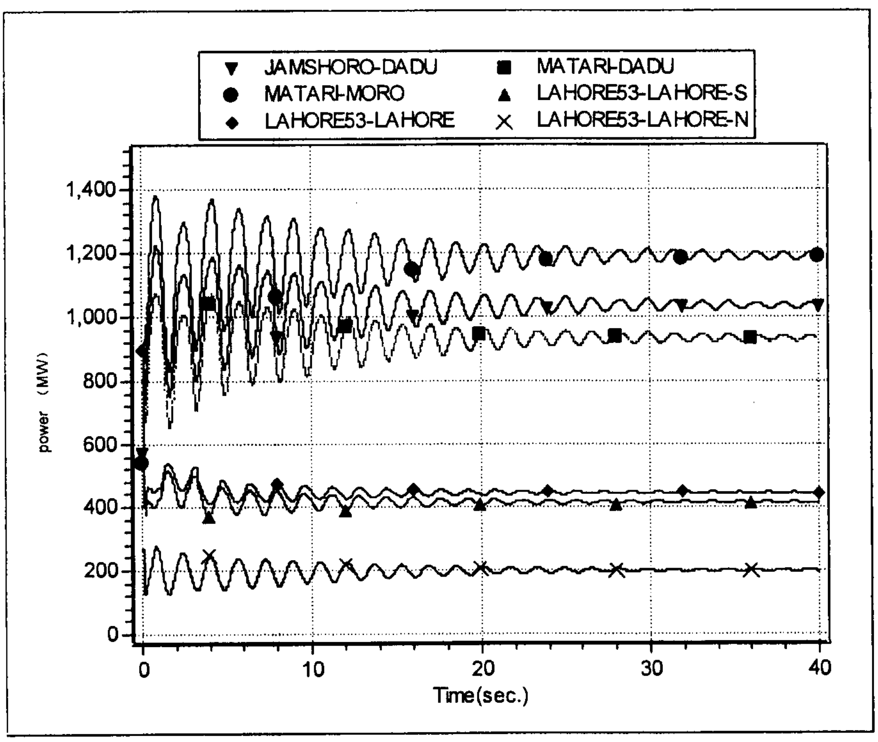

图 3-77 直流单极闭锁故障交流线路功率曲线图
Fig.3-77 HVDC Monopole Block Fault AC Power Curve

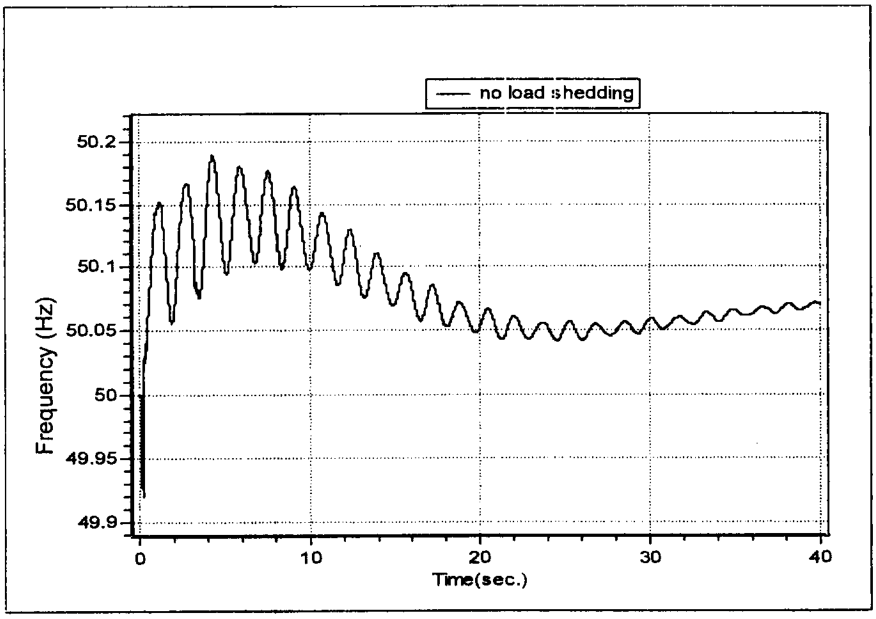

图 3-78 直流单极闭锁故障系统频率曲线图
Fig. 3-78 HVDC Monopole Block Fault System Frequency Curve

可以看出，直流单极闭锁后，盈余功率转移到并列运行的交流通道上，交流系统能够承受。故障后第一摆南北机组功角差约 50 度，功角稳定。故障后电压可恢复到合理范围，系统频率最低约为 49.9Hz，系统频率稳定。

It can be seen that, after HVDC monopole block occurs, the power surplus shifts to the HVAC channel in parallel operation, and the AC system can withstand it. The first swing of power angle difference between south and north generator is about 50 degrees and power angle is stable. The voltage can return to allowable range. The frequency of the system is stable, with the lowest frequency at approximately 49.9Hz.

4）双极闭锁故障不采取措施系统失稳，系统相关曲线如下图：

4）In a bipolar block fault without control measures the system is unstable, the relevant curve of system is indicated below:

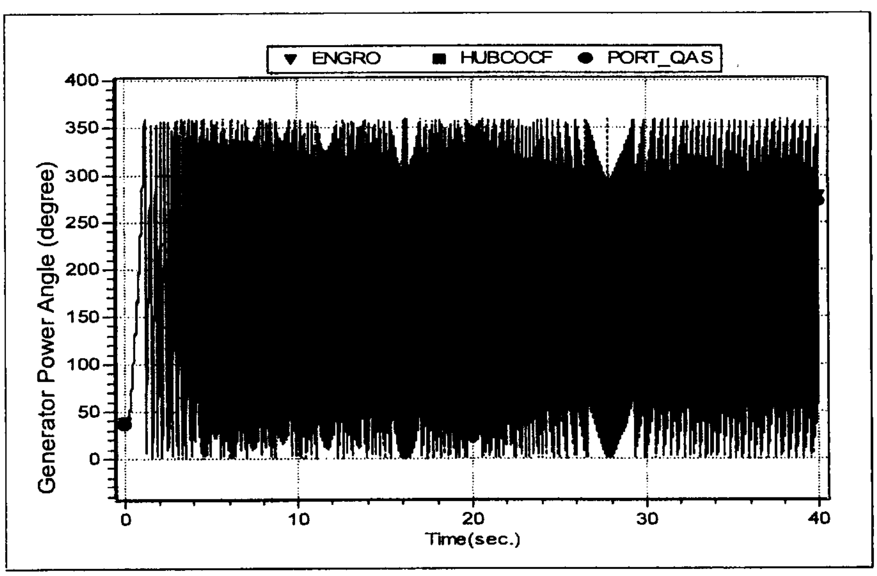

图 3-79 直流双极闭锁故障送端机组功角曲线图
Fig.3-79 HVDC Bipolar Block Fault Power Angle Graph

5）双极闭锁故障后，采取切除送端 3960MW 机组，受端 3000MW 负荷，系统可保持稳定。系统相关曲线如下图：

5）In case of bipolar block fault, 3960MW units require to be switched off and load shedding of 3000MW is required, and after taking these measures, the system resumes stable operation. The relevant curve of system is indicated below:

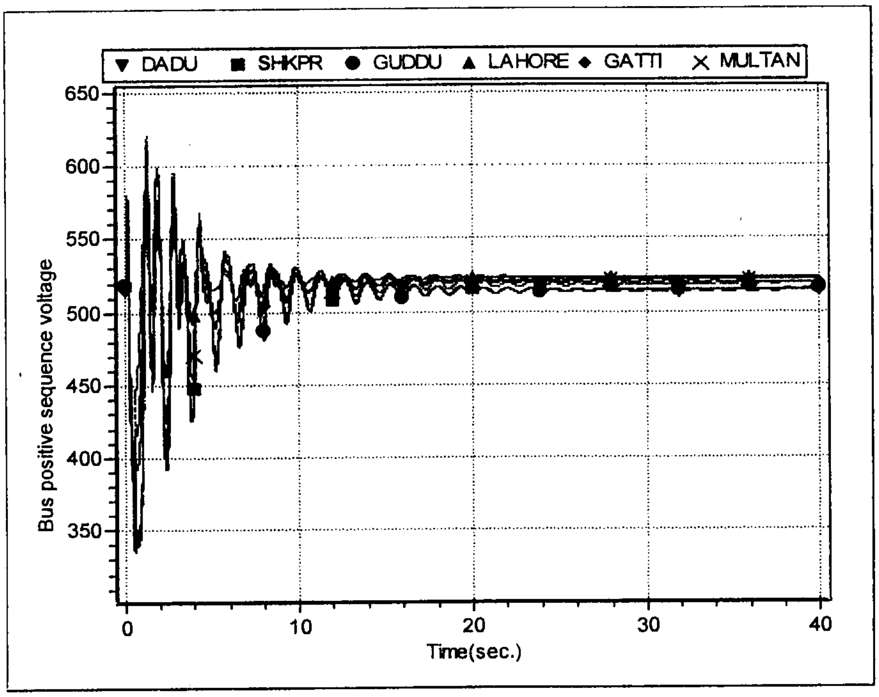

图 3-80　直流双极闭锁故障相关母线电压图
Fig. 3-80 HVDC Bipolar Block Fault-related Bus Voltage Graph

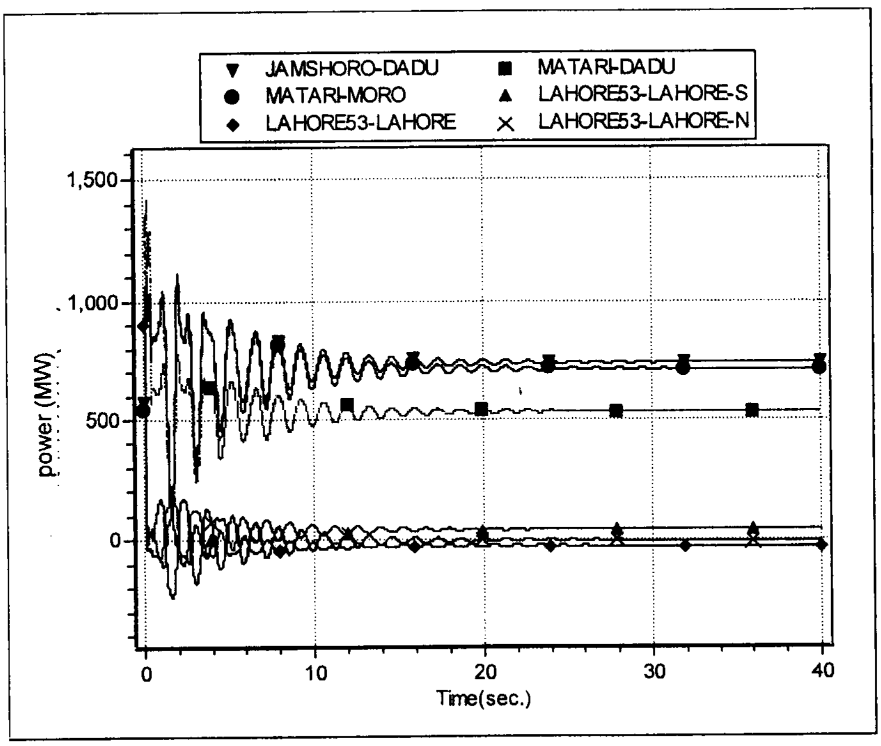

图 3-81　直流双极闭锁故障交流线路功率曲线图
Fig. 3-81 HVDC Bipolar Block Fault AC Power Curve

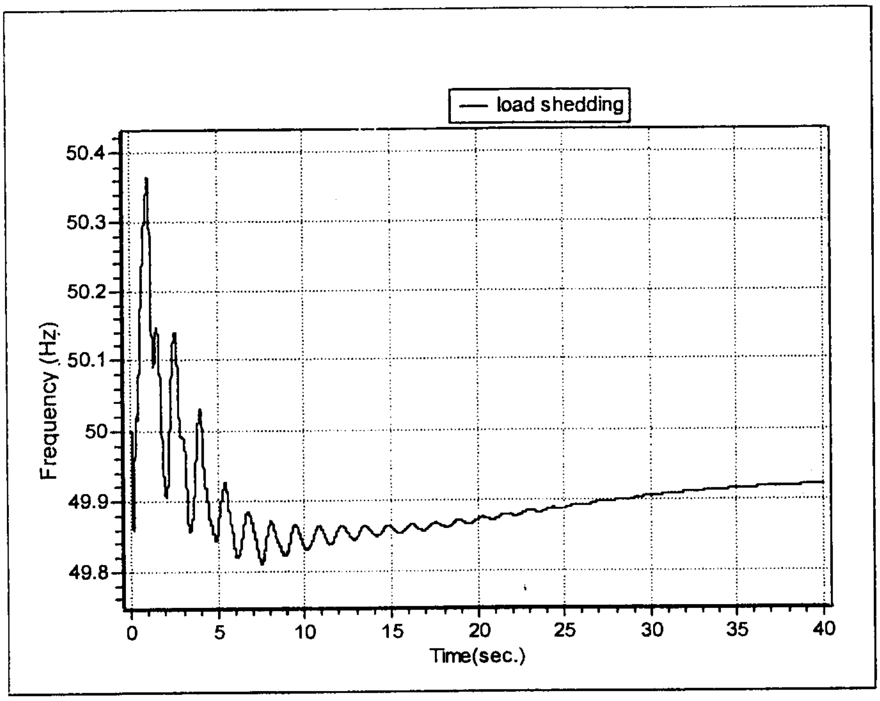

图 3-82 直流双极闭锁故障系统频率曲线图
Fig. 3-82 HVDC Bipolar Block Fault System Frequency Curve

如果双极闭锁后采取送端切机 3960MW、受端切负荷 3000MW 的措施，系统频率不失稳，交流通道的潮流较重，对直流安全稳定有影响，导致切负荷量增加。
If sending-end 3960MW unit switch-off and receiving-end 3000MW load shedding are performed after a bipolar block fault, the system frequency does not lose stability, and the load flow of the AC channel is heavy. This shows that it will have an effect on DC safety and stability, and shed load will be increased.

3.9 小结 Summary

巴基斯坦电网 2018 年夏大方式，默蒂亚里～拉合尔±660kV 直流工程送电 4000MW 方式下，直流送受端系统发生三永 N-1 故障时系统均能保持稳定，故障清除后，直流换流母线电压和功率输出也能保持平稳。直流送受端系统换流站与直流配套电源发生三永 N-2 故障时系统频率过低，采取切负荷措施后，直流换流母线电压和系统频率能保持在合理范围内。直流单极闭锁时，保持暂态稳定。直流双极闭锁时，需要分别采取送端切机 2640MW、受端切负荷 1700MW 的措施后系统恢复稳定运行，如按最严苛方式南部送电 5400MW，北部最小开机，交流补强网络不建设的方式下，直流单极闭锁保持稳定，直流双极闭锁需要分别采取送端切机 3960MW、受端切负荷 3000MW 的措施后系统恢复稳定运行。直流换相失败和直流再启动故障后，随着直流功率的恢复，母线电压经过波动后也逐渐恢复至初始水平。系统存在弱阻尼问题，稳定计算中所有 300MW 以上机组考虑配置 PSS，具体的 PSS 配置和小干扰稳定分析在建议后续展开专题研究。

Under Pakistan Grid 2018 summer maximum-load mode and Matiari-Lahore ±660kV HVDC Project 4000MW power transmission scheme, HVDC system can maintain stable in case of permanent three-phase ground N-1 fault; after removal of fault, the HVDC converting bus voltage and power output can maintain stable. In case of permanent three-phase ground N-2 fault in supporting power plants of HVDC Matiari side, after load shedding measure is taken, the HVDC converting bus voltage and system frequency can maintain in reasonable range. At the time of HVDC monopole block, the system can keep transient stability. At the time of HVDC bipolar block, 2640MW units switching off and 1700MW loads shedding are required to restore the normal stable operation of system. Due to the low damping of system, typical PSS is assumped to be installed at all of the geenrators above 300MW, however, special study of small signal stability and PSS needs to be developed subsequently in the next stage.

4 默蒂亚里～拉合尔±660kV 直流稳定敏感性分析
Matiari-Lahore ±660kV HVDC stability sensitivity analysis

以第 3 章巴基斯坦电网 2018 年夏大正常方式为基础方式，默蒂亚里～拉合尔±660kV 直流工程送电 4000MW，分别考虑不同运行方式下电网安全稳定敏感性分析，各方式内容如表 4-1 所示。

Based on normal Pakistan Grid 2018 summer maximum-load mode in chapter 3 and Matiari-Lahore ±660kV HVDC Project with 4000MW power transmission scheme, it is considered to analyze the grid safety and stability respectively in different modes, with the details indicated by Table 4-1 as below.

表 4-1 不同方式内容表
Table 4-1 Contents of Different Modes

方式 Mode	内容 Contents
基础方式 Basic mode	直流外送 4000MW ，交流 690MW HVDC 4000MW ,HVAC 690MW
方式 1 Mode 1	直流外送 3000MW 降功率运行 DC 3000MW transmission operates with reduced power.
方式 2 Mode 2	受端 660MW 机组停运 Lahore side 660MW unit stops operation
方式 3 Mode 3	全网机组旋转备用率提高到 5% Spinning reserve percentage of units throughout the grid is increased to 5%.
方式 4 Mode 4	2018 年夏小方式 2018 summer off-peak mode

4.1 考虑直流按 3000MW 降功率运行
Consideration on HVDC transmission at 3000MW reduced power

4.1.1 潮流计算
Load flow calculation

考虑默蒂亚里～拉合尔±660kV 直流工程按送电 3000MW 降功率运行方式。
Considering that the transmission operates at 3000MW reduced power for Matiari-Lahore ±660kV HVDC Transmission Project.

潮流计算表明，送受端系统潮流分布均匀、电压水平满足要求。送电 3000MW 降功率运行方式潮流分布如图 4-1 所示。
The load flow calculation shows that, distribution of system load flow is uniform and voltage level meets requirements. When power transmission operates at 3000MW reduced power, load flow distribution is illustrated in Fig. 4-1.

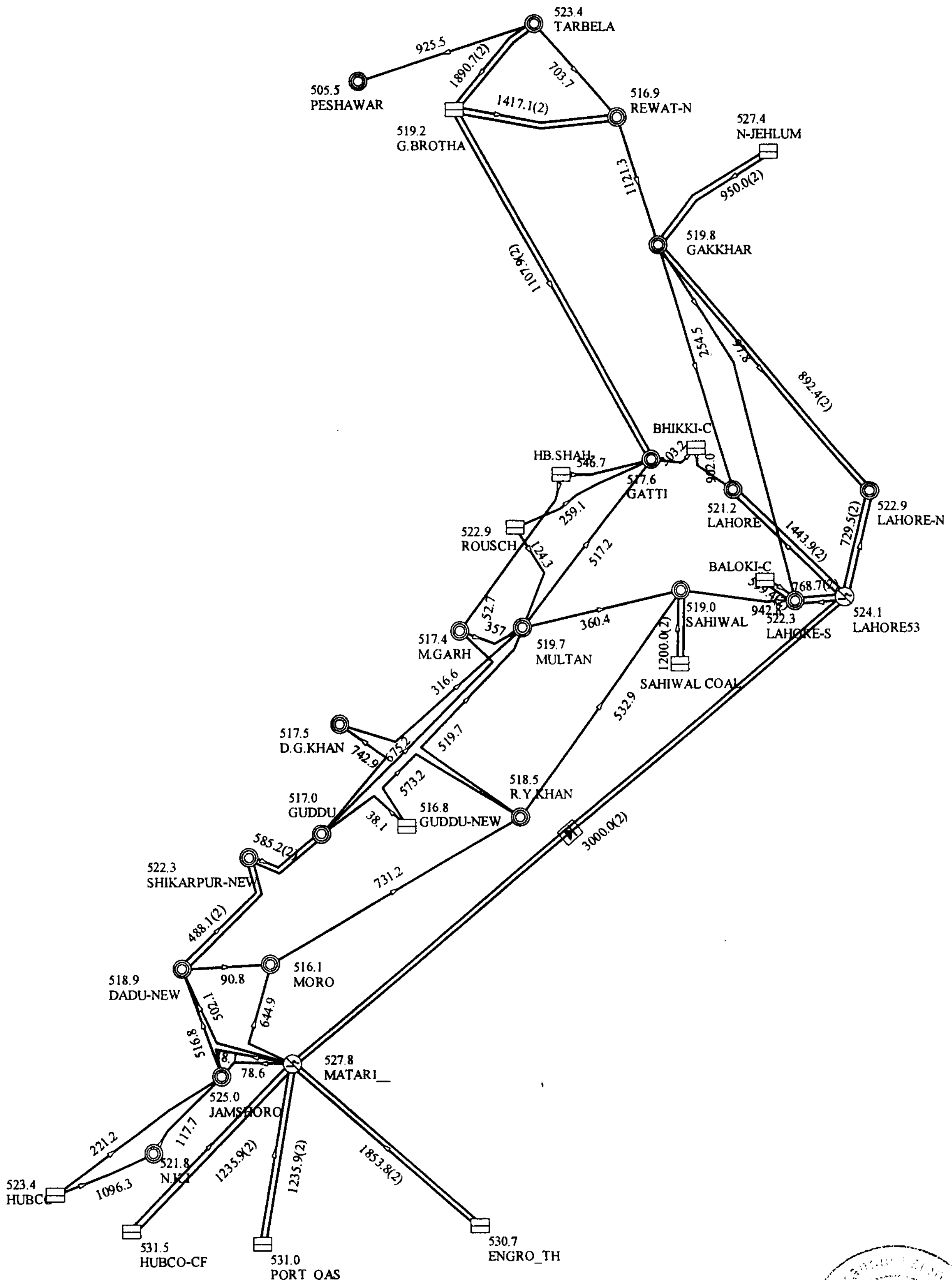

图 4-1 送电 3000MW 降功率运行方式潮流图

Fig. 4-1 Load Flow Diagram for Power Transmission at 3000MW Reduced Power

4.1.2 稳定计算
Stability calculation

考虑默蒂亚里～拉合尔±660kV 直流工程按送电 3000MW 降功率运行方式，稳定计算结果表明，500kV 主干网架线路发生单一故障系统均可保持安全稳定运行,送端电厂送出线路 N-2 需采取切负荷措施使系统频率恢复允许范围。直流单极闭锁故障，系统保持稳定。直流双极闭锁故障，系统失稳，需采取切除送端共 1980MW 机组，同时切除 1000MW 负荷，占全网负荷比例 4%，系统可保持稳定。稳定计算结果如表 4-2 所示:

Considering that Matiari-Lahore ±660kV HVDC Transmission Project operates at 3000MW reduced power, the stability calculation result shows that, when a single fault occurs in 500kV main network line, the system can maintain safe and stable operation, and the load shedding measures for outgoing line N-2 of Matiari side power plant are taken to make system frequency recover its allowable scope. When a HVDC monopole block fault occurs, the system can maintain stable. If the system becomes unstable because of the HVDC bipolar block fault, the 1980MW unit switch-off and 1000MW load (4% of load of the whole grid) shedding is performed to make the system maintain stable. The stability calculation results are shown in Table 4-2:

表 4-2 电网稳定计算结果表
Table 4-2 Grid Stability Calculation Results

线路名称 Name of line	故障类型 Fault type	稳定计算结果 Stability result
送端交流故障 Matiari side AC fault		
MATIARI～JAMSHORO	三永 Permanent three-phase ground fault	稳定 Stable
DADU-NEW～JAMSHORO	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～DADU-NEW	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～MORO	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～THAR COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 1000MW 负荷 1000MW load shedding
受端交流故障 Lahore side AC fault		
LAHORE 换流站～LAHORE SOUTH LAHORE Converter station-LAHORE SOUTH	三永 Permanent three-phase ground fault	稳定 Stable
LAHORE 换流站～LAHORE LAHORE Converter station-LAHORE	三永 Permanent three-phase ground fault	稳定 Stable
LAHORE 换流站～LAHORE NORTH LAHORE Converter station-LAHORE SOUTH	三永 Permanent three-phase ground fault	稳定 Stable
LAHORE 换流站～LAHORE SOUTH LAHORE Converter	三永跳双回 Permanent three-phase ground fault and	稳定 Stable

station-LAHORE SOUTH	double-circuit trip	
LAHORE 换流站～LAHORE LAHORE Converter station-LAHORE	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
LAHORE 换流站～LAHORE NORTH LAHORE Converter station-LAHORE SOUTH	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
直流故障 HVDC fault		
MATIARI～LAHORE 直流 MATIARI-LAHORE HVDC	单极闭锁 Monopole block fault	稳定 Stable
MATIARI～LAHORE 直流 MATIARI-LAHORE HVDC	双极闭锁 Bipolar block fault	切除 1980MW 机组，同时切除 1000MW 负荷后系统恢复稳定 The system restores to the stable state after 1980MW unit switch-off and 1000MW load shedding.

1）MATIARI～MORO 线路三永 N-1，对应的系统响应曲线为：

1）In this case, the system response curve corresponding to MATIARI-MORO line permanent three-phase ground N-1 is presented as follows:

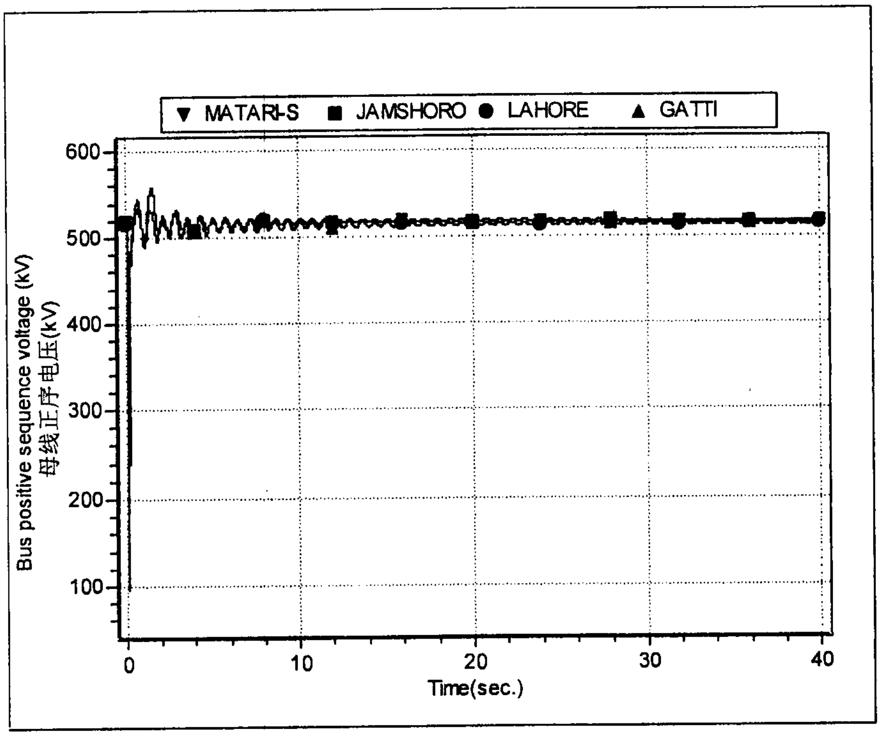

图 4-2 MATIARI～MORO 线路三永 N-1 故障相关母线电压图

Fig.4-2 MATIARI-MORO Line Permanent Three-phase Ground N-1 Fault-related Bus Voltage Graph

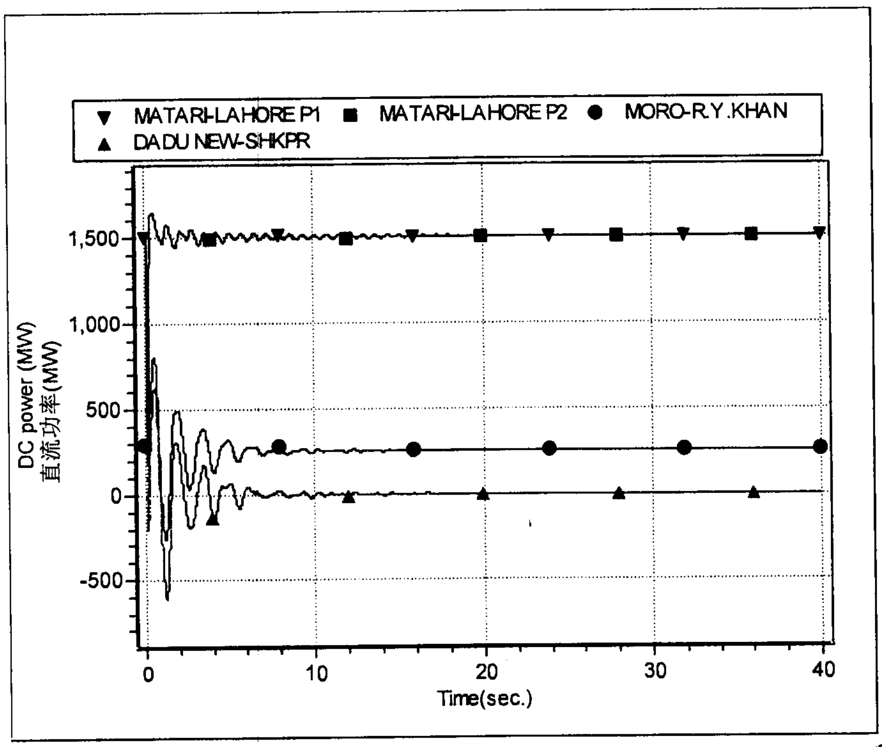

图 4-3 MATIARI～MORO 线路三永 N-1 故障交直流线路功率曲线图

Fig.4-3 MATIARI-MORO Line Permanent Three-phase Ground N-1 Fault-related AC/DC Line Power Graph

2）单极闭锁故障，对应的系统响应曲线为：

2）In this case, the system response curve corresponding to monopole block fault is presented as follows:

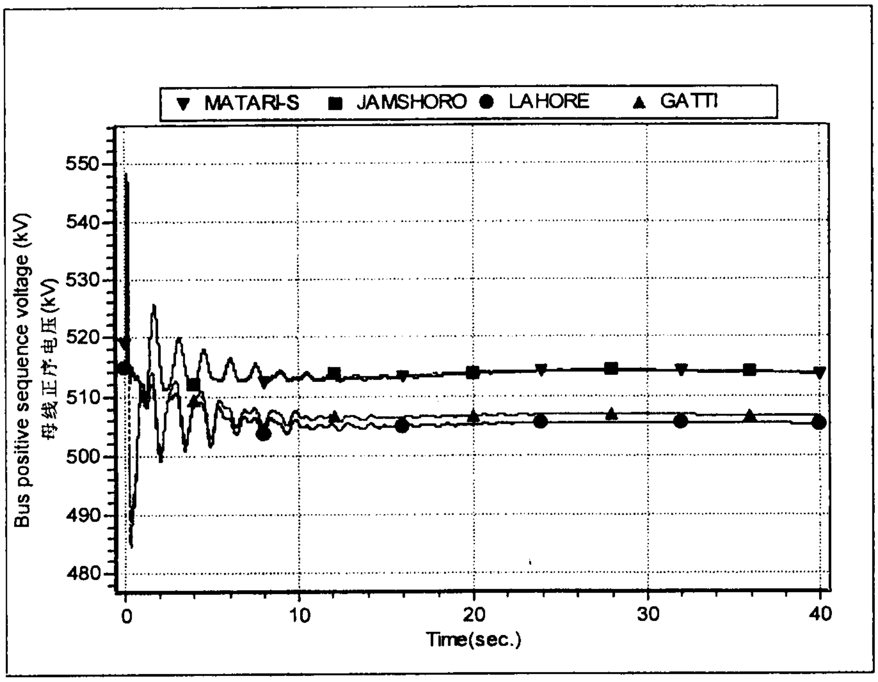

图 4-4 MATIARI～LAHORE 直流单极闭锁故障相关母线电压图

Fig. 4-4 MATIARI-LAHORE HVDC Monopole Block Fault-related Bus Voltage Graph

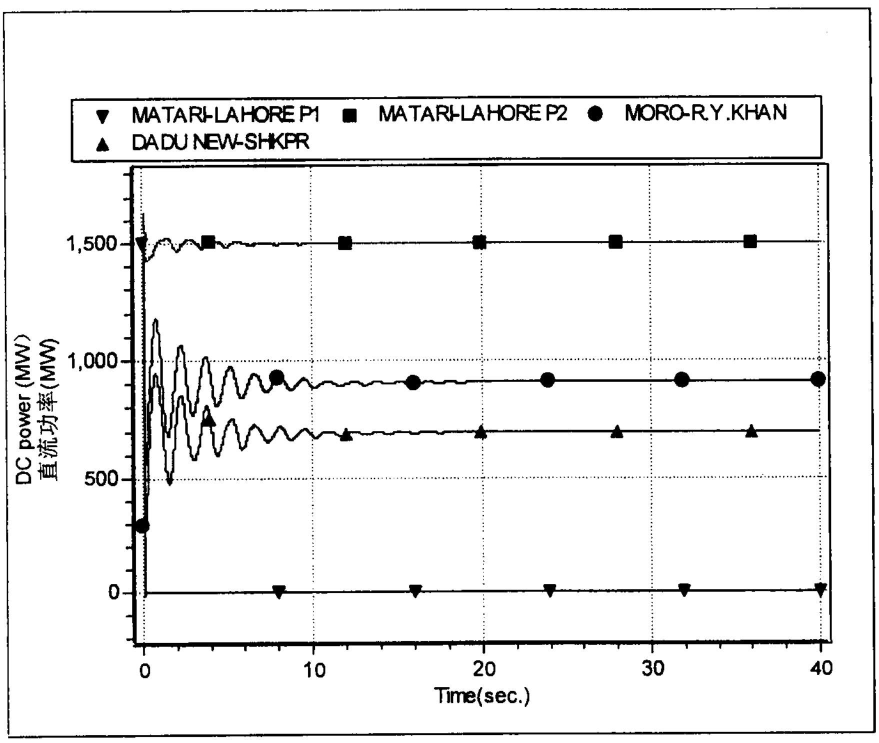

图 4-5 直流单极闭锁故障交直流线路功率曲线图

Fig. 4-5 HVDC Monopole Block Fault-related AC/DC Line Power Graph

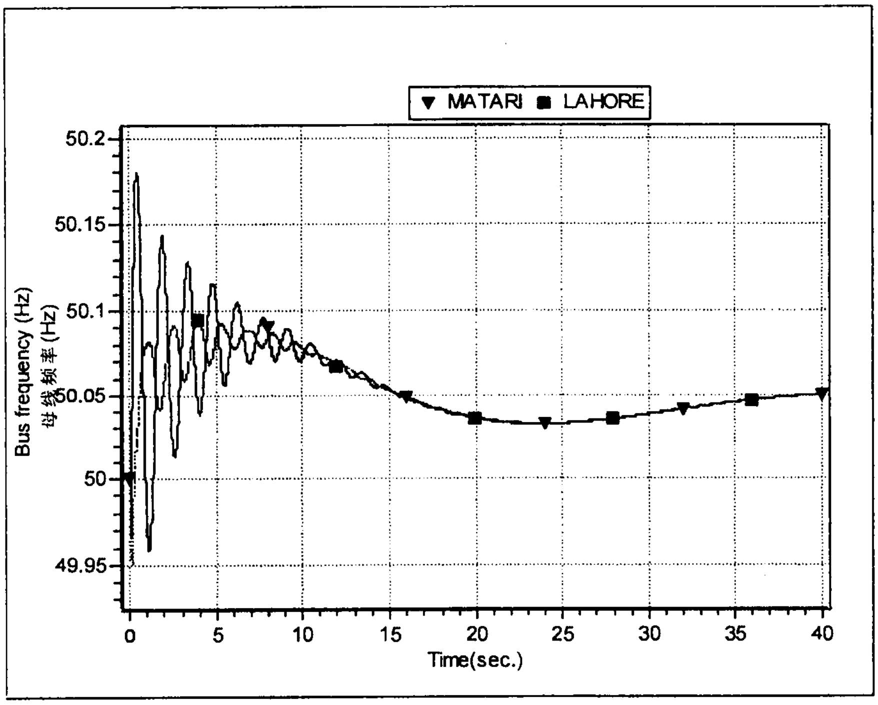

图 4-6 直流单极闭锁故障系统频率曲线图
Fig. 4-6 HVDC Monopole Block Fault-related System Frequency Graph

可以看出，直流单极闭锁后，交流系统能够承受功率转移，系统频率最低约为 50.0Hz，系统频率稳定。
It can be seen that, when a DC monopole block fault occurs, the AC system can withstand power transfer; the lowest system power is about 50.0Hz, which is stable.

3）双极闭锁故障，切机 1980MW、切负荷 1000MW 后，系统保持稳定，对应的系统响应曲线为：
3) The 1980MW unit switch-off and 1000MW load shedding are performed after a bipolar block fault, and then the system keeps stable. The system response curve is presented as follows:

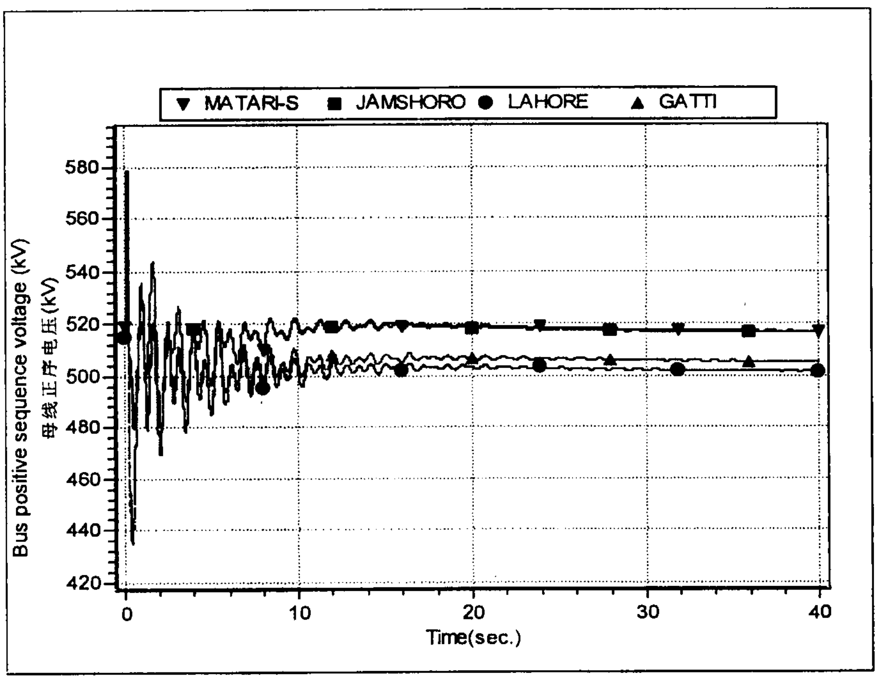

图 4-7 直流双极闭锁故障相关母线电压图
Fig. 4-7 HVDC Bipolar Block Fault-related Bus Voltage Graph

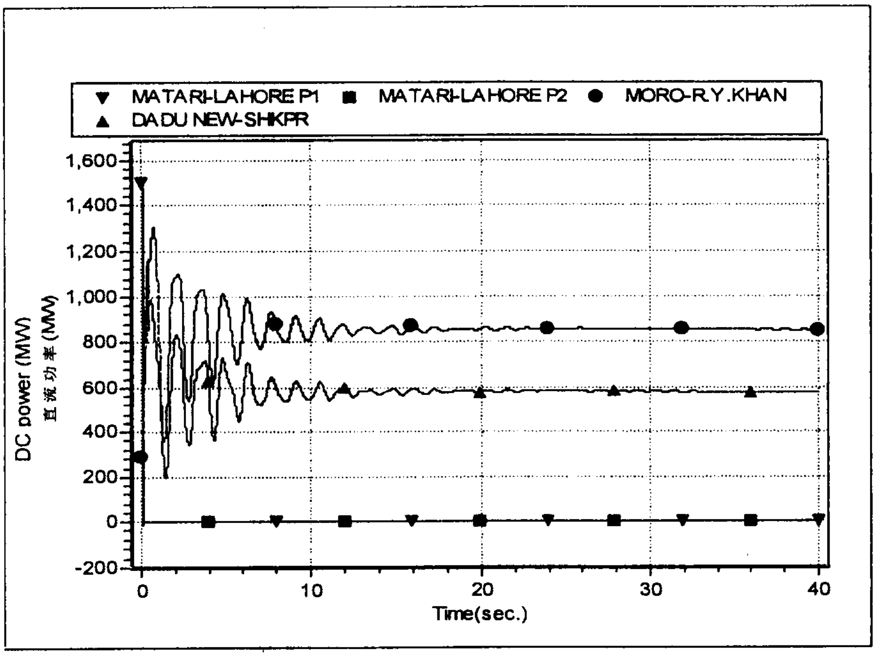

图 4-8 直流双极闭锁故障交直流线路功率曲线图
Fig. 4-8 HVDC Bipolar Block Fault-related AC/DC Line Power Graph

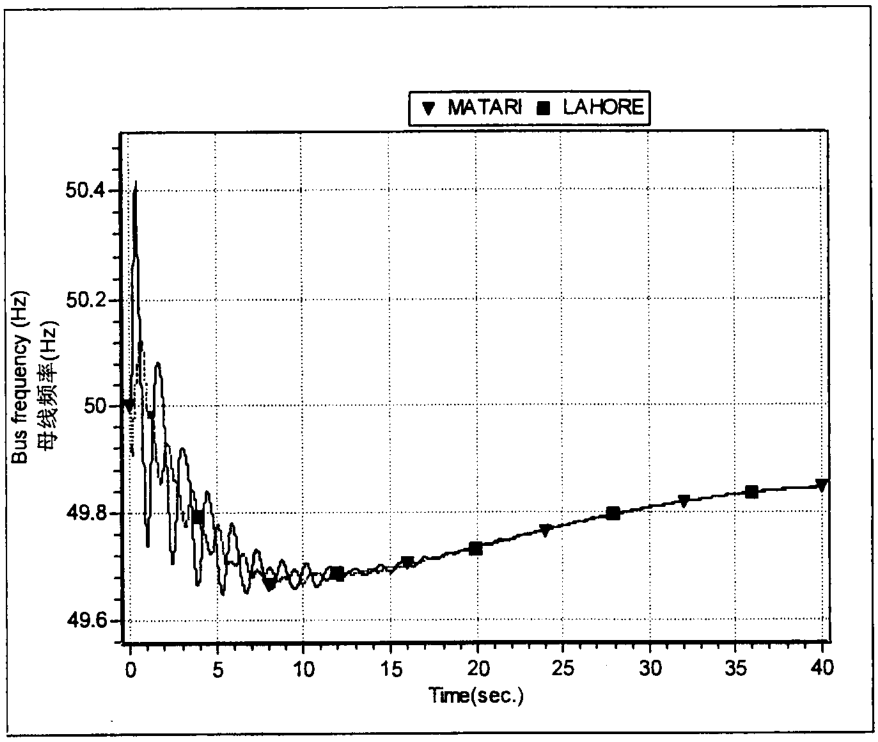

图 4-9 直流双极闭锁故障系统频率曲线图
Fig. 4-9 HVDC Bipolar Block Fault-related System Frequency Graph

如果双极闭锁后采取送端切机 1980MW、受端切负荷 1000MW 的措施，降低沿途电压下降的幅度，系统电压和频率不失稳。与基础方案比较，直流降功率运行方式可减少切机 660MW，减少切负荷 700MW。
If 1980MW unit switch-off and 1000MW load shedding are performed after a bipolar block fault, amplitude of voltage reduction should be lowered along the line to make system voltage and frequency not lose stability. Comparing to the basic mode that HVDC transfers 4000MW, the operating mode of HVDC power reduction can avoid 660MW unit and 700MW load being shedded.

4.2 考虑受端 660MW 机组停运
Consideration on stoppage of Lahore side 660MW unit

4.2.1 潮流计算
Load flow calculation

考虑受端 SAHIWAL 煤电厂一台 660MW 机组停运方式。

Considering that one Lahore side 660MW unit of SAHIWAL coal power plant stops running.

潮流计算表明，送受端系统潮流分布均匀、电压水平满足要求。受端 660MW 机组停运方式潮流分布如图 4-10 所示。
Load flow calculation shows that, distribution of system load flow is uniform and voltage level meets requirements. When Lahore side 660MW unit stops running, load flow distribution is illustrated in Fig. 4-10.

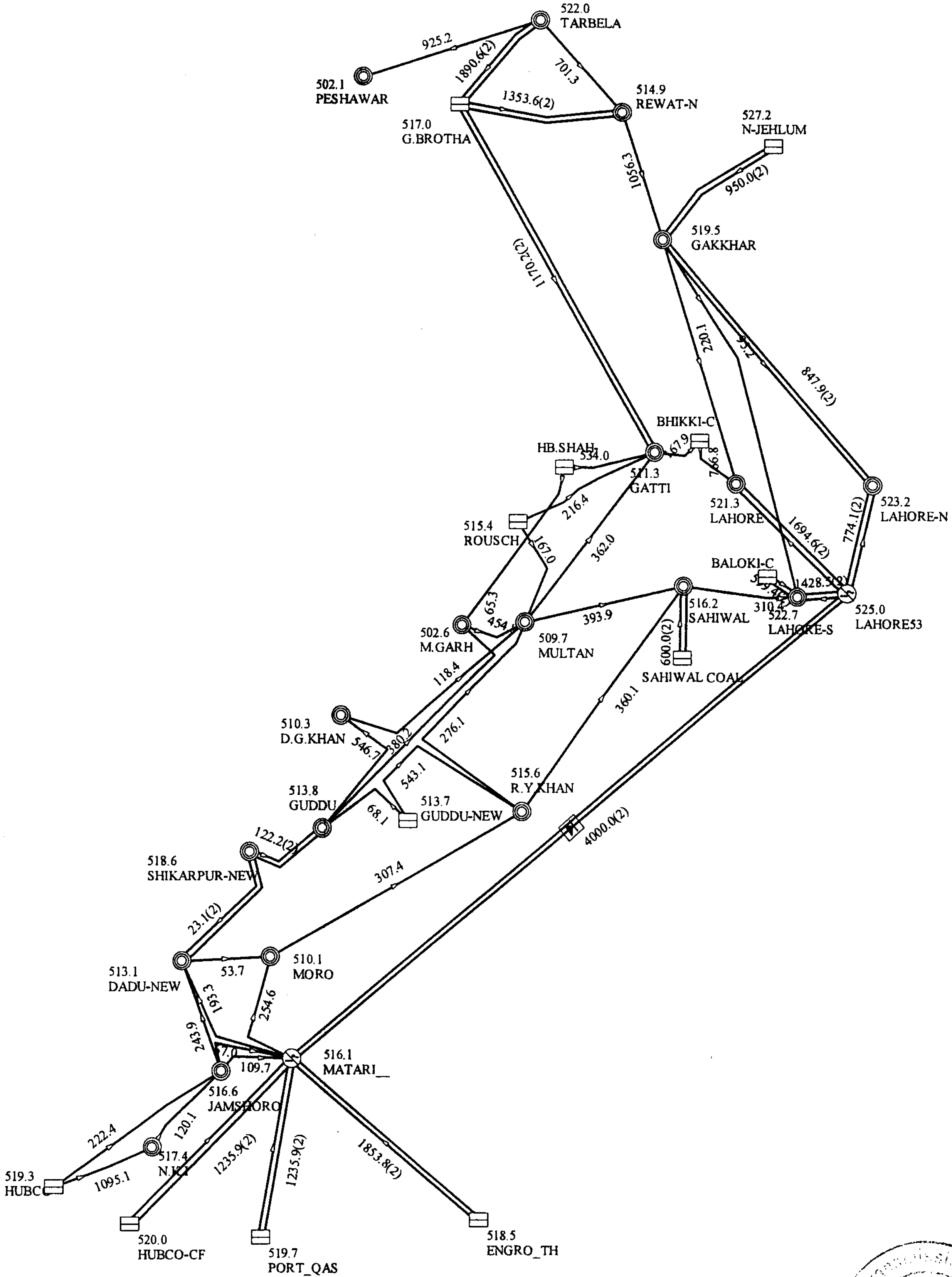

图 4-10 受端 660MW 机组停运方式潮流图

Fig. 4-10 Load Flow Diagram for stoppage of Lahore side 660MW unit

4.2.2 稳定计算
Stability calculation

考虑受端 660MW 机组停运方式，稳定计算结果表明，500kV 主干网架线路发生单一故障系统均可保持安全稳定运行,送端电厂送出线路 N-2 需采取切负荷措施使系统频率恢复允许范围。直流单极闭锁故障，系统可保持稳定，不需要采取切负荷措施。直流双极闭锁故障，系统失稳，需采取切除送端共 3300MW 机组，同时切除 2400MW 负荷，占全网负荷比例 9%，系统可保持稳定。稳定计算结果如表 4-3 所示:
When the shutdown mode of the Lahore 660MW unit is considered, the stability calculation result shows that, when a single fault occurs in 500kV main network line, the system can maintain safe and stable operation, and the load shedding measures for outgoing line N-2 of Matiari side power plant are taken to make system frequency recover its allowable scope. When a HVDC monopole block fault occurs, the system can maintain stable without any load shedding measures. If the system becomes unstable because of the HVDC bipolar block fault, the 3300MW unit switch-off and 2400MW load (9% of load of the whole grid) shedding is performed to make the system maintain stable. The stability calculation results are shown in Table 4-3:

表 4-3 电网稳定计算结果表
Table 4-3 Grid Stability Calculation Results

线路名称 Name of line	故障类型 Fault type	稳定计算结果 Stability Calculation Result
送端交流故障 Matiari side AC Fault		
MATIARI～JAMSHORO	三永 Permanent three-phase ground fault	稳定 Stable
DADU-NEW～JAMSHORO	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～DADU-NEW	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～MORO	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～THAR COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 1000MW 负荷 1000MW load shedding
MATIARI～QASIM COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 400MW 负荷 400MW load shedding
MATIARI～NEW HUBCO COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 400MW 负荷 400MW load shedding
受端交流故障 Lahore side AC Fault		
换流站～LAHORE SOUTH Converter station-LAHORE SOUTH	三永 Permanent three-phase ground fault	稳定 Stable
换流站～LAHORE Converter station-LAHORE	三永 Permanent three-phase ground fault	稳定 Stable
换流站～LAHORE NORTH Converter station-LAHORE NORTH	三永 Permanent three-phase ground fault	稳定 Stable

换流站～LAHORE SOUTH Converter station-LAHORE SOUTH	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
换流站～LAHORE Converter station-LAHORE	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
换流站～LAHORE NORTH Converter station-LAHORE SOUTH	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
直流故障 HVDC Fault		
MATIARI～LAHORE 直流 MATIARI～LAHORE HVDC	单极闭锁 Monopole block	稳定 Stable
MATIARI～LAHORE 直流 MATIARI～LAHORE HVDC	双极闭锁 Bipolar block	切除 3300MW 机组，同时切除 2400MW 负荷后系统恢复稳定 The system restores to the stable state after 3300MW unit switch-off and 2400MW load shedding

1）MATIARI～MORO 线路三永 N-1，对应的系统响应曲线为:

1）In this case, the system response curve corresponding to MATIARI-MORO line three-phase permanent ground fault N-1 is presented as follows:

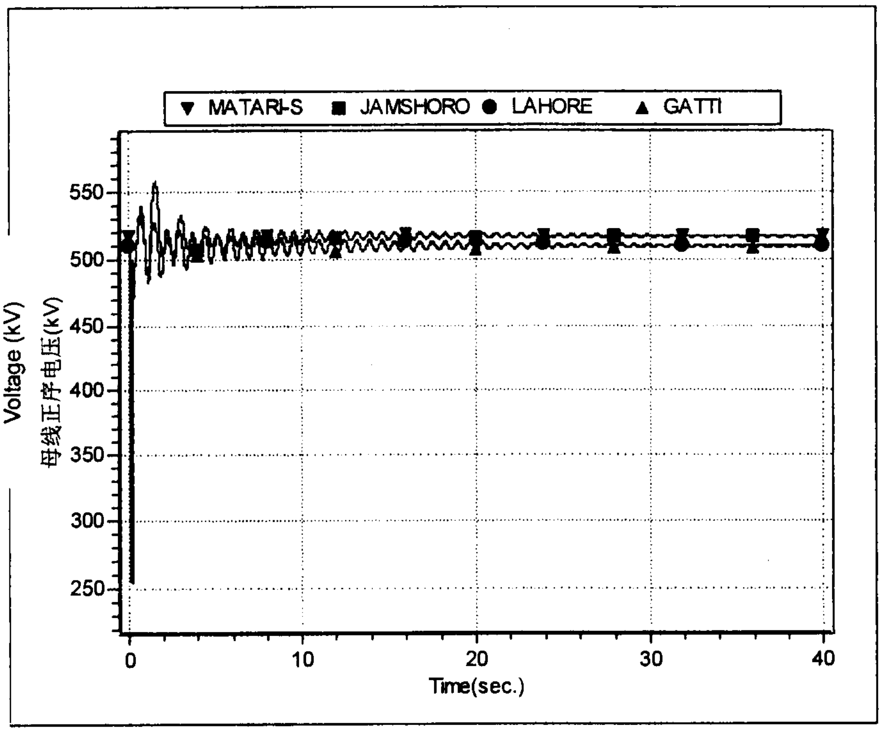

图 4-11 MATIARI～MORO 线路三永 N-1 故障相关母线电压图

Fig. 4-11 MATIARI-MORO Line Permanent Three-phase Ground N-1 Fault-related Bus Voltage Graph

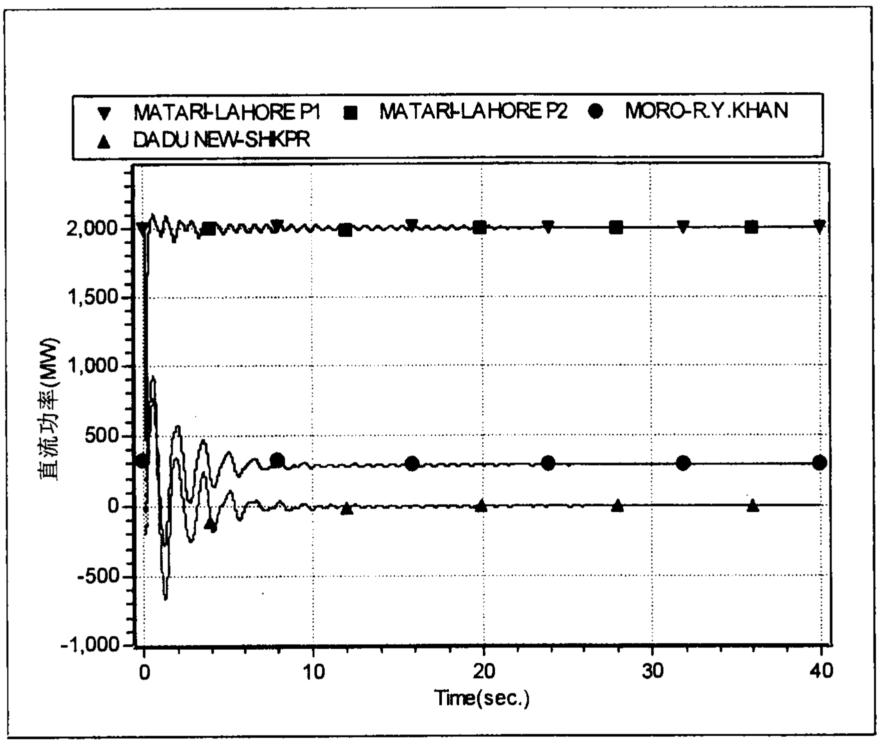

图 4-12 MATIARI～MORO 线路三永 N-1 故障交直流线路功率曲线图

Fig. 4-12 MATIARI-MORO Line Permanent Three-phase Ground N-1 Fault-related AC/DC Line Power Graph

2）单极闭锁故障，系统相关曲线如下图：

2）The system-related curve corresponding to monopole block fault is presented as follows:

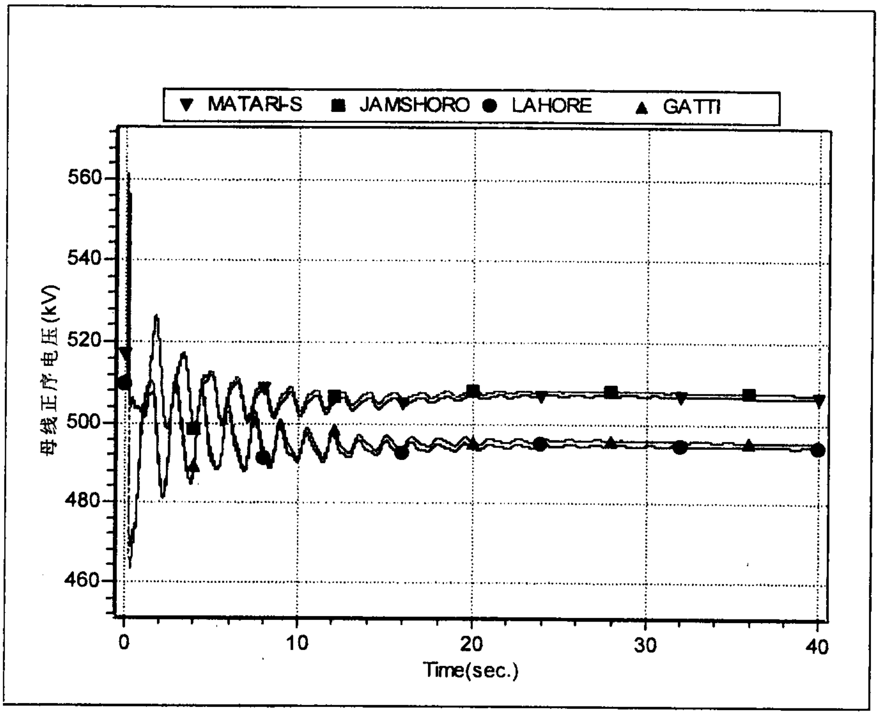

图 4-13 MATIARI～LAHORE 直流单极闭锁故障相关母线电压图

Fig. 4-13 MATIARI～LAHORE HVDC Monopole Block Fault-related Bus Voltage Graph

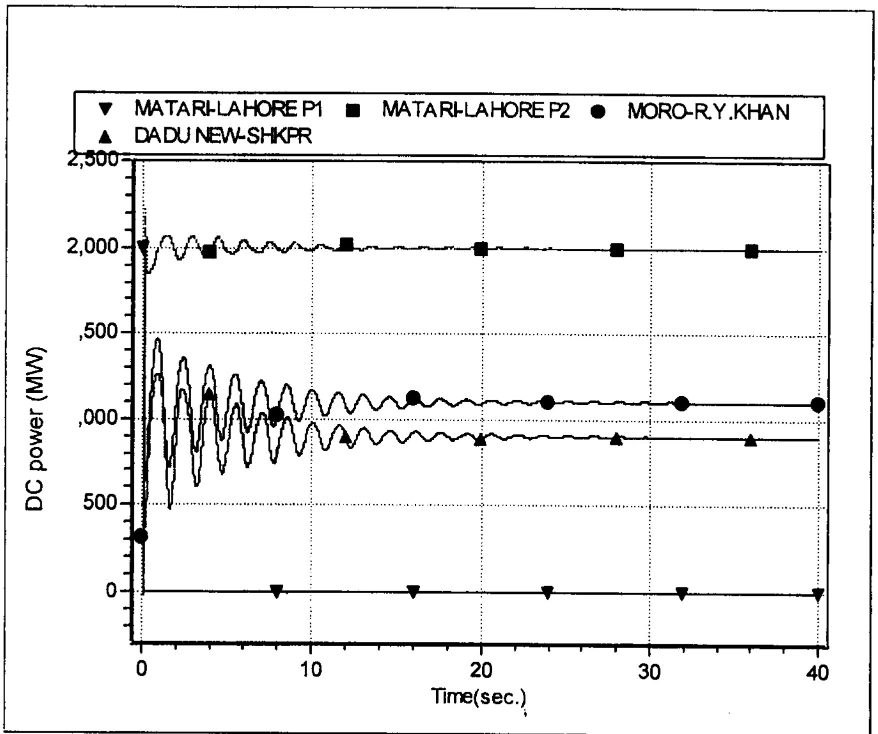

图 4-14 直流单极闭锁故障交直流线路功率曲线图

Fig. 4-14 HVDC Monopole Block Fault-related AC/DC Line Power Graph

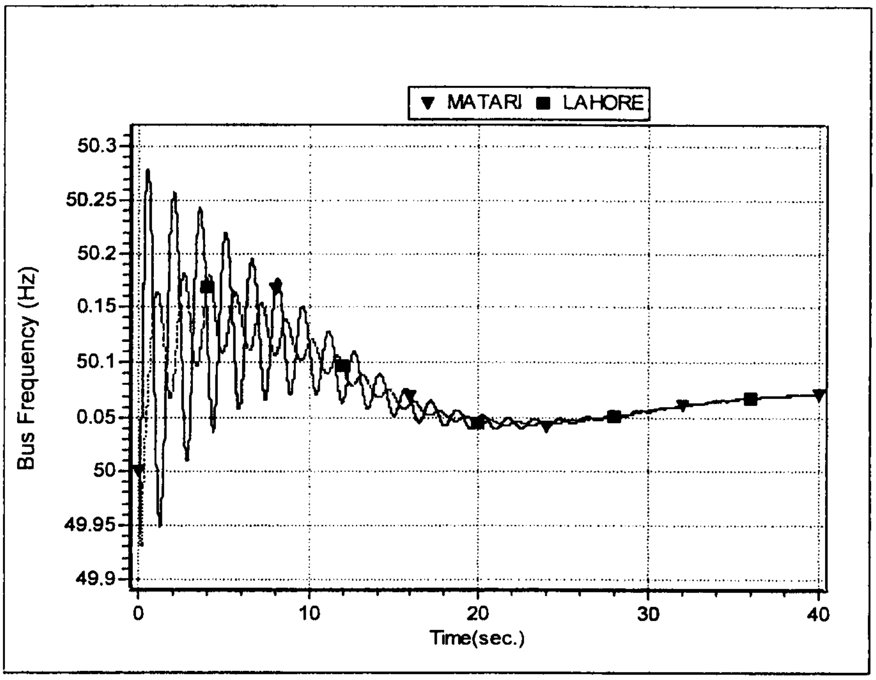

图 4-15 直流单极闭锁故障系统频率曲线图
Fig. 4-15 HVDC Monopole Block Fault-related System Frequency Graph

可以看出，直流单极闭锁后盈余功率转移到接入的交流系统上，交流系统能够承受，系统频率最低约为49.9Hz，系统电压和频率稳定。
It can be seen that, in case of a DC monopole block fault, the redundant power will transfer to the connected AC system, and the AC system can withstand it. The lowest frequency of the system is about 49.9Hz, and system frequency and voltage are stable.

3)双极闭锁故障，切机 3300MW、切负荷 2400MW 后，系统保持稳定，对应的系统响应曲线为：
3)The 3300MW unit switch-off and 2400MW load shedding are performed after a bipolar block fault, and then the system keeps stable. The system response curve is presented as follows:

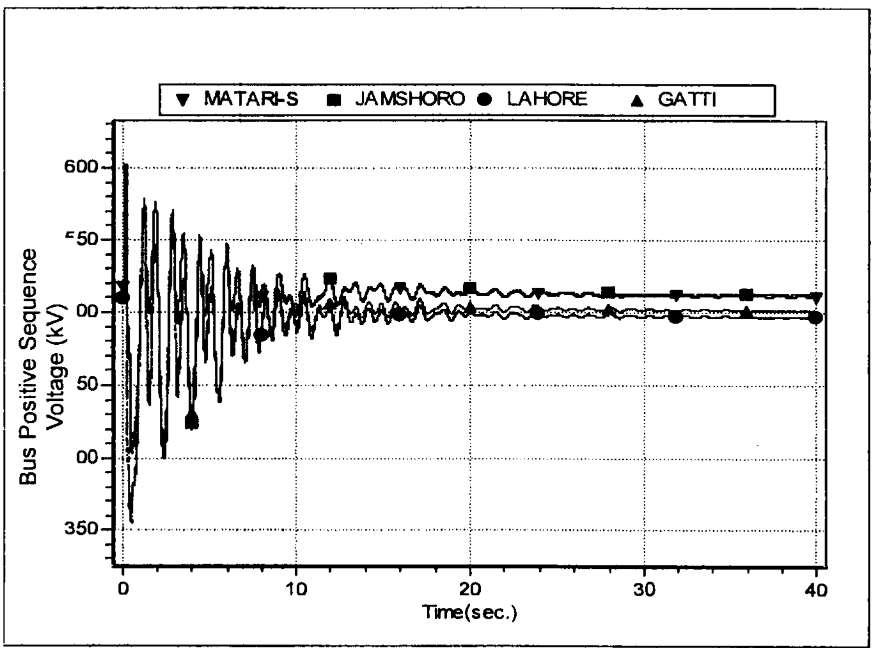

图 4-16 直流双极闭锁故障相关母线电压图
Fig. 4-16 HVDC Bipoar Block Fault-related Bus Voltage Graph

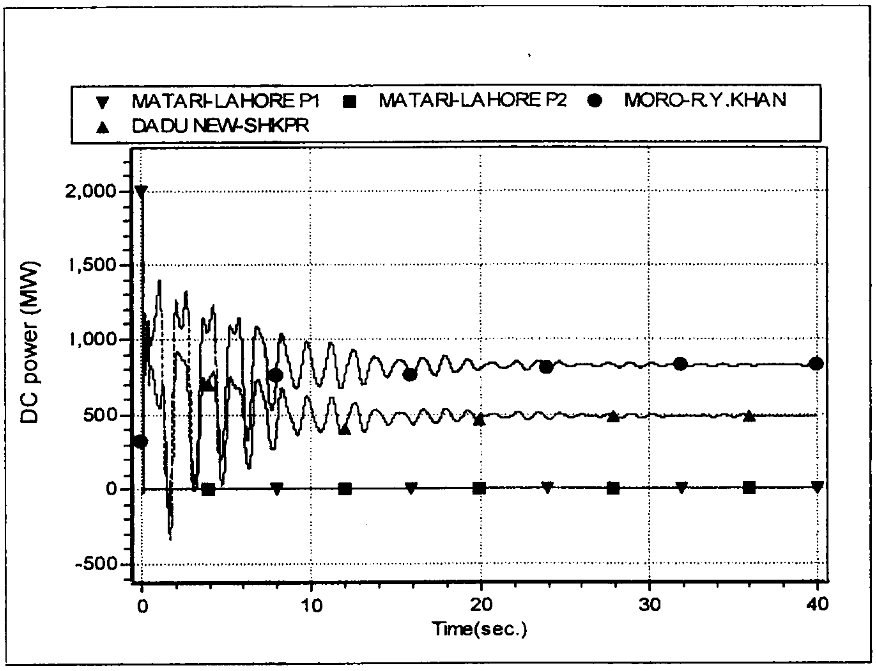

图 4-17 直流双极闭锁故障交直流线路功率曲线图
Fig. 4-17 HVDC Bipolar Block Fault-related AC/DC Line Power Graph

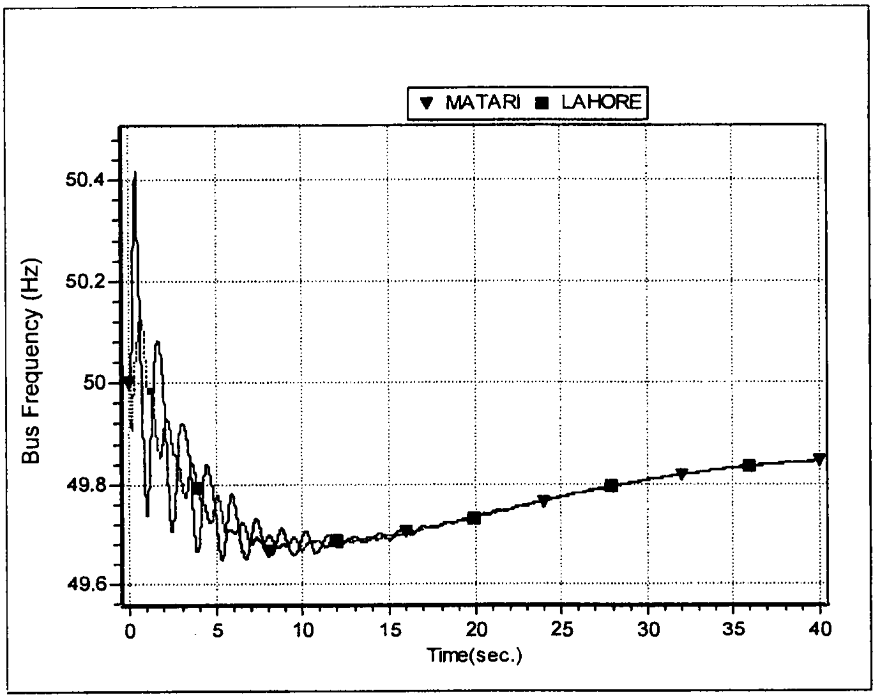

图 4-18 直流双极闭锁故障系统频率曲线图
Fig. 4-18 HVDC Bipolar Block Fault-related System Frequency Graph

如果双极闭锁后采取送端切机 3300MW、受端切负荷 2400MW 的措施，降低沿途电压下降的幅度，系统频率不失稳，与正常方式相比需要多切除 700MW 负荷。由此可以看出，交流通道受端机组停机对直流的安全稳定是有影响的。

If 3300MW unit switch-off and 2400MW load shedding are performed after a bipolar block fault, amplitude of voltage reduction is lowered along the line to make system frequency not lose stability, and additional 700MW load should be shed compared with the normal mode. This shows that shutdown of unit in AC channel has an effect on HVDC safety and stability, and shed load is increased.

4.3 考虑提高全网机组旋转备用率
Consideration on increase of spinning reserve

4.3.1 潮流计算
Load flow calculation

由于在我国调度运行时，旋转备用取 2%～5%，大网取小值，小网取大值，巴基斯坦电网规模相对较小，所以按运行标准考虑将旋转备用率从一台最大单机容量提高至 5%。
For power dispatching and operation in China, the spinning reserve percentage is defined as 2% to 5% (smaller value for big grid and bigger value for small grid). The power grid of Pakistan is relatively small in scale, so the operation standards should be adopted to increase the spinning reserve percentage to 5% from the one maximum unit capacity.

潮流计算表明，送受端系统潮流分布均匀、电压水平满足要求。全网机组旋转备用率提高为 5%方式潮流分布如图 4-19 所示。
Load flow calculation shows that, at the receiving/sending-end, distribution of system load flow is uniform and voltage level meets requirements. When the spinning reserve percentage of units throughout the grid is increased to 5%, load flow distribution is illustrated in Fig. 4-19.

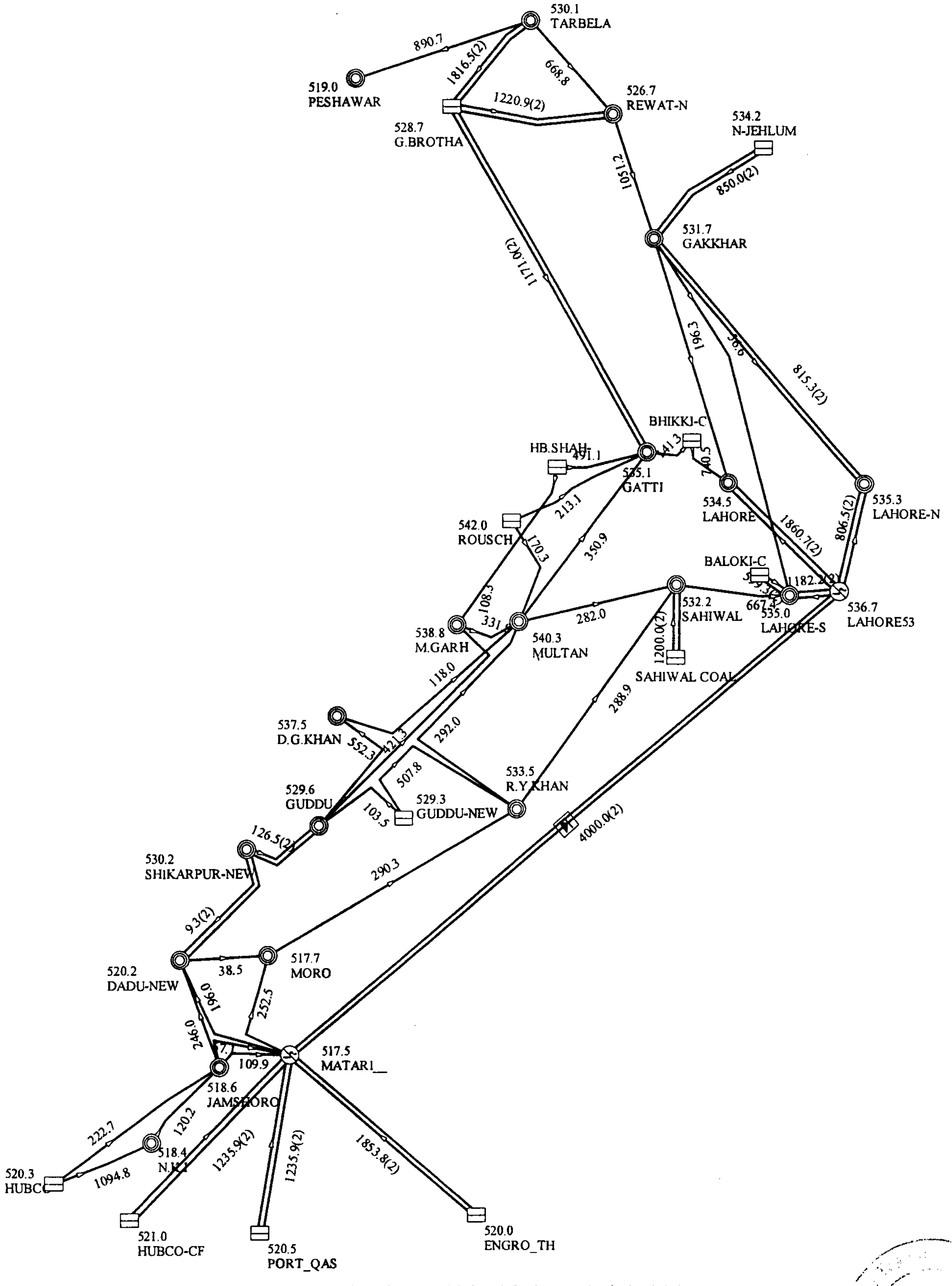

图 4-19 全网机组旋转备用率为 5%方式潮流图

Fig. 4-19 Load Flow Diagram for 5% Spinning Reserve Percentage of Units throughout the Grid

4.3.2 稳定计算
Stability calculation

考虑全网机组旋转备用率为 5%方式，稳定计算结果表明，500kV 主干网架线路发生单一故障系统均可保持安全稳定运行,送端电厂送出线路 N-2 需采取切负荷措施使系统频率恢复允许范围。直流单极闭锁故障，系统可保持稳定，不需要采取切负荷措施。直流双极闭锁故障，系统失稳，需采取切除送端 2640MW 机组，同时切除 1300MW 负荷，占全网负荷比例 5%，系统可保持稳定。稳定计算结果如表 4-4 所示:
When the spinning reserve percentage of units throughout the grid is considered to be 5%, the stability calculation result shows that, when a single fault occurs in 500kV main network line, the system can maintain safe and stable operation, and the load shedding measures for outgoing line N-2 of Matiari side power plant are taken to make system frequency recover its allowable scope. If the HVDC monopole block fault occurs, the system can maintain stable without any load shedding measures. If the system becomes unstable because of the HVDC bipolar block fault, the 2640MW unit switch-off and 1300MW load (5% of load of the whole grid) shedding should be performed to make the system maintain stable. The stability calculation results are shown in Table 4-4:

表 4-4 电网稳定计算结果表
Table 4-4 Grid Stability Calculation Results

线路名称 Name of line	故障类型 Fault type	稳定计算结果 Stability calculation result
送端交流故障 Matiari side AC fault		
MATIARI～JAMSHORO	三永 Permanent three-phase ground fault	稳定 Stable
DADU-NEW～JAMSHORO	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～DADU-NEW	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～MORO	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～THAR COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 600MW 负荷 600MW load shedding
受端交流故障 Lahore side AC fault		
换流站～LAHORE SOUTH Converter station-LAHORE SOUTH	三永 Permanent three-phase ground fault	稳定 Stable
换流站～LAHORE Converter station-LAHORE	三永 Permanent three-phase ground fault	稳定 Stable
换流站～LAHORE NORTH Converter station-LAHORE NORTH	三永 Permanent three-phase ground fault	稳定 Stable

换流站～LAHORE SOUTH Converter station-LAHORE SOUTH	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
换流站～LAHORE Converter station-LAHORE	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
换流站～LAHORE NORTH Converter station-LAHORE NORTH	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
直流故障 HVDC Fault		
MATIARI～LAHORE 直流 MATIARI-LAHORE HVDC	单极闭锁 Monopole block fault	稳定 Stable
MATIARI～LAHORE 直流 MATIARI-LAHORE HVDC	双极闭锁 Bipolar block fault	切除 2640MW 机组，同时切除 1300MW 负荷后系统恢复稳定 The system restores to the stable state after 2640MW unit switch-off and 1300MW load shedding.

1)MATIARI～MORO 线路三永 N-1，对应的系统响应曲线为：
1)In this case, the system response curve corresponding to MATIARI-MORO line three-phase permanent ground fault N-1 is presented as follows:

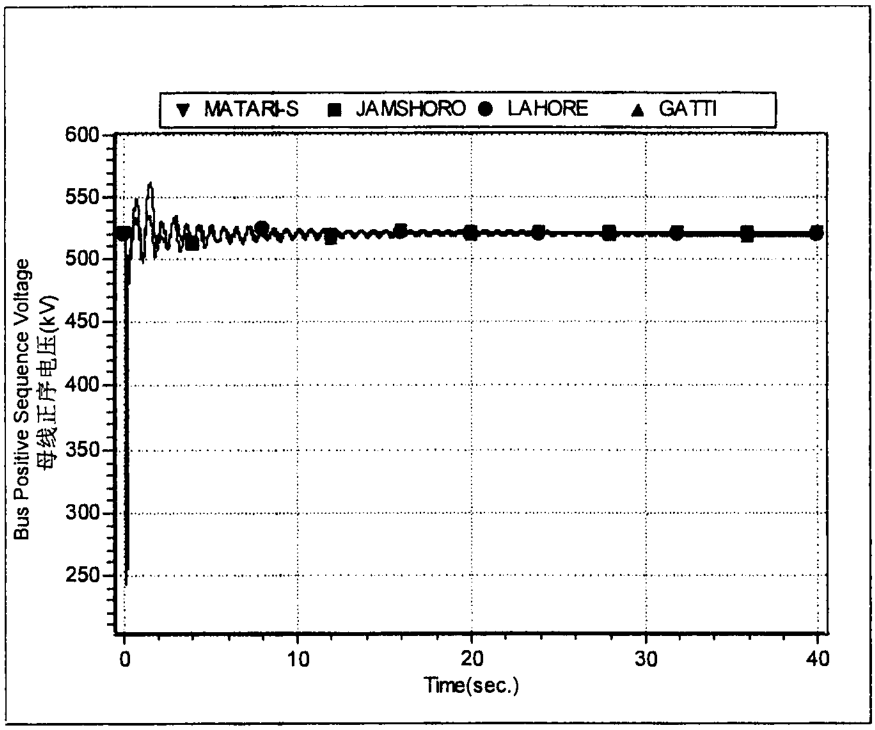

图 4-20 MATIARI～MORO 线路三永 N-1 故障相关母线电压图
Fig.4-20 MATIARI-MORO Line Permanent Three-phase Ground N-1 Fault-related Bus Voltage Graph

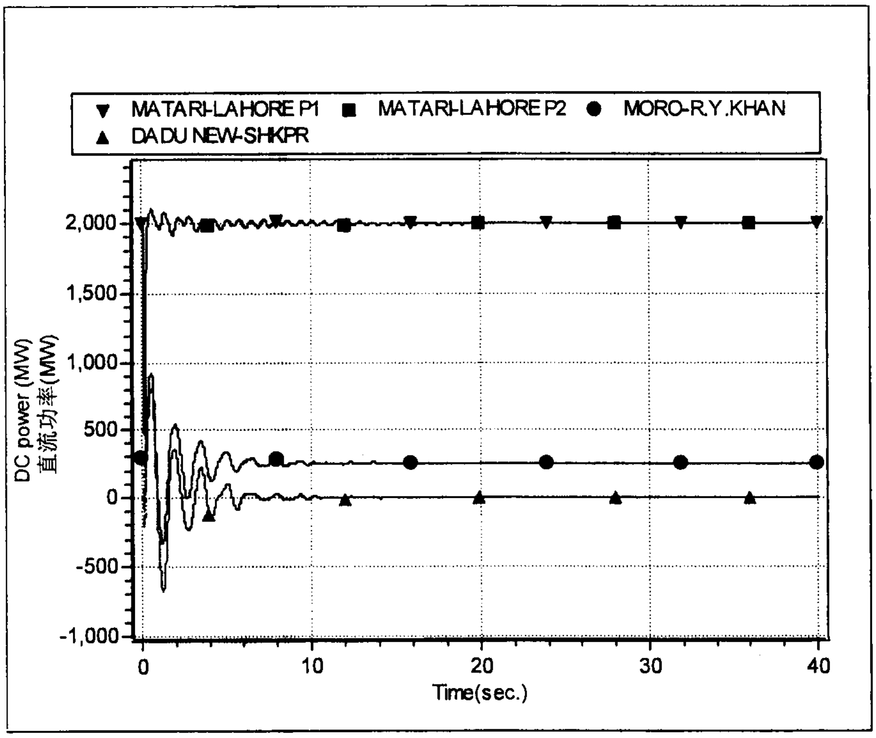

图 4-21 MATIARI～MORO 线路三永 N-1 故障交直流线路功率曲线图
Fig. 4-21 MATIARI～MORO Line Permanent Three-phase Ground N-1 Fault-related AC/DC Line Power Graph

2)单极闭锁故障，系统相关曲线如下图：

2)The system-related curve corresponding to the monopole block fault is shown as follows:

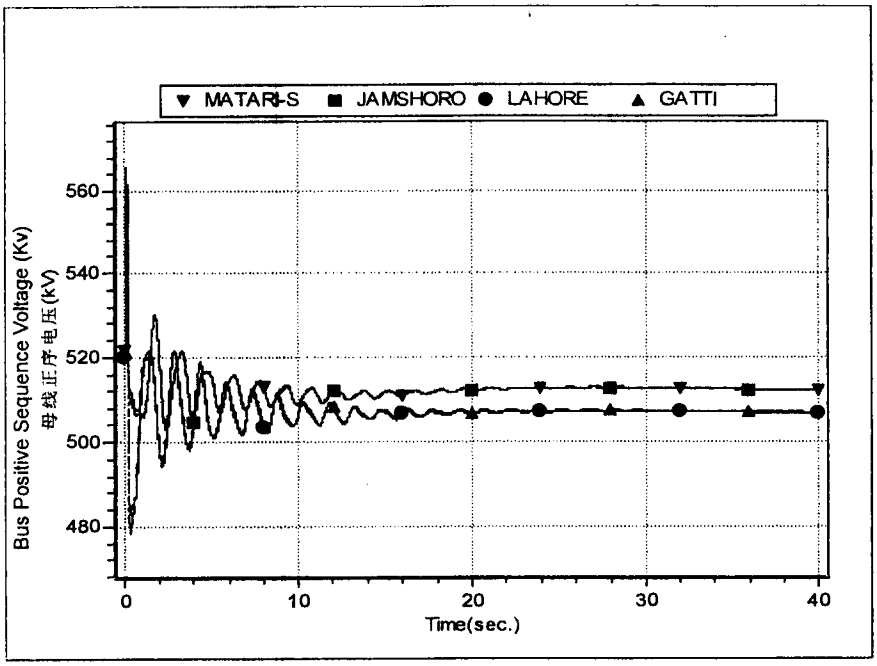

图 4-22 MATIARI～LAHORE 直流单极闭锁故障相关母线电压图

Fig.4-22 MATIARI-LAHORE Line HVDC Monopole Block Fault-related Bus Voltage Graph

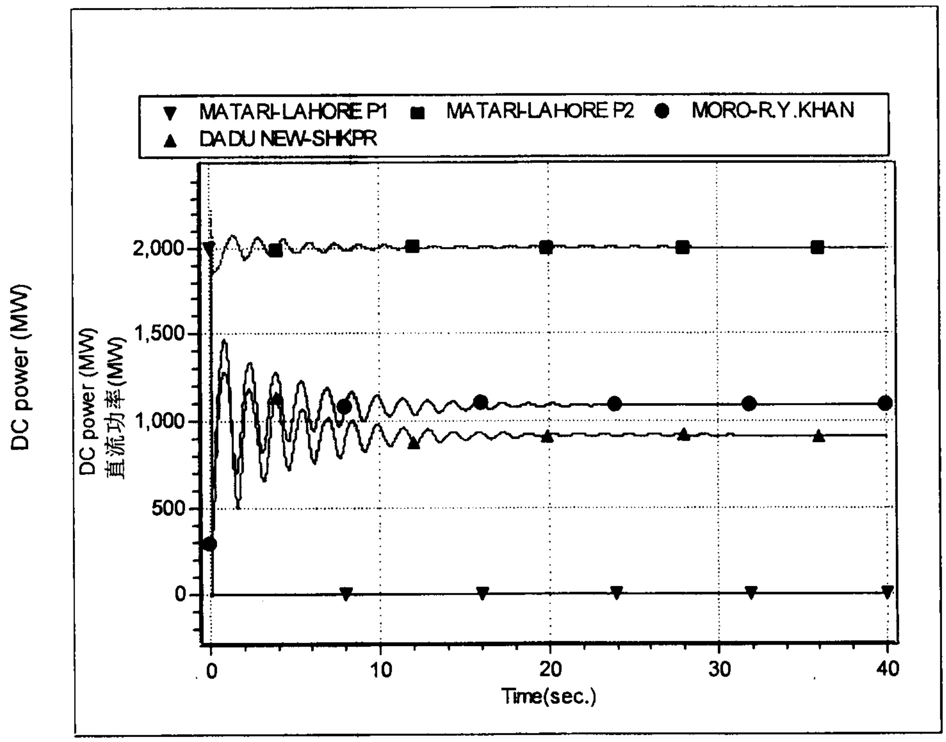

图 4-23 直流单极闭锁故障交直流线路功率曲线图

Fig. 4-23 HVDC Monopole Block Fault-related AC/DC Line Power Graph

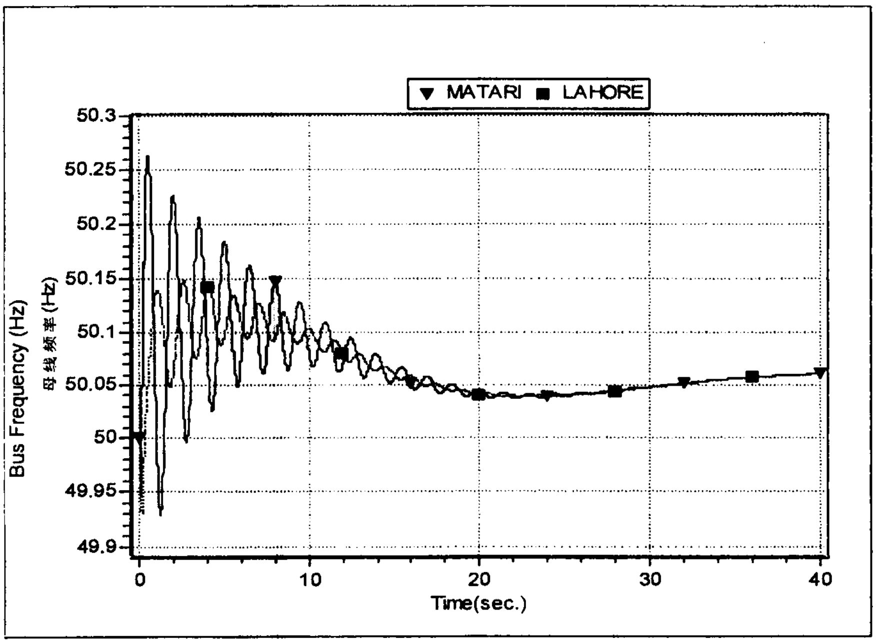

图 4-24 直流单极闭锁故障系统频率曲线图
Fig. 4-24 HVDC Monopole Block Fault-related System Frequency Graph

可以看出，直流单极闭锁后盈余功率转移到接入的交流系统上，交流系统能够承受。系统频率最低约为49.9Hz，系统电压和频率稳定。

It can be seen that, in case of a DC monopole block fault, the redundant power will transfer to the connected AC system, and the AC system can withstand it. The lowest frequency of the system is about 49.9Hz, and system frequency and voltage are stable.

3)双极闭锁故障，切机 2640MW、切负荷 1300MW 后，系统保持稳定，对应的系统响应曲线为：
3)The 2640MW unit switch-off and 1300MW load shedding are performed after a bipolar block fault, and then the system keeps stable. The system response curve is presented as follows:

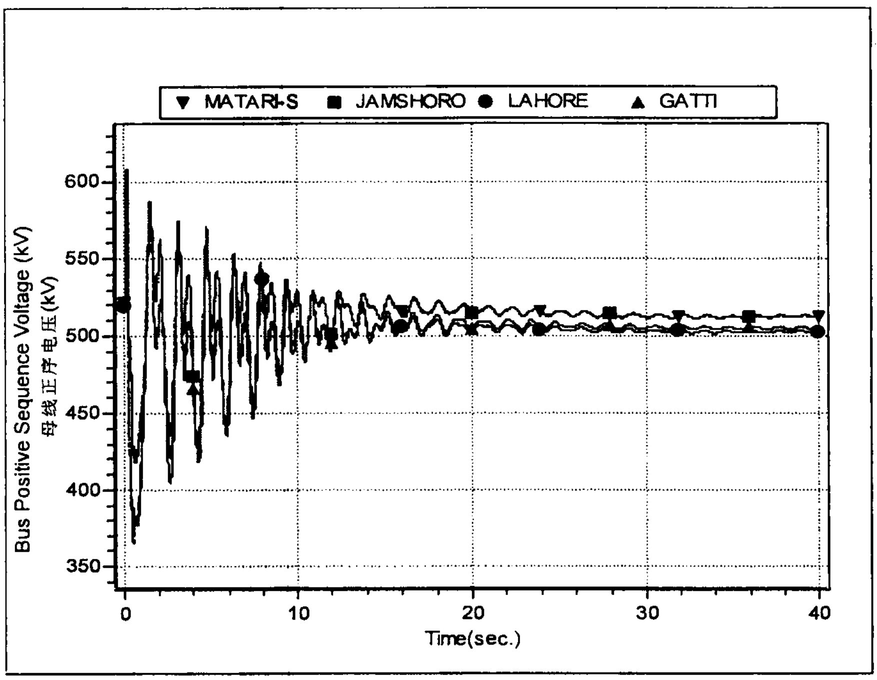

图 4-25 直流双极闭锁故障相关母线电压图
Fig.4-25 HVDC Bipolar Block Fault-related Bus Voltage Graph

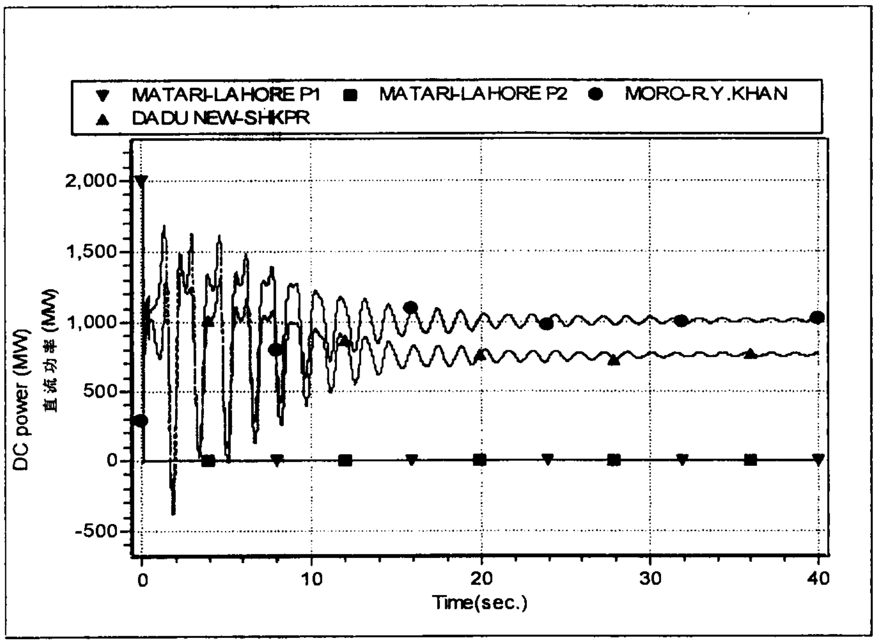

图 4-26 直流双极闭锁故障交直流线路功率曲线图
Fig. 4-26 HVDC Bipolar Block Fault-related AC/DC Line Power Graph

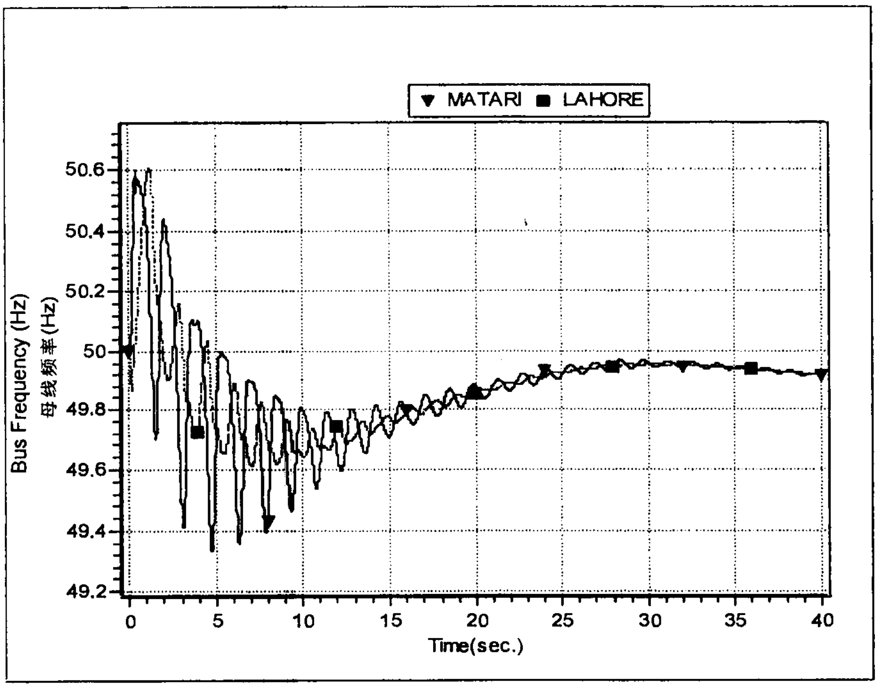

图 4-27 直流双极闭锁故障系统频率曲线图
Fig. 4-27 HVDC Bipolar Block Fault-related System Frequency Graph

如果双极闭锁后采取送端切机 2640MW、受端切负荷 1300MW 的措施，降低沿途电压下降的幅度，系统电压和频率不失稳，与正常方式相比可少切除 400MW 负荷。说明旋转备用提高对直流安全稳定有影响，可降低切负荷措施量。

If 2640MW unit switch-off and 1300MW load shedding are performed after a bipolar block fault, amplitude of voltage reduction should be lowered along the line to make system voltage and frequency not lose stability, and shedded load can reduce by 400MW when compare with the basic mode that only one maximum unit as spinning reserve. This shows that increase of spinning reserve percentage will have an effect on HVDC safety and stability, and shedded load will be decreased.

4.4 2018 年夏小方式
Pakistan Grid 2018 summer off-peak mode

4.4.1 潮流计算
Flow load calculation

考虑默蒂亚里～拉合尔±660kV 直流工程按送电 3300MW 降功率运行方式。
Considering that HVDC transmission operates at 3300MW reduced power for Matiari-Lahore ±660kV DC Transmission Project.

潮流计算表明，送受端系统潮流分布均匀、电压水平满足要求。夏季小方式潮流分布如图 4-28 所示。
Load flow calculation shows that, at the receiving/sending-end, distribution of system load flow is uniform and voltage level meets requirements. The load flow distribution in summer off-peak mode is illustrated in Fig. 4-28.

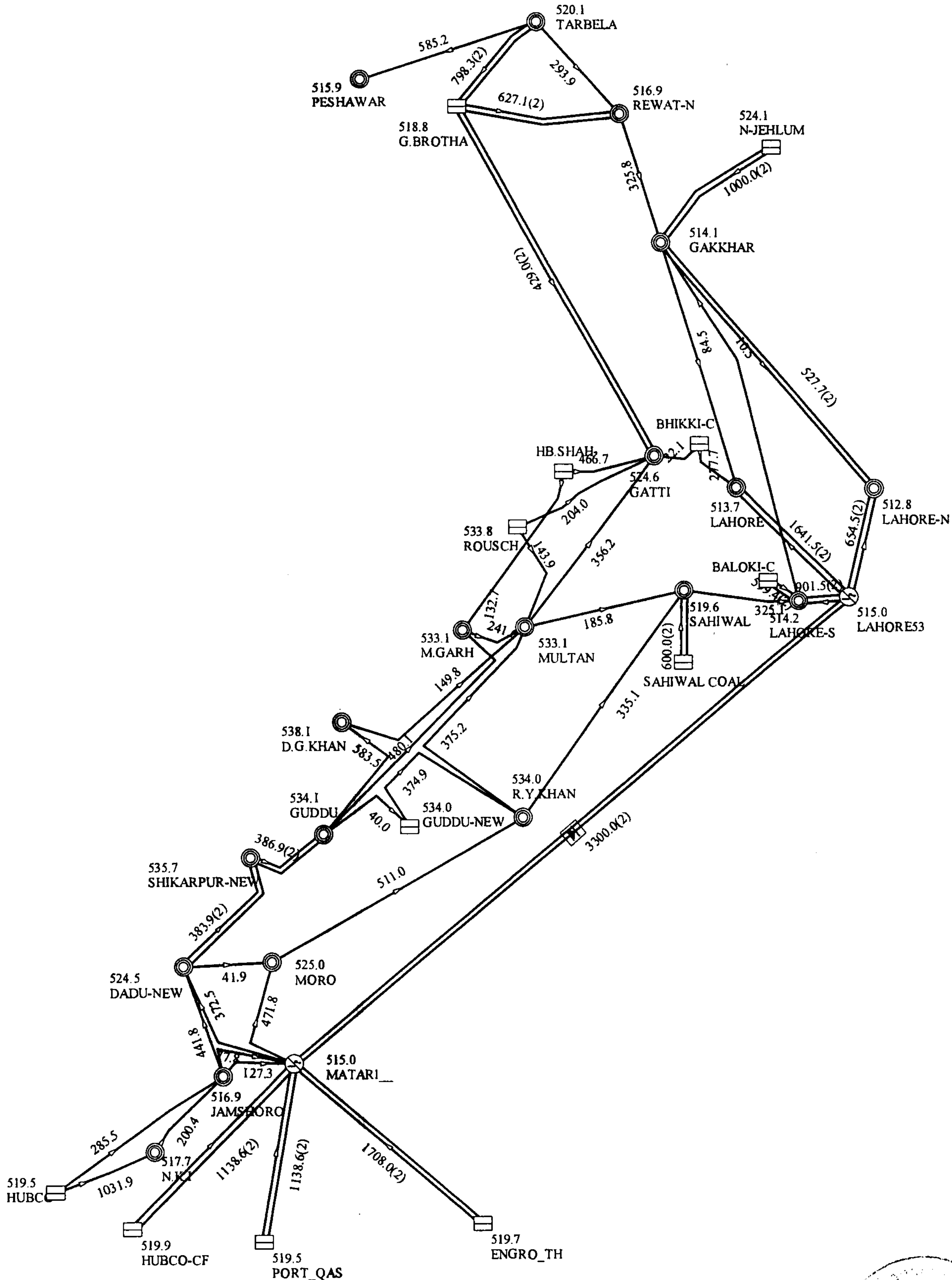

图 4-28 2018 夏小运行方式潮流图

Fig. 4-28 Load Flow Distribution Diagram in Pakistan Grid 2018 Summer Off-peak Mode

4.4.2 稳定计算
Stability calculation

考虑默蒂亚里～拉合尔±660kV 直流工程 2018 夏小运行方式，稳定计算结果表明，500kV 主干网架线路发生单一故障系统均可保持安全稳定运行,送端电厂送出线路 N-2 需采取切负荷措施使系统频率恢复允许范围。直流单极闭锁故障，系统保持稳定。直流双极闭锁故障，系统失稳，需采取切除送端共 2640MW 机组，同时切除 1700MW 负荷，占全网负荷比例 7%，系统可保持稳定。稳定计算结果如表 4-5 所示:

Considering that Matiari-Lahore ±660kV HVDC Transmission Project operates in 2018 Summer off-peak Mode, the stability calculation result shows that, when a single fault occurs in 500kV main network line, the system can maintain safe and stable operation, and the load shedding measures for outgoing line N-2 of Matiari side power plant are taken to make system frequency recover its allowable scope. When a HVDC monopole block fault occurs, the system can maintain stable. If the system becomes unstable because of the HVDC bipolar block fault, the 2640MW unit switch-off and 1700MW load (7% of load of the whole grid) shedding should be performed to make the system maintain stable. The stability calculation results are shown in Table 4-5:

表 4-5　电网稳定计算结果表
Table 4-5 Grid Stability Calculation Results

线路名称 **Name of line**	**故障类型** **Fault type**	**稳定计算结果** **Stability calculation result**
送端交流故障 **Matiari side AC fault**		
MATIARI～JAMSHORO	三永 Permanent three-phase ground fault	稳定 Stable
DADU-NEW～JAMSHORO	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～DADU-NEW	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～MORO	三永 Permanent three-phase ground fault	稳定 Stable
MATIARI～THAR COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 1000MW 负荷 1000MW load shedding
MATIARI～QASIM COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 400MW 负荷 400MW load shedding
MATIARI～NEW HUBCO COAL PLANT	三永跳双回 Permanent three-phase ground fault and double-circuit trip	切 400MW 负荷 400MW load shedding
受端交流故障 **Lahore side AC fault**		
换流站～LAHORE SOUTH Converter station-LAHORE SOUTH	三永 Permanent three-phase ground fault	稳定 Stable
换流站～LAHORE Converter station-LAHORE	三永 Permanent three-phase ground fault	稳定 Stable
换流站～LAHORE NORTH Converter station-LAHORE	三永 Permanent three-phase ground fault	稳定 Stable

NORTH		
换流站～LAHORE SOUTH Converter station-LAHORE SOUTH	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
换流站～LAHORE Converter station-LAHORE	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
换流站～LAHORE NORTH Converter station-LAHORE NORTH	三永跳双回 Permanent three-phase ground fault and double-circuit trip	稳定 Stable
直流故障 HVDC fault		
MATIARI～LAHORE 直流 MATIARI-LAHORE HVDC	单极闭锁 Monopole block fault	稳定 Stable
MATIARI～LAHORE 直流 MATIARI-LAHORE HVDC	双极闭锁 Bipolar block fault	切除 2640MW 机组，同时切除 1700MW 负荷后系统恢复稳定 The system restores to the stable state after 2640MW unit switch-off and 1700MW load shedding.

1)MATIARI～MORO 线路三永 N-1，对应的系统响应曲线为：

1)In this case, the system response curve corresponding to MATIARI-MORO line three-phase permanent ground fault N-1 is presented as follows:

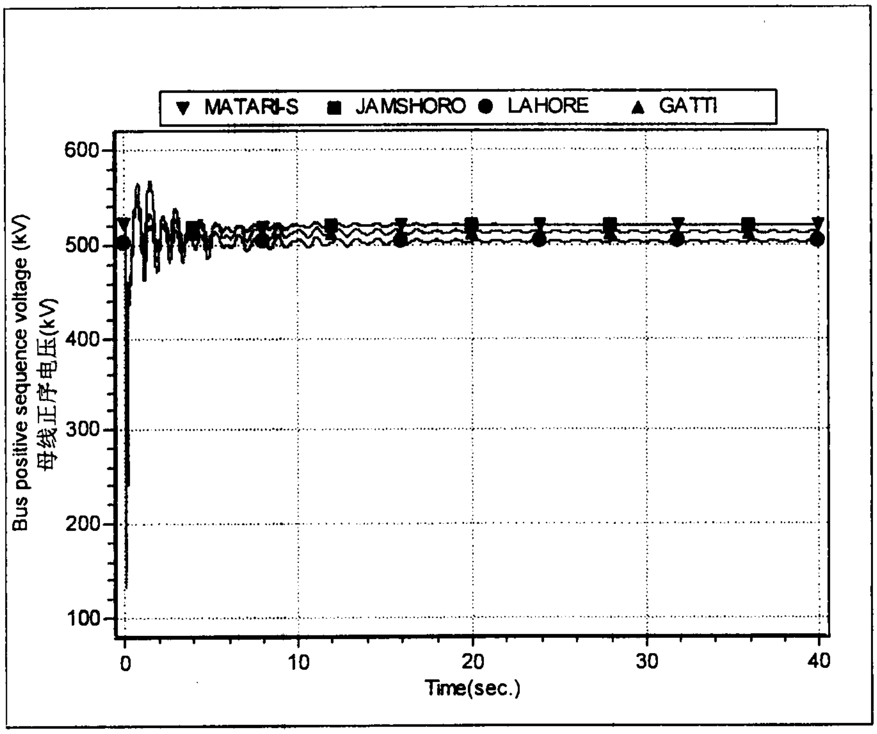

图 4-29　MATIARI～MORO 线路三永 N-1 故障相关母线电压图

Fig. 4-29 MATIARI-MORO Line Permanent Three-phase N-1 Fault-related Bus Voltage Graph

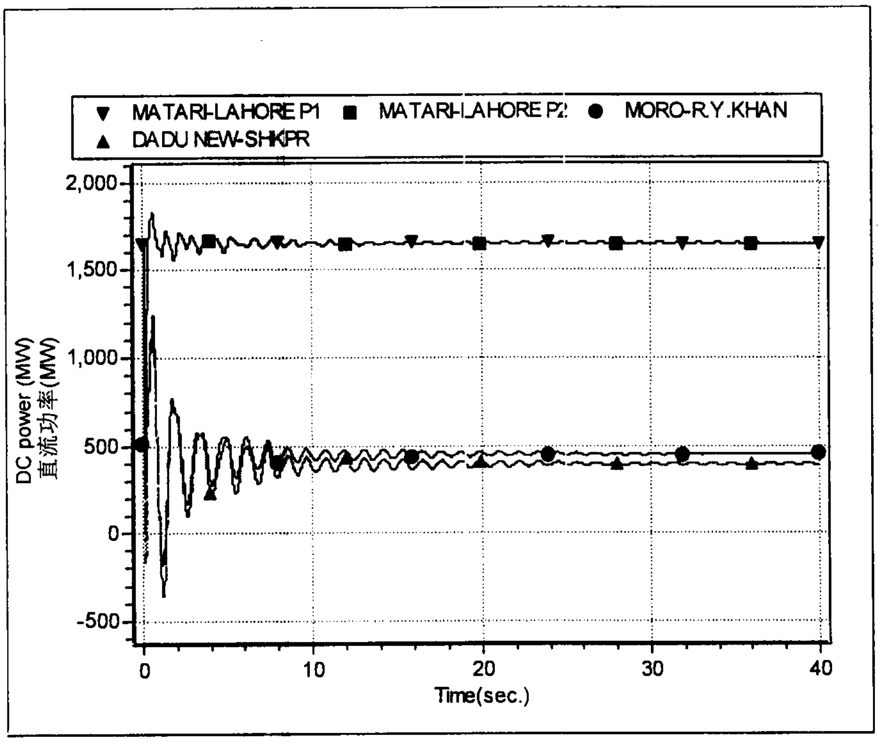

图 4-30 MATIARI～MORO 线路三永 N-1 故障交直流线路功率曲线图

Fig.4-30 MATIARI-MORO Line Permanent Three-phase Ground N-1 Fault-related AC/DC Line Power Graph

2)单极闭锁故障，对应的系统响应曲线为：

2)In this case, the system response curve corresponding to monopole block fault is presented as follows:

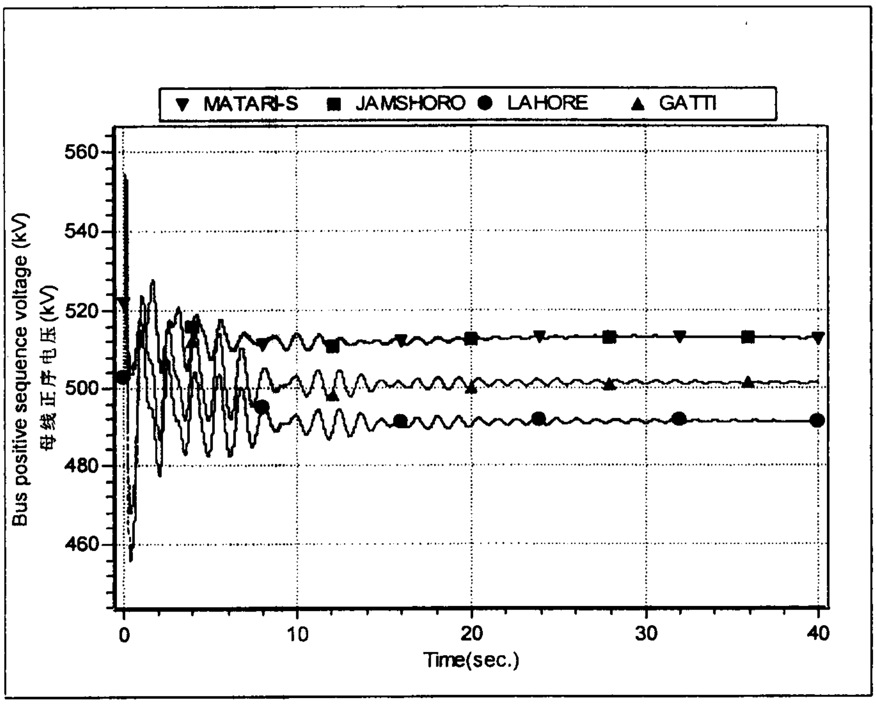

图 4-31 MATIARI~LAHORE 直流单极闭锁故障相关母线电压图

Fig. 4-31 MATIARI-LAHORE HVDC Monopole Block Fault-related Bus Voltage Graph

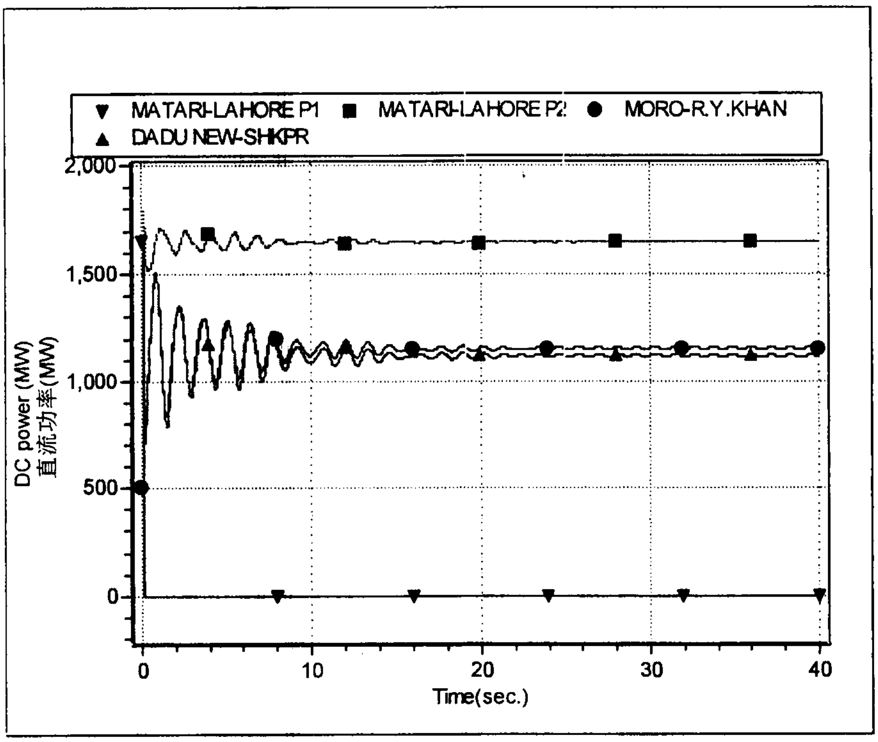

图 4-32 直流单极闭锁故障交直流线路功率曲线图

Fig.4-32 HVDC Monopole Block Fault-related AC/DC Line Power Graph

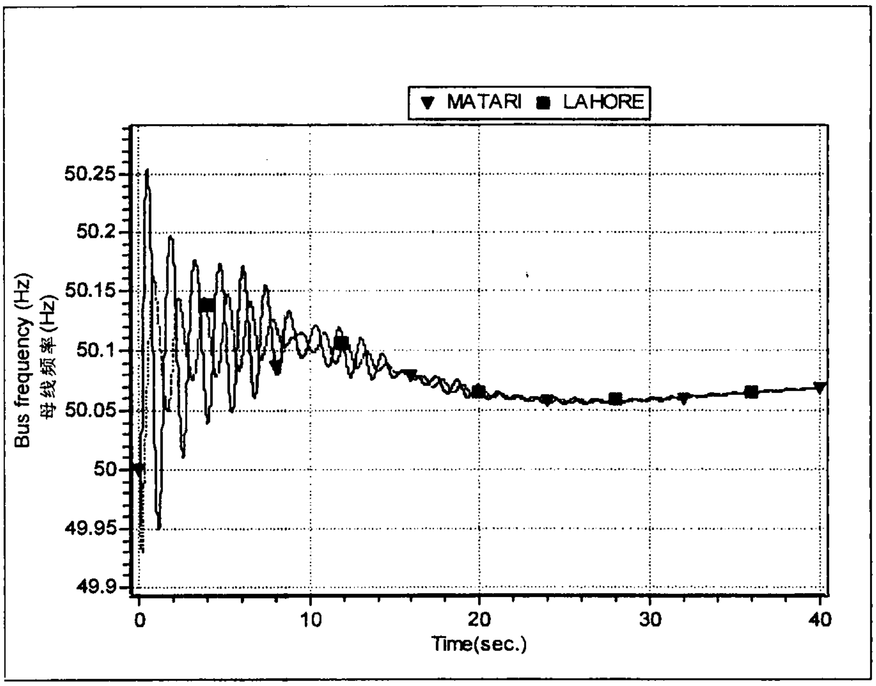

图 4-33 直流单极闭锁故障系统频率曲线图
Fig. 4-33 HVDC Monopole Block Fault-related System Frequency Graph

可以看出，直流单极闭锁后，交流系统能够承受功率转移，系统频率最低约为 49.9Hz，系统频率稳定。
It can be seen that, in case of a DC monopole block fault, the AC system can withstand power transfer. The lowest frequency of the system is about 49.9Hz, and system frequency is stable.

3)双极闭锁故障，切机 2640MW、切负荷 1700MW 后，系统保持稳定，对应的系统响应曲线为：
3)The 2640MW unit switch-off and 1700MW load shedding are performed after a bipolar block fault, and then the system keeps stable. The system response curves are presented as follows:

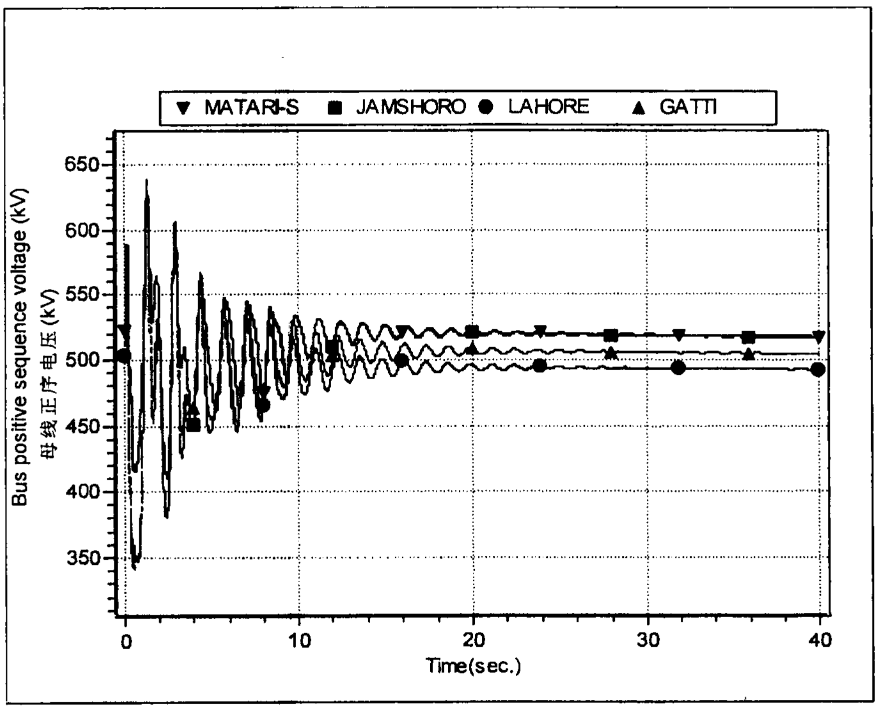

图 4-34 直流双极闭锁故障相关母线电压图
Fig. 4-34 HVDC Bipolar Block Fault-related Bus Voltage Graph

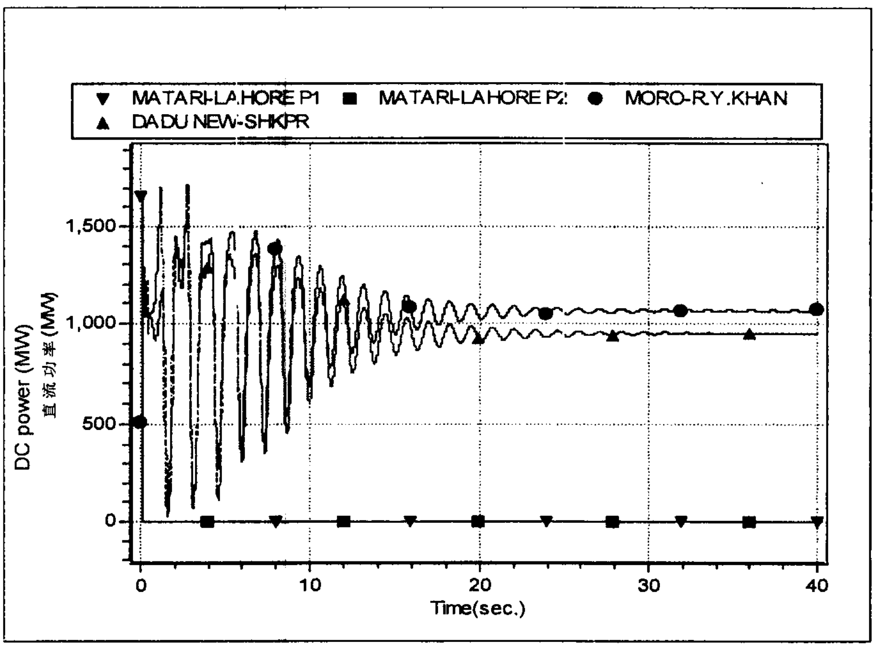

图 4-35 直流双极闭锁故障交直流线路功率曲线图
Fig. 4-35 HVDC Bipolar Block Fault-related AC/DC Line Power Graph

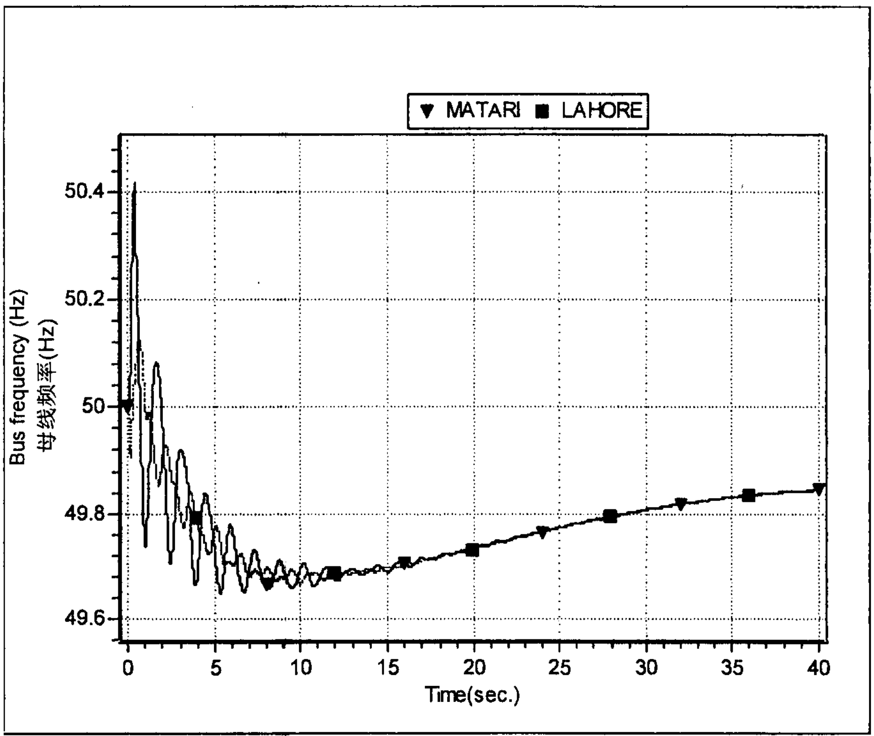

图 4-36 直流双极闭锁故障系统频率曲线图
Fig. 4-36 HVDC Bipolar Block Fault-related System Frequency Graph

如果双极闭锁后采取送端切机 2640MW、受端切负荷 1700MW 的措施，降低沿途电压下降的幅度，系统电压和频率不失稳。

If 2640MW unit switch-off and 1700MW load shedding are performed after a bipolar block fault, amplitude of voltage reduction should be lowered along the line to make system voltage and frequency not lose stability.

4.5 小结
Summary

巴基斯坦默蒂亚里～拉合尔±660kV 直流考虑不同方式，进行安全稳定校核，结论如表 4-6 所示：
Different modes are considered for Pakistan Matiari-Lahore ±660kV DC for security and stability check. The results are shown in Table 4-6:

表 4-6 不同方式稳定计算结果表
Table 4-6 Stability Calculation Results in Different Modes

序号 S/N	方式 Mode	故障类型 Fault type			
		交流 N-1 AC N-1	交流 N-2 AC N-1	单极闭锁 Monopole block	双极闭锁 Bipolar block
方式 1 Mode 1	直流外送 3000MW 降功率运行 DC transmission is operated at a reduced power transmission power of 3000MW.	稳定 Stable	MATIARI～THAR 切 1000MW 负荷 MATIARI～QASIM 切 400MW 负荷 MATIARI～HUBCO 切 400MW 负荷 1000MW load shedding for MATIARI～THAR; 400MW load shedding for MATIARI～QASIM; 400MW load shedding for MATIARI～HUBCO	稳定 Stable	切除 1980MW 机组，同时切除 1000MW 负荷后系统恢复稳定 After 1980MW unit switch-off and 1000MW load shedding, the system restores to stable operation.
方式 2 Mode 2	受端 660MW 机组停运 Lahore side 660MW unit stops operation	稳定 Stable	MATIARI～THAR 切 1000MW 负荷 MATIARI～QASIM 切 400MW 负荷 MATIARI～HUBCO 切 400MW 负荷 1000MW load shedding for MATIARI～THAR; 400MW load shedding for MATIARI～QASIM; 400MW load shedding for MATIARI～HUBCO	稳定 Stable	切除 3300MW 机组，同时切除 2400MW 负荷后系统恢复稳定 After 3300MW unit switch-off and 2400MW load shedding, the system restores to stable operation.
方式 3 Mode 3	全网机组旋转备用率提高到 5% Spinning reserve rate of units in the whole grid is increased to 5%.	稳定 Stable	MATIARI～THAR 切 600MW 负荷 600MW load shedding for MATIARI～THAR	稳定 Stable	切除 2640MW 机组，同时切除 1300MW 负荷后系统恢复稳定 After 2640MW unit switch-off and 1300MW load shedding,

					the system restores to stable operation.
方式 4 Mode 4	2018 年夏小方式 2018 summer off-peak mode	稳定 Stable	MATIARI～THAR 切 1000MW 负荷 MATIARI～QASIM 切 400MW 负荷 MATIARI～HUBCO 切 400MW 负荷 1000MW load shedding for MATIARI～THAR; 400MW load shedding for MATIARI～QASIM; 400MW load shedding for MATIARI～HUBCO	稳定 Stable	切除 2640MW 机组，同时切除 1700MW 负荷后系统恢复稳定 After 2640MW unit switch-off and 1700MW load shedding, the system restores to stable operation.

综上所述，交流网架加强部分不能按时投产、受端机组停运、风电大发都将降低系统稳定性，直流降功率运行、提高全网机组旋转备用率可减少双极闭锁后采取切机切负荷的措施量。

In conclusion, the Lahore side unit stops operation will reduce system stability. The operating mode of HVDC power reduction and increase of spinning reserve rate of units in the whole grid can decrease unit switch-off and load shedding after a bipolar block fault occurs.

5 远景年默蒂亚里～拉合尔±660kV 直流安全稳定分析 Security and stability analysis of Matiari – Lahore ±660kV DC line in future year

5.1 巴基斯坦电网 2022 年概况 Overview of 2022 Pakistan power grid

根据巴基斯坦电网规划，为满足巴基斯坦信德省规划电源送出需求和旁遮普省和伊斯兰堡地区负荷发展需要，规划巴基斯坦国内建设默蒂亚里分别至拉合尔的±660kV 直流输电工程和默蒂亚里至费萨拉巴德的±600kV 高压直流输电工程，送电容量均为 4000MW。
According to the Pakistan power grid planning, to meet the power supply demand of Sindh province as well as the load demand of Punjab and Islamabad region, the Matiari – Lahore ±660kV HVDC transmission project and Matiari – Faisalabad ±600kV HVDC transmission project are designed to be constructed in Pakistan, and the power transmission capacity of each project is 4000MW.

至 2022 年，规划建设塔吉克斯坦至白沙瓦（PESHAWAR）的±500kV 直流输电工程（CASA1000），输电容量 1000MW，并配套建设 500kV 电网工程；规划建设南部信德省默蒂亚里至拉合尔的±660kV 直流工程和默蒂亚里至费萨拉巴德西的±600kV 高压直流输电工程，送电容量均为 4000MW；旁遮普省和伊斯兰堡负荷中心新建部分 500kV 变电站，受端 500kV 环网结构供电能力进一步提高。2022 年电网规划如图 5-1 所示。
By the end of 2022, Tajikistan – PESHAWAR ±500kV DC transmission project (CASA1000) with a transmission capacity of 1000MW will be constructed, and a supporting 500kV power grid project will also be built; in south Sindh, the Matiari – Lahore ±660kV HVDC transmission project and Matiari – Faisalabad ±600kV HVDC transmission project will be built, and the power transmission capacity of each project is 4000MW. In Punjab and Islamabad load centre, part of 500kV substation will be newly built, and the power supply capacity of load center 500kV looped network structure will be improved further. For 2022 power grid planning, please see Fig. 5-1.

2015～2022 年期间，巴基斯坦电网规划建设电源装机总规模为 17705MW，其中火电 13665MW、水电 2690MW、新能源 1350MW，K2/K3 核电 2200MW；其中，结合电源建设工期，考虑上述清单中规划煤电、风电、光伏项目于 2018 年投产，水电项目于 2022 年投产；到 2022 年，巴基斯坦电网年末装机将达到 47045MW。

From 2015 to 2022, the overall power installation capacity proposed by Pakistan power grid planning is 17705MW, including 13665MW thermal power, 2690MW hydropower, 1350MW new energy and 2200MW K2/K3 nuclear power; according to the power source construction period and considering about the listed coal power, wind electricity and photovoltaic project which will be put into operation in 2018, the hydroelectric project which will be put into operation in 2022; by the end of 2022, the installation capacity of Pakistan power grid at the end of the year will reach 47045MW.

巴基斯坦国家电网按输电区域划分为巴基斯坦国家输电公司（NTDC）及卡拉奇 KESC 工业园负荷，根据巴方提供最新的负荷预测数据，巴基斯坦电网 2022 年最大负荷将达到 38250MW。
Pakistan state grid is divided into Pakistan National Transmission and Dispatch Company (NTDC) and Karachi Electric Supply Corporation industrial park load based on their locations; according to the latest load prediction provided by Pakistan, the maximum load in 2022 will be 38250MW.

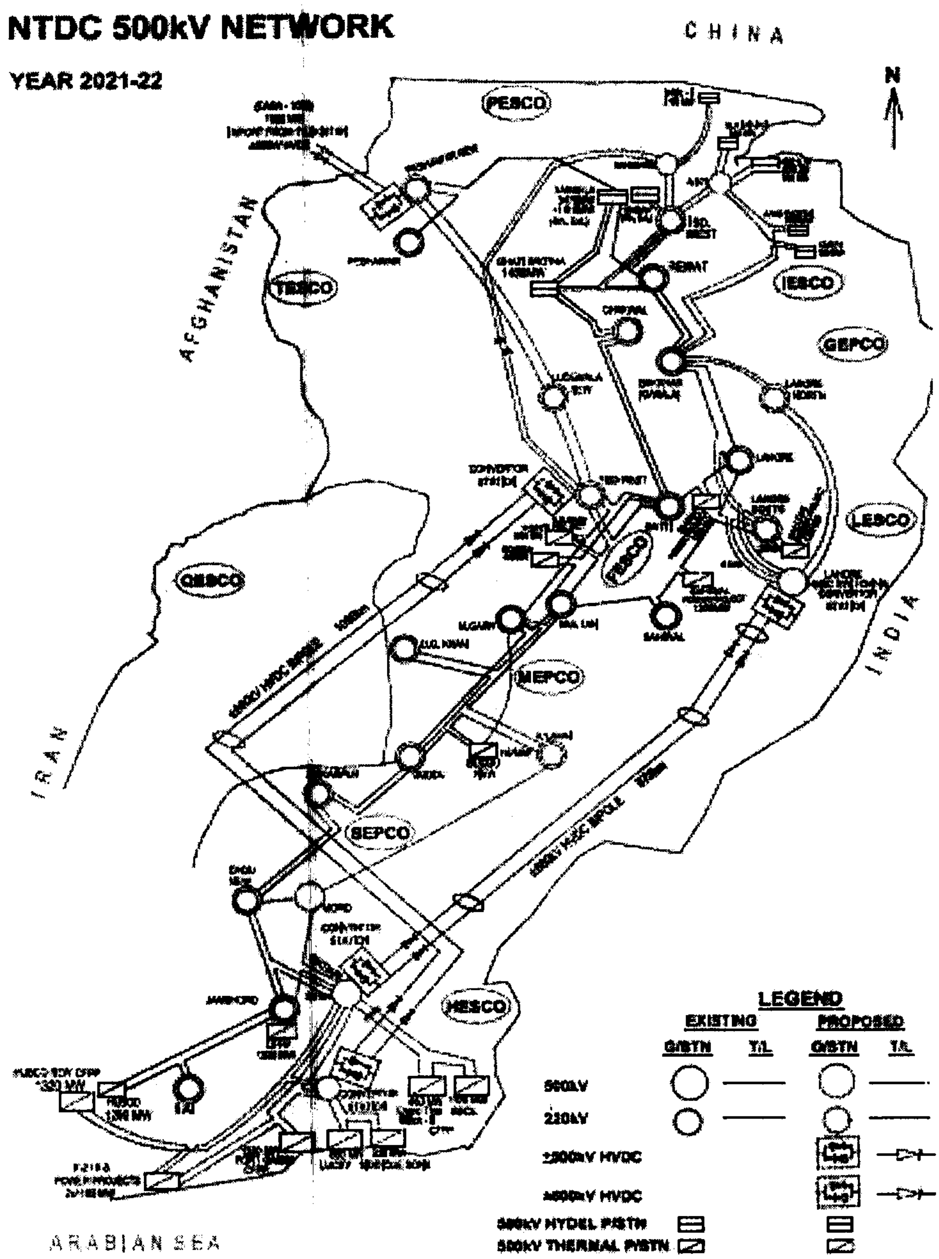

图 5-1 2022 年巴基斯坦 500kV 及以上电网规划图
Fig. 5-1 Planning Graph of 2022 Pakistan Power Grid 500kV or above

5.2 交流故障对系统的影响
Impacts of AC fault on system

5.2.1 潮流计算
Load flow calculation

计算采用巴基斯坦电网 2022 年冬大方式，巴国内 MATIARI～LAHORE 与 MATIARI～FBD 直流分别从南部向负荷中心拉合尔以及费萨拉巴德输送电 4000MW，南北 500kV 交流通道从南部由南到北至 DADU-NEW 潮流 347MW,换流站至 DADU-NEW 潮流为 227MW，换流站至 MORO 潮流为 223MW。潮流计算表明，默蒂亚里～拉合尔直流电力主要通过换流站～LAHORE-S、换流站～LAHORE-N 和换流站～LAHORE 三个通道送出，三个通道潮流分别为 1153MW、1522MW、1097MW。系统潮流分布均匀，电压水平满足要求。正常方式潮流计算结果如图 5-2 所示。

The calculation applies the Pakistan power grid 2022 winter maximum-load mode. The 4000 MW HVDC power of MATIARI - LAHORE and MATIARI - FBD HVDC Transmission Projects in Pakistan is transmitted to the two load centers –Lahore and Faisalabad from the south. The load flow of south-north 500kV AC channel is 347MW from south to north to DADU-NEW; the load flow of converter station～DADU-NEW is 227MW; the load flow of converter station～MORO is 223 MW. The load flow calculation indicates that Matiari-Lahore HVDC power will be mainly transmitted through three channels, Converter Station～Lahore-S, Converter Station～Lahore-N and Converter Station～Lahore, of which the load flows will be 1153MW, 1522MW and 1097MW respectively. The distribution of system load flow is uniform and voltage level meets requirements. The results of load flow computation in normal mode are illustrated in Fig. 5-2.

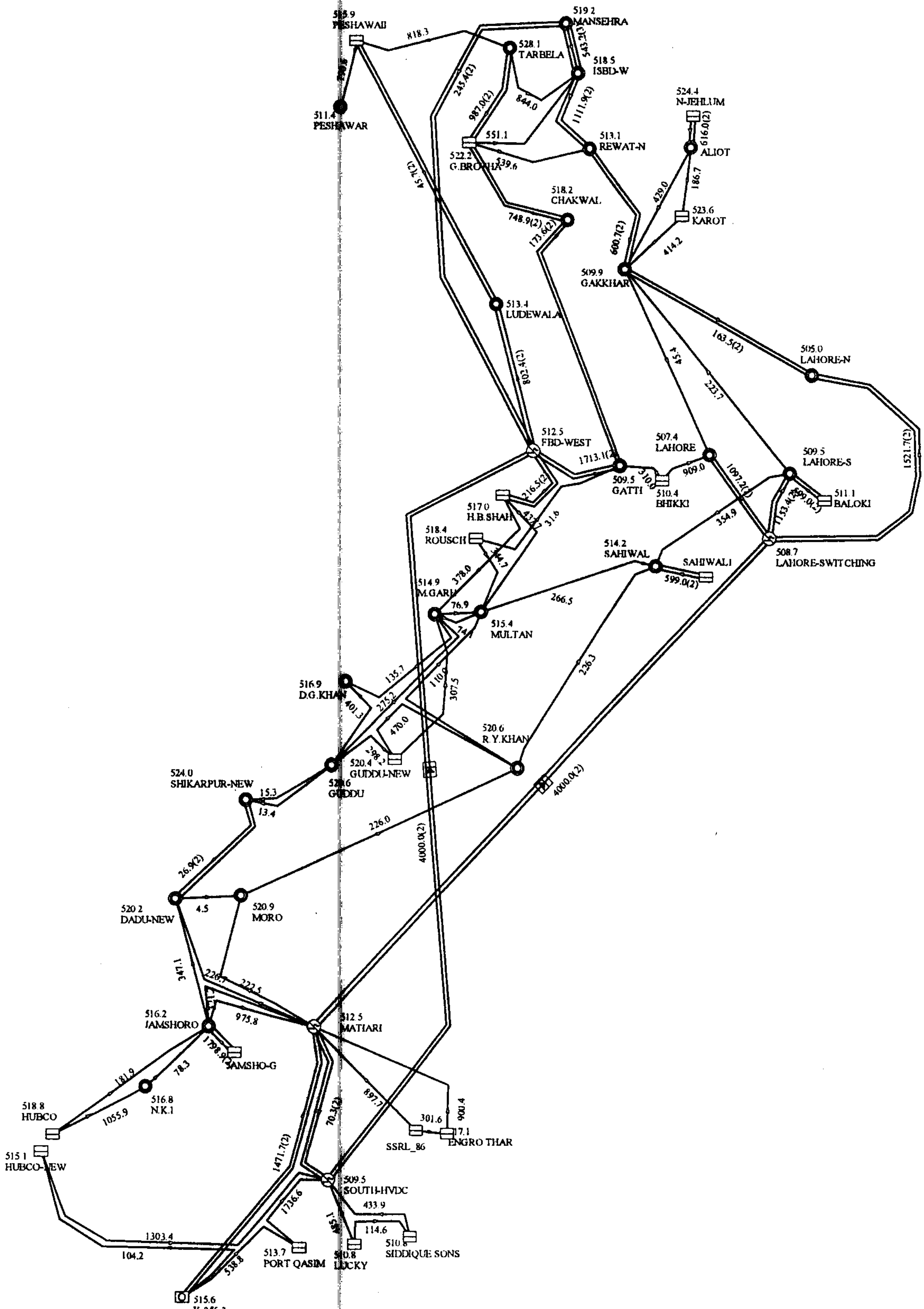

图5-2 2022年冬大方式潮流图

Fig. 5-2 Load Flow under 2022 Winter Maximum-load Mode

5.2.2 稳定计算
Stability calculation

采用巴基斯坦电网 2022 年冬大方式，巴国内 MATIARI～LAHORE 与 MATIARI～FBD 直流分别输送电 4000MW。稳定计算表明，500kV 主干网架线路发生单一故障、严重故障系统均可保持安全稳定运行。稳定计算结果如表 5-1 所示。

The calculation applies the Pakistan power grid 2022 winter maximum-load mode, the power transmission capacity of MATIARI - LAHORE and MATIARI - FBD HVDC Transmission Projects in Pakistan is 4000MW respectively.。

The stability calculation result shows that, when a single fault or serious fault occurs in 500kV main network line, the system can maintain safe and stable operation. For the stability calculation result, please see Table 5-1.

表 5-1 电网稳定计算结果表
Table 5-1 Grid Stability Calculation Results

线路名称 Name of line	故障类型 Fault Type	稳定计算结果 Stability Result
	单一故障 Single fault	
MATIARI～MORO	三永 Permanent Three-phase ground fault	稳定 Stable
MATIARI～JAMSHORO	三永 Permanent Three-phase ground fault	稳定 Stable
MORO～DADU-NEW	三永 Permanent Three-phase ground fault	稳定 Stable
MORO～R.Y.KHAN	三永 Permanent Three-phase ground fault	稳定 Stable
MATIARI～THAR COAL PLANT	三永 Permanent Three-phase ground fault	稳定 Stable
CHAKWAL～GATTI	三永 Permanent Three-phase ground fault	稳定 Stable
LAHORE-SWITCHING～LAHORE-N	三永 Permanent Three-phase ground fault	稳定 Stable
SAHIWAL～LAHORE-S	三永 Permanent Three-phase ground fault	稳定 Stable
LAHORE-HVDC～LAHORE	三永 Permanent Three-phase ground fault	稳定 Stable
	严重故障 Serious fault	
K2/K3 核电站～LAHORE 直流送端换流站 K2/K3 nuclear power plant～LAHOREDC sending-end converter station	三永跳双回 Permanent Three-phase ground fault and double-circuit trip	稳定 Stable
FBD 直流受端换流站～GATTI FBD DC receiving-end converter station～GATTI	三永跳双回 Permanent Three-phase ground fault and double-circuit trip	稳定 Stable

LAHORE 直流受端换流站～LAHORE LAHORE DC receiving-end converter station～LAHORE	三永跳双回 Permanent Three-phase ground fault and double-circuit trip	稳定 Stable

1)JAMSHORO～DADU-NEW 线路三永 N-1，对应的系统响应曲线为：
1)In this case, the system response curve corresponding to JAMSHORO～DADU-NEW line three-phase permanent ground fault N-1 is presented as follows:

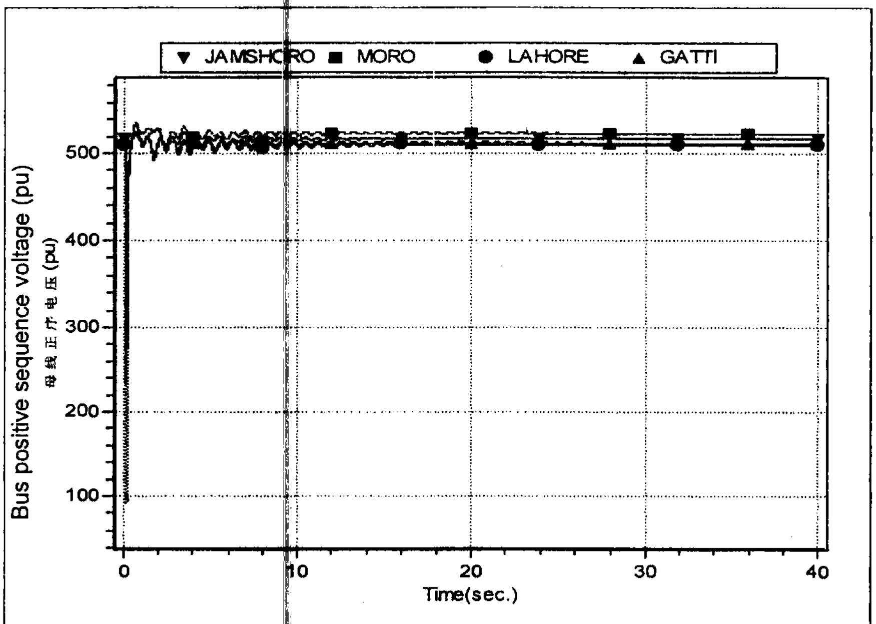

图 5-3 JAMSHORO～DADU-NEW 线路三永 N-1 故障相关母线电压图
Fig. 5-3 JAMSHORO～DADU-NEW Line Permanent Three-phase N-1 Ground Fault-related Bus Voltage Graph

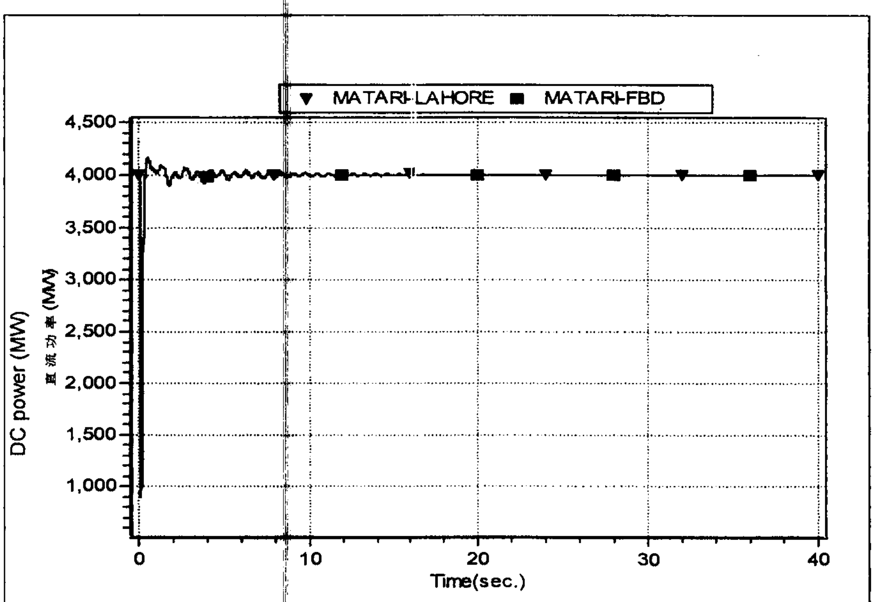

图 5-4 JAMSHORO～DADU-NEW 线路三永 N-1 故障直流线路功率曲线图
Fig. 5-4 JAMSHORO～DADU-NEW Line Permanent Three-phase N-1 Ground Fault-related DC Line Power Graph

2)K2/K3 核电站～MATIARI 直流送端换流站线路三永 N-2，对应的系统响应曲线为：
2)The system response curve corresponding to K2/K3 Nuclear Power Plant～MATIARI HVDC Converter Station permanent three-phase ground N-2 is presented as follows:

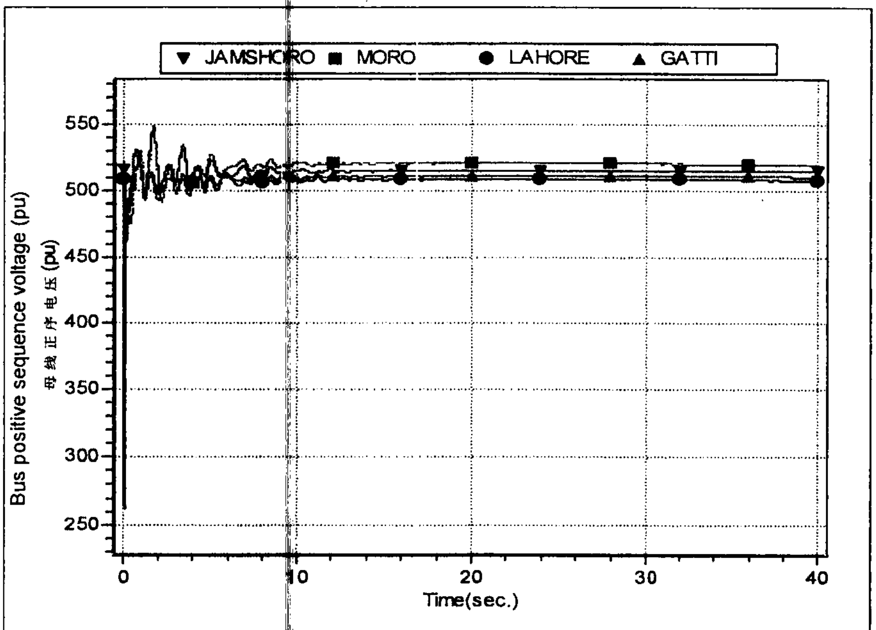

图 5-5 K2/K3 核电站～MATIARI 直流送端换流站线路三永 N-2 故障相关母线电压图
Fig. 5-5 K2/K3 Nuclear Power Plant～MATIARI HVDC Converter Station Permanent Three-phase N-2 Ground Fault-related Bus Voltage Graph

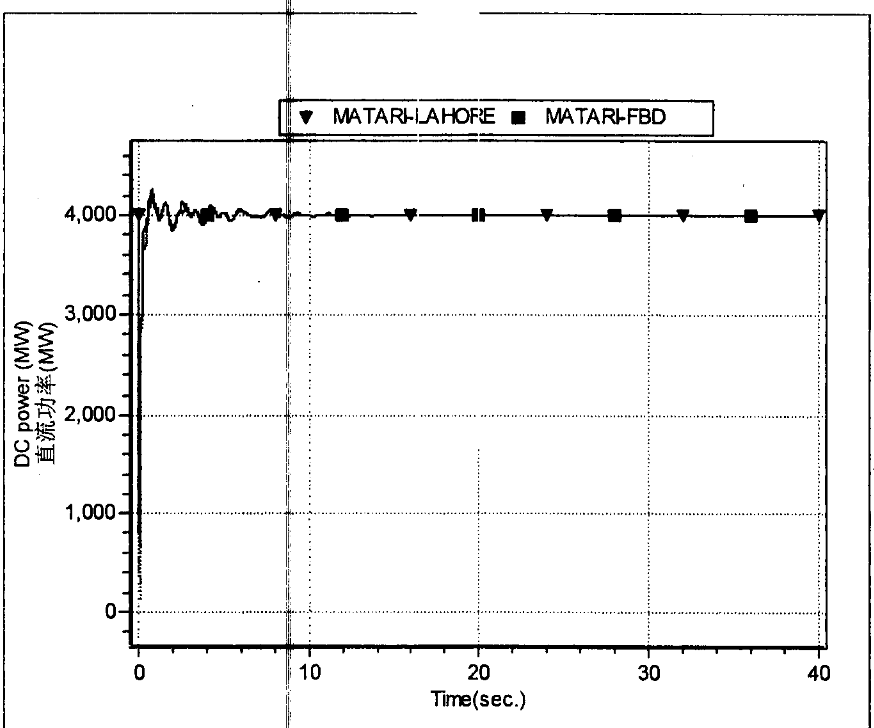

图 5-6 K2/K3 核电站～MATIARI 直流送端换流站线路三永 N-2 故障直流线路功率曲线图
Fig. 5-6 K2/K3 Nuclear Power Plant～MATIARI HVDC Converter Station Permanent Three-phase N-2 Ground Fault-related DC Line Power Graph

5.3 直流闭锁对系统的影响
Impacts of DC block on system

计算采用巴基斯坦电网 2022 年冬大方式，巴国内 MATIARI～LAHORE 与 MATIARI～FBD 直流分别输送电 4000MW。稳定计算表明，如表 5-2 所示，巴国内 MATIARI～LAHORE 直流输电工程发生单极闭锁故障，无需采取措施系统保持稳定运行；发生双极闭锁故障，需要采取切机 1980MW 的措施，采取措施后系统恢复稳定运行。MATIARI～FBD 直流输电工程发生单极闭锁故障，无需采取措施系统保持稳定运行；发生双极闭锁故障，需要采取切机 1320MW 的措施，采取措施后系统恢复稳定运行。
The calculation applies the Pakistan power grid 2022 winter maximum-load mode, the power transmission capacity of MATIARI - LAHORE and MATIARI - FBD HVDC Transmission Projects in Pakistan is 4000MW respectively. The stability calculation shows that, as shown in Table 5-2, for the Pakistani MATIARI - LAHORE HVDC transmission project, no measure is taken to keep systems run stably in case of monopole block fault; and 1980MW unit is switched off to restore stable operation of the system in case of bipolar block fault. For the MATIARI - FBD HVDC transmission project, no measure is taken to keep systems run stable in case of monopole block fault; and 1320MW unit is switched off to restore stable operation of the system in case of bipolar block fault.

表 5-2 电网稳定计算结果表
Table 5-2 Grid Stability Calculation Results

线路名称 Name of line	故障类型 Fault Type	稳定计算结果 Stability Calculation Result
单一故障 Single fault		
MATIARI～LAHORE 直流 MATIARI - LAHORE HVDC	单极闭锁 Monopole block	稳定 Stable
MATIARI～FBD 直流 MATIARI - FBD HVDC	单极闭锁 Monopole block	稳定 Stable
严重故障 Serious fault		
MATIARI～LAHORE 直流 MATIARI - LAHORE HVDC	双极闭锁 Bipolar block	切机 1980MW 后系统恢复稳定 The system restores to the stable state after 1980MW unit switch-off
MATIARI～FBD 直流 MATIARI - FBD HVDC	双极闭锁 Bipolar block	切机 1320MW 后系统恢复稳定 The system restores to the stable state after 1320MW unit switch-off

1)MATIARI～LAHORE 和 MATIARI～FBD 分别发生直流单极闭锁，对应的系统响应曲线为：
1)In this case, the system response curve corresponding to converter MATIARI – LAHORE and MATIARI - FBD monopole block fault is presented as follows:

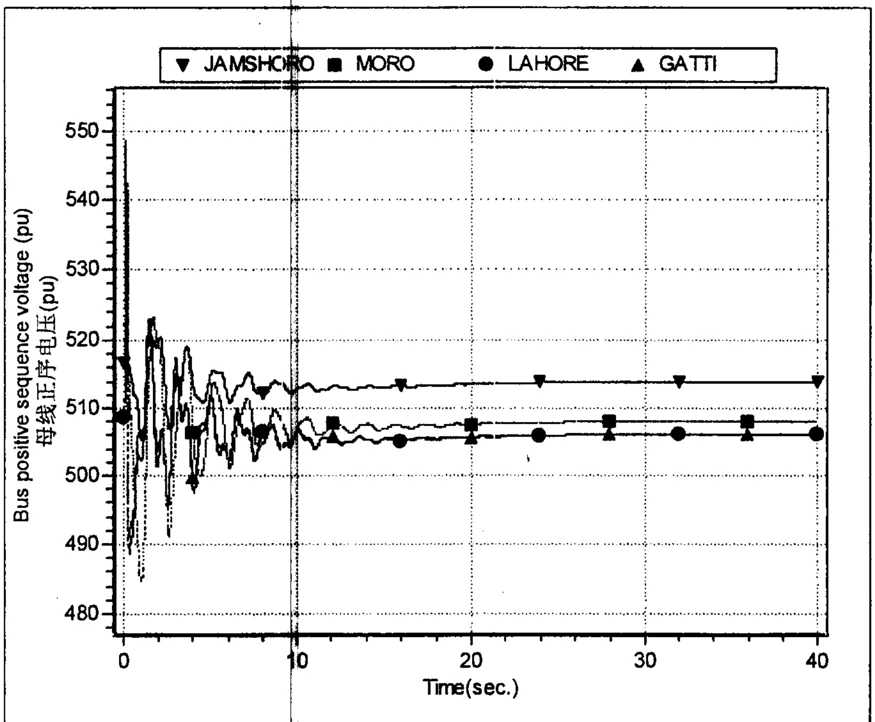

图 5-7 MATIARI～LAHORE 直流单极闭锁故障相关母线电压图
Fig. 5-7 MATIARI-LAHORE HVDC Monopole Block Fault-related Bus Voltage Graph

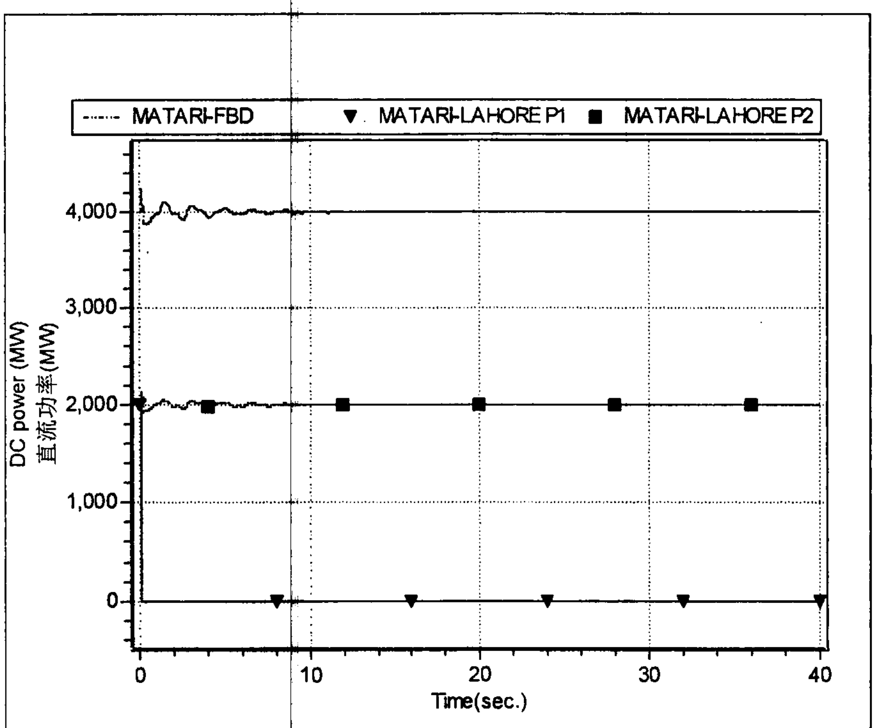

图 5-8 MATIARI～LAHORE 直流单极闭锁故障直流线路功率曲线图
Fig. 5-8 MATIARI-LAHORE HVDC Monopole Block Fault HVDC Line Power Graph

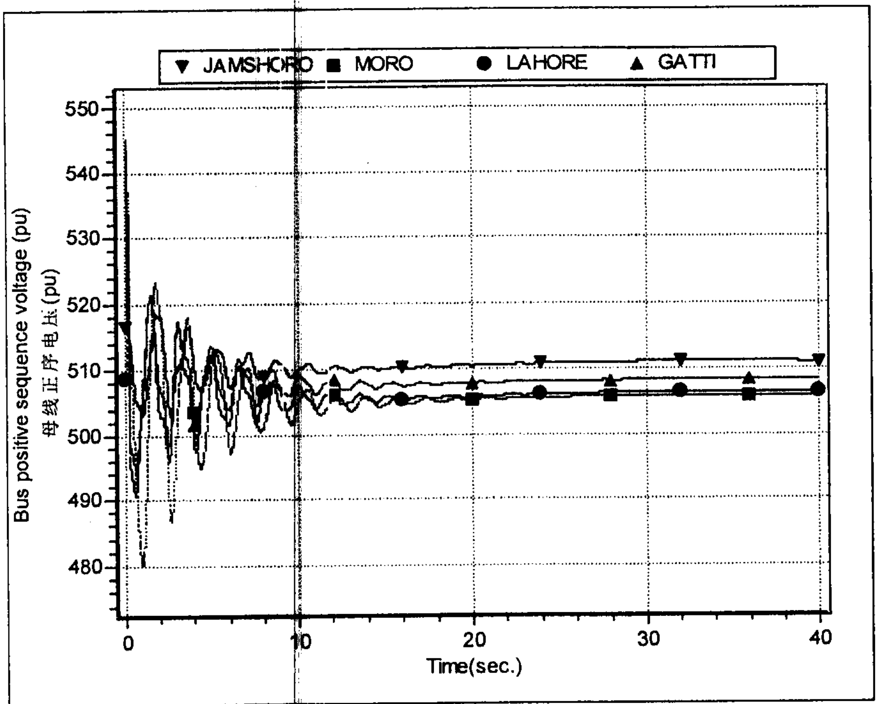

图 5-9 MATIARI~FBD 直流单极闭锁故障相关母线电压图
Fig. 5-9 MATIARI-FBD HVDC Monopole Block Fault-related Bus Voltage Graph

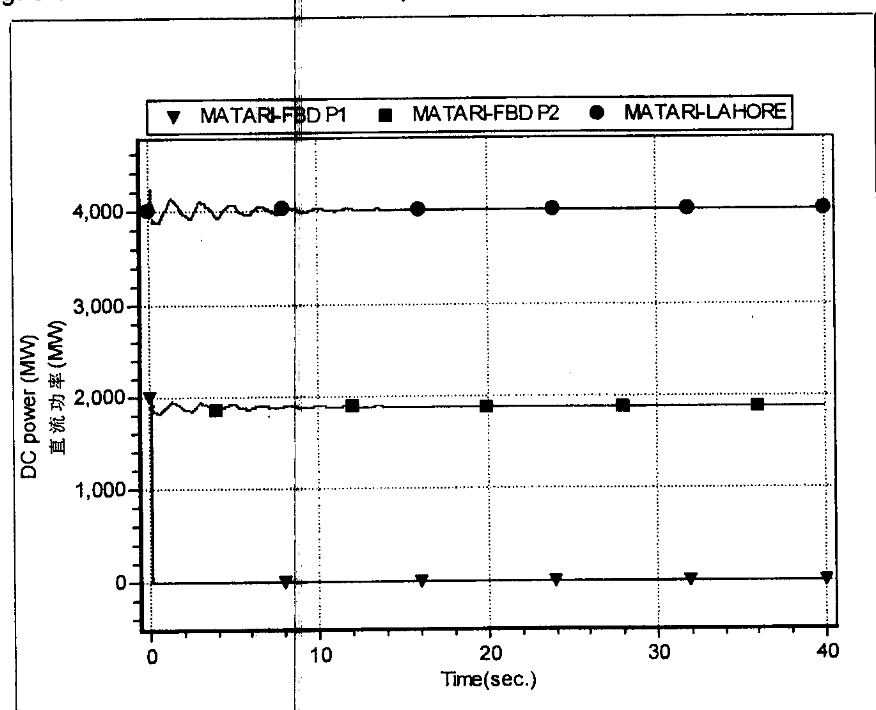

图 5-10 MATIARI~FBD 直流单极闭锁故障直流线路功率曲线图
Fig. 5-10 MATIARI-FBD HVDC Monopole Block Fault HVDC Line Power Graph

可以看出，直流单极闭锁后，盈余功率转移到接入的交流系统上，交流系统能够承受,系统电压和频率保持稳定。

It can be seen that, in case of a HVDC monopole block fault, the redundant power transfers to the connected AC system, and the AC system can withstand it. The system frequency and voltage are stable.

2)MATIARI～LAHORE 发生直流双极闭锁，需要采取切除送端 1980MW 机组的措施，系统可保持稳定，对应的系统响应曲线为：

2)If a HVDC bipolar block fault is found in MATIARI～LAHORE line, the 1980MW unit switch-off is performed to make the system maintain stable. The system response curves are as follows:

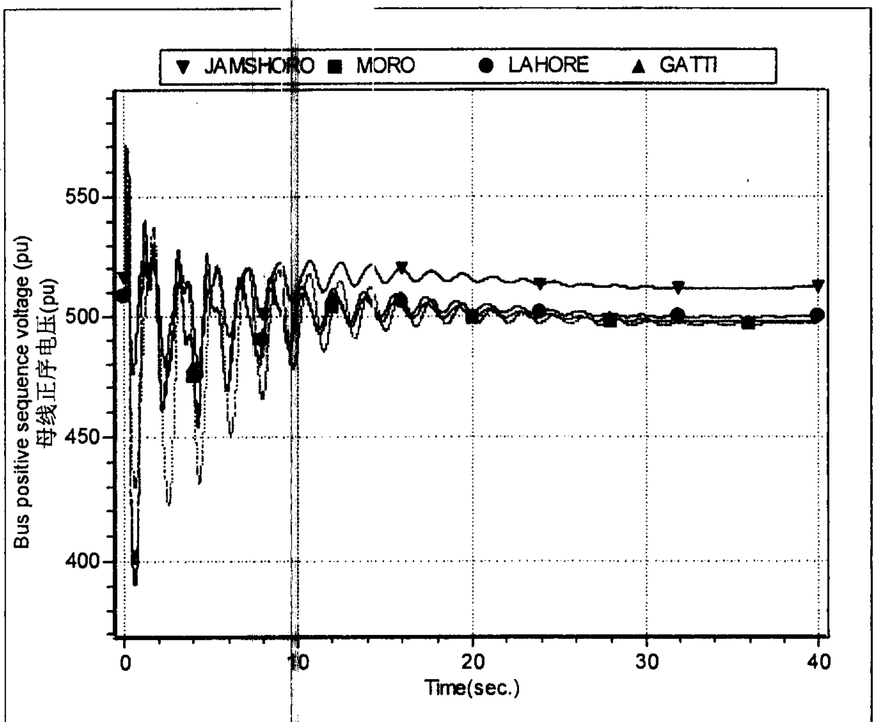

图 5-11 MATIARI～LAHORE 直流双极闭锁故障相关母线电压图
Fig.5-11 MATIARI～LAHORE HVDC Bipolar Block Fault-related Bus Voltage Graph

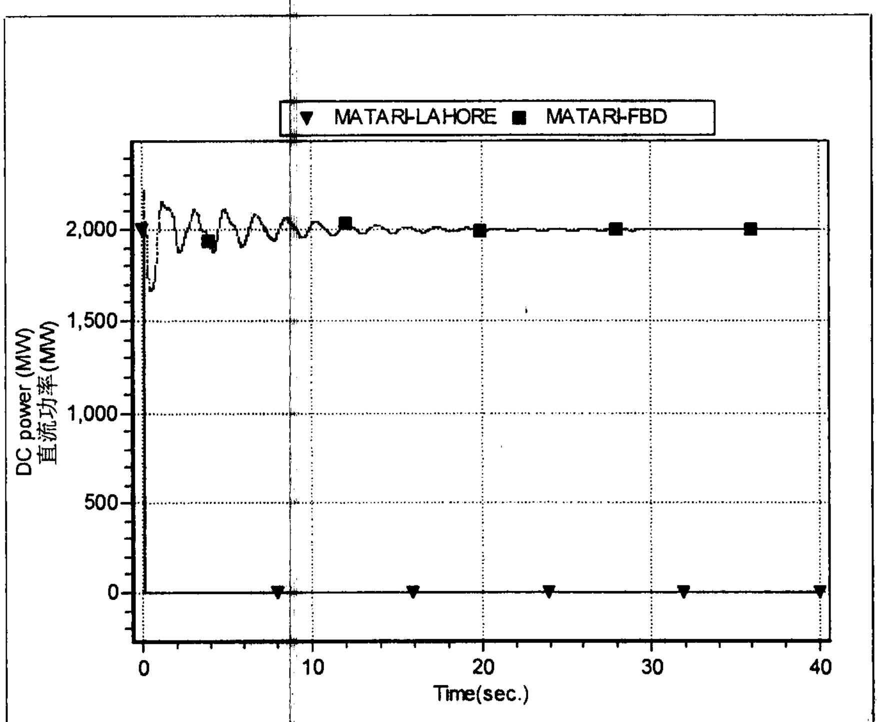

图 5-12 MATIARI～LAHORE 直流双极闭锁故障直流线路功率曲线图
Fig.5-12 MATIARI～LAHORE HVDC Bipolar Block Fault HVDC Line Power Graph

3)MATIARI～FBD 发生直流双极闭锁，需要采取切除送端 1320MW 机组的措施，系统可保持稳定，对应的系统响应曲线为：
3)If a HVDC bipolar block fault is found in MATIARI～LAHORE line, the 1320MW unit switch-off should be performed to make the system maintain stable. The system response curves are as follows:

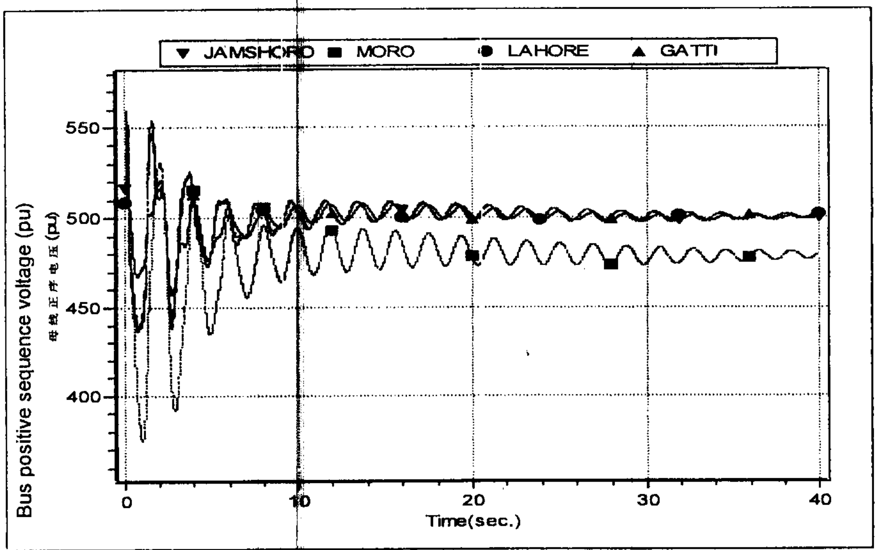

图 5-13 MATIARI～FBD 直流双极闭锁故障相关母线电压图
Fig. 5-13 MATIARI～FBD HVDC Bipolar Block Fault-related Bus Voltage Graph

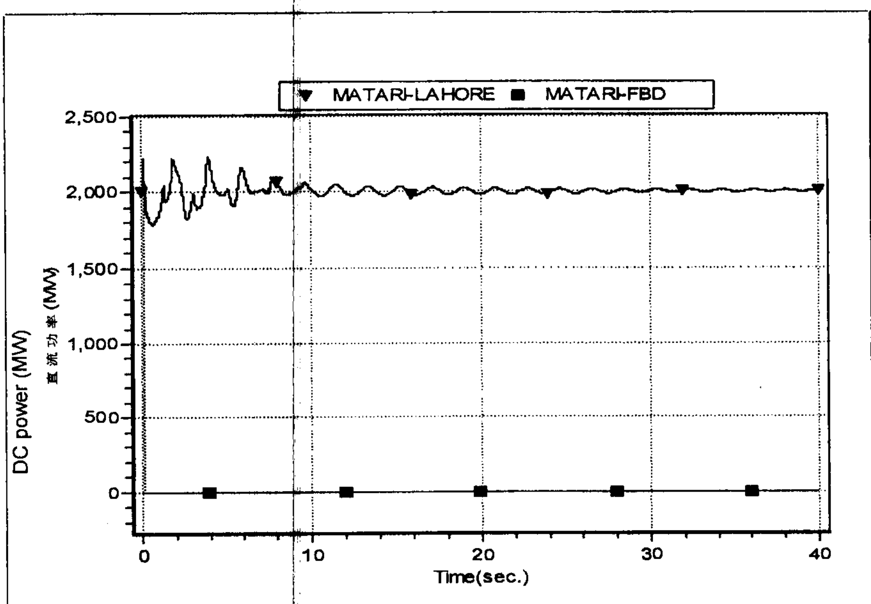

图 5-14 MATIARI～FBDE 直流双极闭锁故障直流线路功率曲线图
Fig. 5-14 MATIARI～FBDE HVDC Bipolar Block Fault HVDC Line Power Graph

5.4 小结

远景年 2022 年，巴国内 MATIARI～LAHORE、MATIARI～FBD 直流输电工程发生单极闭锁故障，无需采取措施系统保持稳定运行；发生双极闭锁故障，需要分别采取切机 1980MW 和切机 1320MW 的措施，采取措施后系统恢复稳定运行。
In the future year 2022, for the MATIARI - LAHORE and MATIARI – FBD HVDC transmission projects in Pakistan, no measure is taken to keep systems run stable in case of monopole block fault; and 1980MW and 1320MW unit is switched off to restore stable operation of the system in case of bipolar block fault.

6 结论及建议
Conclusions and suggestions

6.1 结论
Conclusions

关于默蒂亚里～拉合尔±660kV 直流输电工程，2018 投产年巴基斯坦电网接入直流后，安全稳定分析结论如下：

After HVDC access of Pakistan power grid in 2018 operation year, for the Matiari – Lahore ±660kV HVDC transmission project, the conclusions on security and stability analysis are described as follows:

（1）500kV 主干网架线路发生单一故障系统可保持安全稳定运行；

When a single fault occurs in 500kV main network line, the system can maintain safe and stable operation.

（2）按最严苛方式校核，直流单极闭锁时，保持暂态稳定。直流双极闭锁时，需要采取送端切机 3960MW、受端切负荷 3000MW 的措施后系统恢复稳定运行；

For worst case, the system keeps transient stability in case of HVDC monopole block fault. In case of HVDC bipolar block fault, the 3960MW unit switch-off and 3000MW load shedding shall be performed to restore the system to stable state.

（3）考虑提高全网机组旋转备用率可减少双极闭锁故障后的切负荷量；

An increase of spinning reserve rate of units in the whole grid can decrease load shedding after a bipolar block fault occurs.

（4）交流网架补强、受端机组多开机等情况，可提高系统安全稳定性；

System security level will be enhancing, consider the AC compensation network and more Lahore side units in service.

本次研究以巴方提供的数据为基础，进行补充完善，计算原则和标准同巴方沟通确认。计算仿真结果表明，N-1 故障，系统可以保持安全稳定运行，N-2 故障通过采取措施可以保持系统安全稳定运行，默蒂亚里～拉合尔±660kV 直流输电工程项目技术可行。

This research is base on the raw data provided by NTDC, HVDC model is added to the data and some generator parameters are adjusted. The calculation principle and stability standard are discussed and checked with NTDC. The simulation result shows that the system can keep stable under N-1 fault without mitigation measures and N-2 fault with mitigation measures. This result can confirm the feasibility of Matiari – Lahore ±660kV HVDC transmission project.

6.2 建议
Suggestions

（1）推荐巴基斯坦电网在直流系统建设同时，在直流工程送端和受端安装安控系统，以确保电网安全;

While Pakistan Power Grid constructs HVDC system, the stability control system is recommended to be installed in the receiving/sending-end of HVDC transmission project so as to ensure the safety of power grid at detailed design/implementation stage;

（2）由于系统存在弱阻尼现象，小干扰稳定分析和 PSS 配置建议在后续展开专题研究；

Due to the low damping of system, small signal stability and PSS installation study is suggested to be conducted at detailed design/implementation stage;

（3）此安全稳定报告为应巴方要求，在可研阶段确定项目可行性，为最终的输电方案提供技术支持，最终的输电方案须由巴方确定，电网安全运行由巴方负责。

Upon request of Pakistan, this security and stability report is prepared to confirm the feasibility of this HVDC project, and provides the technical support for the final power transmission scheme. The final power transmission scheme must be desided and confirmed by Pakistan. The system operation is responsibility of Pakistan.

国家电网公司
STATE GRID
CORPORATION OF CHINA

报告编号:

Report No.:WA00191K-SS-03A

巴基斯坦默蒂亚里～拉合尔±660kV 直流输电工程
±660kVHVDC Project from Matiari to Lahore in Pakistan

可行性研究
Feasibility Study

电力系统一次
Power System Primary Part

送端默蒂亚里换流站接入系统设计
Access System Design of Matiari Converter Station

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Task Basis and Main Principles

0.1 任务依据

Task basis

（1）中国电力技术装备有限公司关于巴基斯坦默蒂亚里～拉合尔±660kV直流输电工程可行性研究的合同（电力系统一次）。
The Contract on the Feasibility Study of Pakistan Matiari-Lahore ±660kV DC Transmission Project of China Electric Power Equipment & Technology Co., Ltd. (Power System Primary Part);

（2）巴基斯坦电网扩展规划（National Power System Expansion Plan），2011年，加拿大SNC-兰万灵集团公司。
National Power System Expansion Plan (2001), SNC-Lavalin Group Inc.

（3）2014年11月《中华人民共和国政府与巴基斯坦伊斯兰共和国政府关于中巴经济走廊能源项目合作的协议》、2015年4月中方领导人出访巴基斯坦中巴双方签署的51项合作协议。
The *Agreement on the Energy Project Cooperation of the China–Pakistan Economic Corridorbetween the Governments of the People's Republic of China and Islamic Republic of Pakistan* signed in November, 2014 and the cooperation agreements on 51 projects signed between China and Pakistan during Chinese leaders' visit to Pakistan in April, 2015.

0.2 技术标准

Technical standards

本工程应贯彻、引用的技术标准主要有：
The technical standards to be implemented and referenced for the Project mainly include:

（1）IEC 62001-2004 Guide to the specification and design evaluation of a.c. filters for HVDC systems（HVDC系统用交流滤波器的规范和设计评价指南）

（2）IEC 60909-02001-07 INTERNATIONL STANDARD: Short-circuit in three-phase a.c.system，Part 0 Calculation of currents交流系统三相短路电流计算

（3）电力系统设计规程　SDJ161-85
Code for Design of Power System　(SDJ161-85)

（4）电力系统安全稳定导则DL755-2001
Guidelines for Power System Security and Stability(DL755-2001)

.（5）Pakistan Standard：NEPRA Grid Code 2005(《并网准则》巴基斯坦电力监管局)

0.3 设计水平年

Design level year

巴基斯坦默蒂亚里～拉合尔±660kV直流工程计划2018年双极投运。工程可研设计水平年考虑为2018年。
The Pakistan Matiari-Lahore ±660kV DC Transmission Project is planned to be put into double-pole operation in 2018, and the year of 2018is considered as the design level year for the feasibility study of the Project.

1 电力系统概况

Power System Overview

目前，巴基斯坦输电网最高电压等级为500kV，已形成覆盖全国主要地区的主网架结构，形成南部、北部向伊斯兰堡、旁遮普省负荷中心供电的2~4回500kV输电通道，在负荷中心建成环网。巴基斯坦国家电网按输电区域划分为巴基斯坦国家输电公司（NTDC）及卡拉奇KESC工业园。
At present, the maximum voltage class of Pakistan transmission grid is 500kV. The main grid structure covering major regions throughout the country has been formed, the 2 to 4-circuit 500kV transmission channels for supplying power from southern and northern parts to the load centersin Islamabad and Punjab have been established, and a looped network has been built in the load centers. The State Grid of Pakistan is divided into National Transmission &Despatch Co. Ltd. (NTDC) and Karachi Electric Supply Co. Ltd. (KESC) Industrial Park by transmission areas.

巴基斯坦电网主网架电压等级为500kV、220kV，地方配电公司电压等级为132kV、66kV，其中66kV电压等级正初步向132kV过渡。目前巴基斯坦电网有500kV变电站12座，变电容量15750MVA，220kV变电站29座，变电容量1823.10MVA，500kV线路长度5144km，220kV线路长度8358km。
The voltage classes of the main grid of the Pakistan Power Grid are 500kV and 220kV, and that of local power distribution companies are 132kV and 66kV (66kV is being initially transformed to 132kV). Now, there are twelve 500kV substations (with capacity of 15750MVA) and twenty-nine 220kV substations (with capacity of 1823.10MVA) in the Pakistan Power Grid, with 500kV line and 220kV line being5144kmand8358km long respectively.

按照地理位置，巴基斯坦地方配电公司包括旁遮普省和伊斯兰堡地区的IESCO、LESCO、GEPCO、FESCO、MEPCO配电公司、信德省和卡拉奇地区的SEPCO、HESCO配电公司及卡拉奇KESC工业园、俾路支省的QESCO、北部地区的PESCO、TESCO配电公司。
Based on the geographical position, the local power distribution companies of Pakistan include IESCO, LESCO, GEPCO, FESCO and MEPCO power distribution companies in Punjab and Islamabad, SEPCO and HESCO power distribution companies in Sindh and Karachi, KESC Industrial Park in Karachi, QESCO in Balochistan, and PESCO and TESCO power distribution companies in the northern part.

2014年巴基斯坦电网最大负荷需求23040MW，实际最大负荷18830MW，装机24110MW，电源利用容量约67%。用电结构中，以居民生活用电比重最大，约45%左右；工业用电比重其次，约29%；农业、商业及其它大用户用电比重分别在11%、8%和7%左右。巴基斯坦用电负荷主要集中在中部旁遮普省和伊斯兰堡地区，约占全国60%左右；信德省及卡拉奇地区约占20%，俾路支省约6%，开伯尔-普赫图赫瓦省及周边北部地区约占14%左右，目前巴基斯坦电网形成了北部水电、南部火电围绕负荷中心向中部供电的局面。
In 2014, the maximum load demand of the National Power System was 23040MW, the actual maximum load was 18830MW, the installed capacity was 24110MW, and the power utilization capacity was about 67%. In the electricity consumption structure, the household consumption by residents takes up the largest proportion, about 45%; the industrial electricity consumption comes second, about 29%; and the consumption by farming, commerce and other large users about 11%, 8% and 7%, respectively. The electrical load in Pakistan is concentrated in Punjab and Islamabad in the middle part, accounting for about 60% of the total of the country; Sindh and Karachi takes up about 20%, Balochistan about 6%, and Khyber Pakhtunkhwa and surrounding northern areas about 14% At present, the Pakistan Power Grid has formeda power supply patternwith hydropower in the north and thermal power in the southsupplying power to the central areas through the load centers.

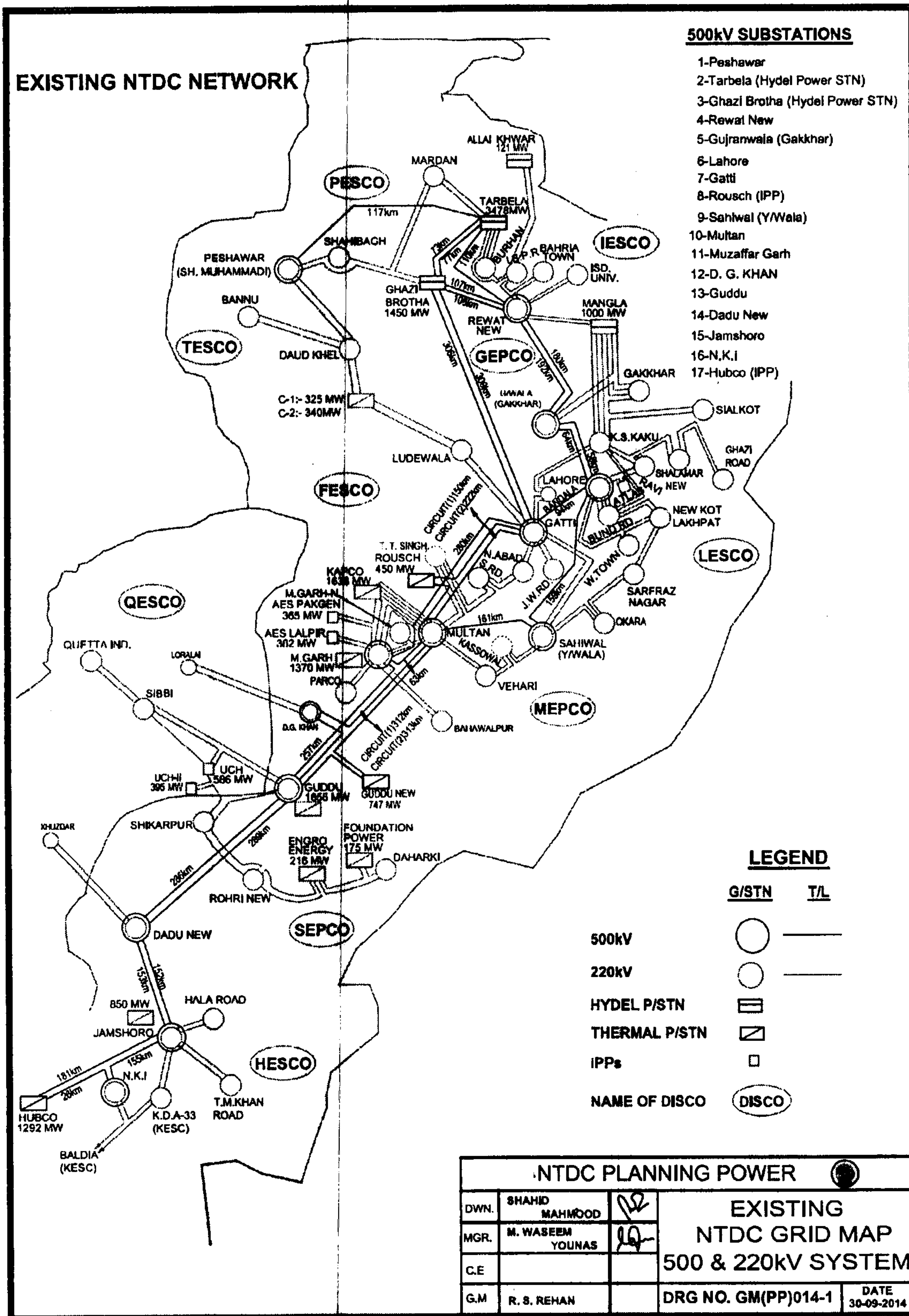

图1-1 2014年巴基斯坦220kV及以上电网地理接线图

Fig. 1-1 Geographical Connection Diagram of Pakistan Power Grid (220kV and Above) in 2014

2 电力系统发展规划

Power System Development Plan

2.1 电力需求预测

Power demand forecast

1971年以来，巴基斯坦用电量整体上呈持续上升趋势，在1998年、2008年出现回落，2010年以来至今用电增速放缓。1972～2012年期间，巴基斯坦全社会用电量年均增长率为6.9%。
The electricity consumption of Pakistan has been rising overall since 1971, but dropped in 1998 and 2008, and from 2010 to now, the increase of electricity consumption slows down. From 1972 to 2012, the average annual growth rate of total electricity consumption of Pakistan was up to 6.9%.

巴基斯坦国家电网按输电区域划分为巴基斯坦国家输电公司（NTDC）及卡拉奇KESC工业园负荷，根据巴方提供最新的负荷预测数据，巴基斯坦电网2017年、2018年、2020年和2023年最大负荷将分别达到26680MW、28020MW、30820MW和38250MW，2015～2020年年均增长率4.9%，2020～2023年年均增长率7.5%。
The State Grid of Pakistan is divided into NTDC and Karachi Electric Supply Co. Ltd. (KESC) Industrial Park loads according to the transmission areas, and in accordance with the latest load forecast data provided by Pakistan, the maximum loads of the National Power System will be respectively up to 26680MW, 28020MW, 30820MW and 38250MW in 2017, 2018, 2020 and 2023, the average annual growth rate will be 4.9% from 2015 to 2020 and the average annual growth rate will be 7.5% from 2020 to 2023.

表2.1-1 巴基斯坦电力需求预测表
Table 2.1-1 Pakistan Power Demand Forecast

单位：10MW
Unit: 10MW

年份 Year	2015	2017	2018	2020	2015～2020年年均增长率 Average annual growth rate from 2015 to 2020	2023	2020～2023年年均增长率 Average annual growth rate from 2020 to 2023
Nationwide	2422	2668	2802	3082	4.9%	3825	7.5%
其中：NTDC Incl.: NTDC	2121	2335	2449	2685	4.8%	3364	7.6%
KESC	301	333	353	397	5.7%	461	6.4%

2.2 电源安排

Power supply arrangement

根据巴基斯坦提供的电源规划有关情况，安排规划电源的投产时序。电源项目2016年、2017年、2018年、2019年、2020年、2021年、2022年投产规模分别达到635 MW、6425.5 MW、5419MW、5419MW、3572MW、5390MW、2730MW。
According to the power generations planning which advised by Pakistan, the planning of the power generationsCOD timefor 2016, 2017, 2018, 2019, 2020, 2021, 2022, is 635 MW, 6425.5 MW, 5419MW, 5419MW, 3572MW, 5390MW and 2730MW respectively.

表2.2-1 巴基斯坦电网规划电源建设安排表

Table 2.2-1 Construction Arrangement for Planned Power Supply Projects of Pakistan Power Grid

单位：MW
Unit: MW

Sr. #	Fiscal Year	Name of Project	Fuel	Location	Installed Capacity (MW)	Expected Comissioning Date
		Existing capacity				
1	2015-16	CHASNUPP-III	Nucl	Chashma, KPK	340	May-16
2		Zonergy-II	Solar	Lal Sohnra (Cholistan), Punjab	100	May-16
3		M/s Hamza Sugar Mills Ltd.	Baggase	Khanpur, Punjab	15	May-16
4		M/s Yunus Energy Ltd.	Wind	Jhimpir, Sindh	50	Jun. 2016
5		M/s Metro Power Co. Ltd.	Wind	Jhimpir, Sindh	50	Jun. 2016
6		M/s Gul Ahmed Energy Limited	Wind	Jhimpir, Sindh	50	Jun. 2016
7		M/s Tapal Wind Energy (Pvt.) Limited	Wind	Jhimpir, Sindh	30	Jun. 2016
8	2016-17	Zonergy-III, IV & V	Solar	Lal Sohnra (Cholistan), Punjab	300	Jul. 2016
9		M/s Tenaga Generasi Limited	Wind	Gharo/Bhambore/Kuttikun, Sindh	49.5	Sep. 2016
10		M/s Master Wind Energy Limited	Wind	Jhimpir, Sindh	49.5	Sep. 2016
11		M/s HydroChina Dawood Power Ltd.	Wind	Gharo, Sindh	49.5	Sep. 2016
12		M/s United Energy Pakistan Limited	Wind	Jhimpir, Sindh	99	Sep. 2016
13		M/s Tenaga Generasi Limited		Gharo, Sindh	49.5	Sep. 2016
14		M/s Layyah Sugar Mills Ltd.	Baggase	Layyah, Punjab	41	Dec. 2016
15		CHASHNUPP-IV	Nucl	Chashma, KPK	340	Dec. 2016
16		Zonergy-VI	Solar	Lal Sohnra (Cholistan), Punjab	100	Dec. 2016
17		Zonergy-VII	Solar	Lal Sohnra (Cholistan), Punjab	100	Jan. 2017
18		Zonergy-VIII & IX	Solar	Lal Sohnra (Cholistan), Punjab	200	Feb. 2017

19		LNG Based Plants (2*GT)	LNG	Bhikki, Punjab	800	Mar. 2017
20		Patrind HPP	Hydel	Kunhar River, KPK/AJK	147	Mar. 2017
21		LNG Based Plants (2*GT)	LNG	Haveli Bahadur Shah (Jhang), Punjab	800	Apr. 2017
22		Gas Based Power Plants	LNG	Existing Plant Sites	1000	Apr. 2017
23		LNG Based Plants (2*GT)	LNG	Baloki, Punjab	800	May. 2017
24		M/s Alliance Sugar Mills Ltd.	Baggase	Ghotki, Sindh	19	Feb. 2017
25		M/s Chanar Sugar Mills Ltd.	Baggase	Tandlianwala, Punjab	22	Jun. 2017
26		M/s Sachal Energy Development (Pvt.) Limited	Wind	Jhimpir, Sindh	49.5	Jun. 2017
27		Tarbela 4th Ext. Project	Hydel	Tarbela, KPK	1410	Jun. 2017
28	2017-18	Neelum Jhelum Hydel	Hydel	Nauseri/Muzaffarabad, AJK	969	Aug. 2017
29		M/s Etihad Power Generation Ltd.	Baggase	Rahim Yar Khan, Punjab	67	Feb. 2017
30		M/s Almoiz Industries Ltd.	Baggase	Mianwali, Punjab	36	Dec. 2017
31		M/s Safina Sugar Mills	Baggase	Lalian, Sagodha	20	Dec. 2017
32		M/s Shahtaj Sugar Mills Ltd.	Baggase	MandiBahauddin, Punjab	32	Dec. 2017
33		M/s RYK Energy Ltd.	Baggase	Rahim Yar Khan, Punjab	32	Dec. 2017
34		M/s SSJD Bioenergy	Baggase	Mirpurkhas, Sindh	12	Dec. 2017
35		M/s Lumen EnergiaPvt Ltd	Baggase	Jhang, Punjab	12	Dec. 2017
36		Shandong Imported Coal Based Power Project	Coal	Sahiwal, Punjab	1320	Dec. 2017
37		LNG Based Plants (1*ST)	LNG	Bhikki, Punjab	400	Dec. 2017
38		LNG Based Plants (1*ST)	LNG	Baloki, Punjab	400	Dec. 2017
39		LNG Based Plants (1*ST)	LNG	Haveli Bahadur Shah (Jhang), Punjab	400	Dec. 2017

40		M/s Jhampir Wind Power (Pvt.) Limited	Wind	Jhimpir, Sindh	50	Feb. 2018
41		M/s Hawa Energy (Pvt.) Limited	Wind	Jhimpir, Sindh	50	Mar. 2018
42		M/s Hartford Alternative Energy (Pvt.) Limited	Wind	Jhimpir, Sindh	50	Apr. 2018
43		M/s Tricon Boston Consulting Corporation (Pvt.) Limited (A)	Wind	Jhimpir, Sindh	50	Apr. 2018
44		M/s Tricon Boston Consulting Corporation (Pvt.) Limited (B)	Wind	Jhimpir, Sindh	50	May. 2018
45		M/s Tricon Boston Consulting Corporation (Pvt.) Limited (C)	Wind	Jhimpir, Sindh	50	May. 2018
46		M/s Three Gorges Second Wind Fram Pakistan Ltd (Wind Eagle Limited)	Wind	Jhimpir, Sindh	49.5	Jun. 2018
47		M/s Three Gorges Second Wind Fram Pakistan Ltd (Wind Eagle Limited)	Wind	Jhimpir, Sindh	49.5	Jun. 2018
48		Port Qasim Power Project	Coal	Port Qasim Karachi, Sindh	1320	Jun. 2018
49	2018-19	GolenGol HPP	Hydel	Chitral, KPK	106	Jul. 2018
50		EngroPowergen Project	Coal	Thar, Sindh	660	Oct. 2018
51		GulpurPoonch river	Hydel	Poonch River/Gulpur, AJK	102	Oct. 2018
52		M/s Zephyr Power Pvt. Ltd.	Wind	Gharo, Sindh	50	Nov. 2018
53		Coal Plant at Salt Range	Coal	Salt Range, Punjab	300	Jan. 2019
54		Shanghai Electric Power Project	Coal	Thar, Sindh	1320	Jan. 2019
55		Grange Holding	Coal	Arifwala, Punjab	163	Jan. 2019
56		HUB Power Company Ltd.	Coal	HUB, Baluchistan	1320	Jan. 2019
57		Lucky Electric	Coal	Port Qasim, Sindh	660	Mar. 2019

		Power Company Ltd.				
58		Siddiqsons Limited	Coal	Port Qasim, Sindh	350	Mar. 2019
59	2019-20	TPS Jamshoro (Phase-1)	Coal	Jamshoro, Sindh	660	Jun. 2019
60		CASA	Import	Cross Border Interconnection	1000	Jul. 2019
61		Coal Plant at Muzaffargarh	Coal	Muzaffargarh, Punjab	600	Sep. 2019
62		TPS Jamshoro (Phase-2)	Coal	Jamshoro, Sindh	660	Dec. 2019
63		KeyalKhwar	Hydel	Dasu District, KPK	128	Jan. 2020
64		Other Wind Power Plants	Wind	Sindh	524	Feb. 2020
65	2020-21	Karachi Coastal Power Plant (unit-1)	Nucl	Karachi	1100	Nov. 2020
66		Dasu HPP (Phase-1)	Hydel	7km upstream of Dasu Village on Indus River, KPK	2160	Feb. 2021
67		Karot HPP	Hydel	Jehlum River, Distt. Rawalpindi, Punjab	720	Jun. 2021
68		Tarbela 5th Ext. Project	Hydel	Tarbela, KPK	1410	Jun. 2021
69	2021-22	Suki Kinari HPP	Hydel	Kunhar River/Mansehra, KPK	870	Jul. 2021
70		Karachi Coastal Power Plant (unit-2)	Nucl	Karachi	1100	Oct. 2021
71		Kotli	Hydel	Poonch River/Kotli, AJK	100	Jun. 2022
72		Coal Plant at Lakhra	Coal	Lakhra, Sindh	660	Jun. 2022

3 工程概况

Project Overview

3.1 默蒂亚里～拉合尔直流工程概况

Overview of Matiari-Lahore DC Transmission Project

为促进信德省塔尔煤田及沿海煤电的开发外送，满足旁遮普省及伊斯兰堡地区用电负荷增长的需求，规划建设默蒂亚里～拉合尔±660kV直流输电工程。工程起点巴基斯坦南部信德省默蒂亚里，途径信德、旁遮普2省，落点中部旁遮普省拉合尔地区，直流线路长度约878km，输电容量4000MW，规划2018年底投产。
To promote the development and transmission of Thar Coal Field in Sindh and the coastal coal power and meet the requirements for the increase of electrical loads in Punjab and Islamabad, the Matiari-Lahore ±660kV DC Transmission Project shall be planned and constructed. The Project starts from Matiari, Sindh (in the south of Pakistan) to Lahore, Punjab (in the central area) via Sindh and Punjab, and the DC line is about 878km long, the power transmission capacity is 4000MW and it is to be put into operation at the end of 2018.

3.2 送端能源资源及电源概况

Overview of sending-end energy resources and power supplies

3.2.1能源资源情况

Status of energy resources

塔尔煤田位于巴基斯坦信德省东南部塔尔沙漠境内（距卡拉奇约410km，距海德拉巴市300km，距米迪市约65km，最近城镇为西部25km的伊斯兰姆考特镇），南北长140km，东西宽65km，面积在9100km^2，煤炭资源量为1755亿t，占全国的94%，是巴基斯坦最大的煤田。在资源量中，探明储量27亿t，控制储量94亿t，预测储量507亿t，远景储量1127亿t。
Thar Coal Field is located in the Thar Desert in the southeast of Sindh, Pakistan (about 410km from Karachi, 300km from Hyderabad and about 65km from Midi City, and the nearest town is Islamcot Town which is 25km from the west of it), which is 140km from south to north and 65km from east to west, with the area of 9100km^2, and the coal resources are 175.5 billion tons, accounting for 94% of the country, so it is the largest coal field in Pakistan. In the resources, the proved reserves are up to 2.7 billion tons, the controlled reserves are up to 9.4 billion tons, the prognostic reserves are up to 50.7 billion tons and the prospective reserves are up to 112.7 billion tons.

塔尔煤田煤层厚度为0.20~22.81m，埋藏深度为150~203m。其中，主要煤层厚度在12~21m之间，平均埋藏深度170m，全部适合露天开采，塔尔煤田煤类从褐煤到次烟煤均有分布，以褐煤为主。根据钻孔煤样分析资料，整个塔尔煤田原煤收到基化学组分及有关特征为：水分46.77%，挥发分23.42%，固定碳16.66%，灰分6.24%，硫分1.16%，发热量3208kcal/kg。
The thickness of coal seam of the Thar Coal Field is 0.20~22.81m, with the burial depth of 150~203m. The thickness of main coal seam is from 12m to 21m, with the average burial thickness of 170m, all of which are suitable for open pit mining, and different coal types (varying from lignitic coal to subbituminous coal) are distributed in the Thar Coal Field and lignitic coal occupies first place. Based on the analysis data of drilled coal samples, the as-received-basis chemical constituents and relevant characteristics of raw coal in the Thar Coal Field are shown as follows: moisture: 46.77%, volatile matter: 23.42%, fixed carbon: 16.66%, ash content: 6.24%, sulphur content: 1.16% and calorific value: 3208k cal/kg.

目前塔尔煤炭尚未开发，仅有少数煤矿在开展前期工作，开发潜力大。由于塔尔煤田煤炭水分高，发热量低，不适宜远距离外运，最好的利用方式是建设坑口电厂就地转化。目前塔尔煤田内共有四个区块在开展前期工作，即区块I、区块II、区块IV、区块VI，其中区块I和区块II进展较快。

Now, the Thar coal has not been developed, and only a minority of coal mines are performing the preliminary work, so it has a large development potential. For the coal produced from the Thar Coal Field is characterized by high moisture level and low calorific value, the long-distance outward transport should not be adopted, and the optimum method of utilization is to construct a pithead coal power plant for on-site conversion. At present, there are a total of 4 blocks in the Thar Coal Field for performing the preliminary work, i.e. Block I, Block II, Block III and Block IV, and the progress of Block I and Block II are faster.

塔尔煤田区块 I 面积为150km²，地质资源量34亿t。先期开采区域地表面积18.90 km²，三个可采煤层平均厚度为23m，平均埋藏深度150m，可采原煤量4.8亿t，剥离量28亿m³，平均剥采比为5.88 m³/t，规划初期规模650万t/年。塔尔煤田区块 II 面积95.5km²，地质资源量20亿t，其中可采储量15.7亿t。煤层埋藏平均深度140m，平均剥采比为6.6m³/t，规划初期规模350万t/年。

The area of Block I in the Thar Coal Field is 150km² and the geological resources are 3.4 billion tons. The surface area of the preliminary mining area is 18.90 km², the average thickness of 3 commercial seams is 23m, the average burial depth is 150m, the quantity of workable raw coal is 0.48 billion tons, the stripping volume is 2.8 billion m³, the average stripping ratio is 5.88 m³/t and the preliminary scale planned is 6.5 million t/year. The area of the Thar Coal Field Block II is 95.5km² and the geological resources are 2 billion tons, including the recoverable reserves of 1.57 billion tons. The average burial depth of seam is 140m, the average stripping ratio is 6.6m³ and the preliminary scale planned is 3.5 million t/year.

3.2.2电源概况

Power supply overview

送端信德省配套电源考虑2014年11月《中华人民共和国政府与巴基斯坦伊斯兰共和国政府关于中巴经济走廊能源项目合作的协议》优先实施项目清单中的安格鲁燃煤电厂（2×330MW）、塔尔煤田一区块坑口燃煤电厂（2×660MW），卡西姆港燃煤电厂（2×660MW）；此外根据电源项目最新进展，考虑积极推动清单中胡布克扩建燃煤电厂（2×660MW）。配套电源总装机容量4620MW，满足默蒂亚里～拉合尔直流工程送电需要。

Based on the Agreement Between the Government of the People's Republic of China and the Government of the Islamic Republic of Pakistan on the Energy Project Cooperation of the China–Pakistan Economic Corridor in November, 2014, priority shall be given to the carrying out of Engro Coal Power Plant (2×330MW), Thar Coal Field Block I Pithead Coal Power Plant (2×660MW) and Port Qasim Coal Power Plant (2×660MW) described in the list of projects in the receiving-end supporting power supply of Sindh; besides, according to the latest progress of power supply projects, Hubco Expanded Coal Power Plant (2×660MW) in the list will be actively promoted. The total installed capacity of supporting power supply is 4620MW to meet the requirements for the power transmission of Matiari-Lahore DC Transmission Project.

A、 安格鲁燃煤电厂
Engro Coal Power Plant

安格鲁燃煤电厂位于塔尔煤田区块 II，为坑口燃煤电厂，装机容量2×330MW，业主为信德安格鲁煤炭公司，中国机械设备工程股份有限公司以EPC方式参与，已完成可研报告并通过巴方评审。

As a pithead coal power plant, Engro Coal Power Plant is located in Block II of the Thar Coal Field, with the installed capacity of 2×330MW, and Sindh Engro Coal Company is the Employer and China Machinery Engineering Corporation participates in it with the method of EPC, and the feasibility study report has been completed and has passed the review of Pakistan.

B、 塔尔煤田一区块坑口燃煤电厂
Thar Coal Field Block I Pithead Coal Power Plant

塔尔煤田一区块坑口燃煤电厂位于塔尔煤田区块 I，装机容量2×660MW，中国电力国际有限公司以BOO方式控股开发，目前已完成初可研审查并完成可研报告。

Thar Coal Field Block I Pithead Coal Power Plant is located in Block I of the Thar Coal Field, with the installed capacity of 2×660MW, and China Power International Development Limited holds shares and develops with the method of BOO and has completed the preliminary feasibility study examination and the feasibility study report now.

C、 卡西姆港燃煤电厂
Port Qasim Coal Power Plant

卡西姆港燃煤电厂位于卡拉奇东南约47km的卡西姆港，为进口燃煤电厂，装机容量2×660MW，中国电力建设股份有限公司以BOOT方式控股开发，目前已完成可研报告并通过中方评审。
As an imported coal power plant, Port Qasim Coal Power Plant is located in the Port Qasim about 47km from the southeast of Karachi, with the installed capacity of 2×660MW, and China Power International Development Limited holds shares and develops with the method of BOO, and the feasibility study report has been completed and has passed the review of China now.

D、 胡布克扩建燃煤电厂
Hubco Expanded Coal Power Plant

胡布克扩建燃煤电厂位于卡拉奇西北约30km的胡布港，为进口燃煤电厂，装机容量2×660MW，业主为胡布电力公司，中国电力建设股份有限公司参与开发，目前已完成厂址总规划、接入系统规划、环评。
As an imported coal power plant, Hubco Expanded Coal Power Plant is located in the Hub Port about 30km northwest of Karachi, with the installed capacity of 2×660MW, and Hub Power Company Limited is the Employer and PowerChina Limited participates in its development, and at present, the overall site planning, access system planning and environmental impact assessment have been completed.

表3.2-1 信德省主要火电项目前期工作情况
Table 3.2-1 Preliminary Work of Major Thermal Power Plants in Sindh

单位：MW
Unit: MW

	项目名称 Project name	装机容量 Installed capacity	参与单位 Participating units	前期进度 Preliminary progress	投产时间 Production time
1	安格鲁燃煤电厂 Engro Coal Power Plant	2×330	业主为信德安格鲁煤炭公司，中国机械设备工程股份有限公司以EPC方式参与With Sindh Engro Coal Company as the Employer, and China Machinery Engineering Corporation participatingthrough EPC mode	完成可研报告 Feasibility study report completed	2019.6
2	塔尔煤田一区块坑口燃煤电厂 Thar Coal Field Block I PitheadCoal Power Plant	2×660	中国电力国际有限公司以BOO方式控股开发Held and developed by China Power International Development Limited through BOO mode	完成可研报告 Feasibility study report completed	2020.8
3	卡西姆港燃煤电厂 Port Qasim Coal Power Plant	2×660	中国电力建设股份有限公司以BOOT方式控股开发 Held and developed by Power Construction Corporation of China through BOOT mode	完成可研报告并通过中方评审Feasibility study report completed and Chinese party's review passed	2018.6
4	胡布克扩建燃煤电厂 HubcoExpanded Coal Power	2×660	业主为胡布克电力公司，中国电力建设股份有限公	正在开展可研 Feasibility study in	2020.8

	Plant		司参与开发 WithHubcoElectric Power Company as the Employer, and Power Construction Corporation of China participatingin the development	progress	
	合计 Total	4620			

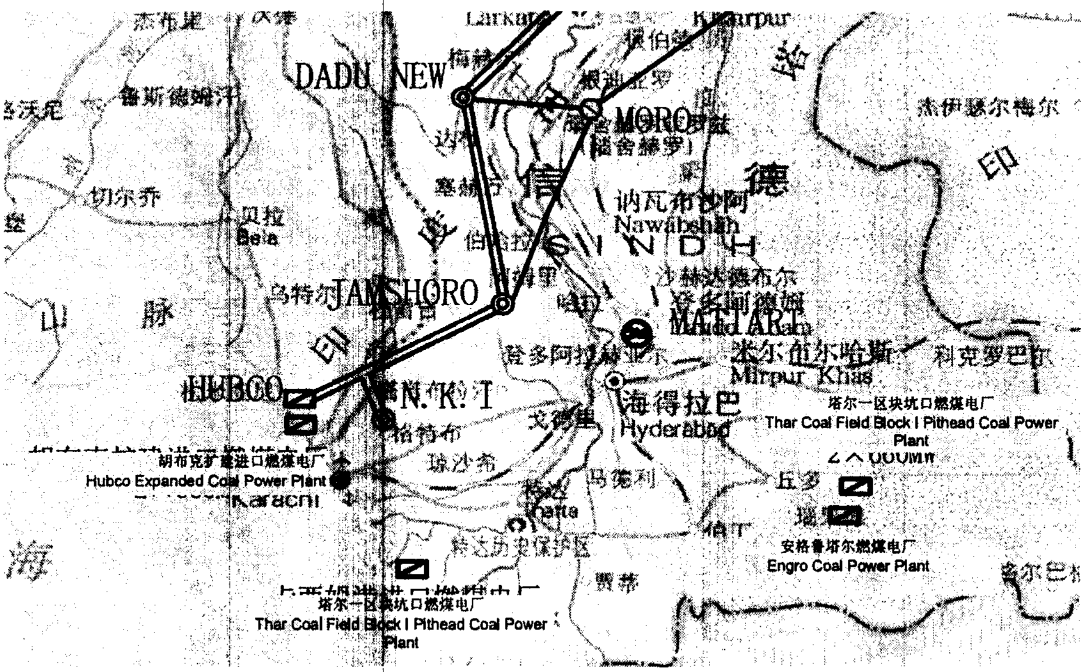

图3.2-1 信德省主要火电项目分布图
Fig.3.2-1 Distribution of Major Thermal Power Plants in Sindh

3.3 送端电力平衡分析

Analysis on sending-end power balance

（1）计算水平年：2017～2020年及2023年；
Calculation level year: 2017-2020 and 2023;

（2）信德省和卡拉奇电网备用容量按最大负荷的10%考虑；信德省和卡拉奇地区包括SEPCO、HESCO配电公司及卡拉奇KESC工业园，最大负荷同时率按0.85考虑。
10% of the maximum load is taken as the spare capacity of the power grids in Sindh and Karachi; Sindh and Karachi is home to SEPCO and HESCO power distribution companiesand Karachi KESC Industrial Park, and the maximum load coincidence factor will be determined at 0.85

（3）电源装机考虑已投及在建火电、水电项目，考虑巴基斯坦规划火电、水电项目，风电、光伏、生物质发电不参与平衡。
For the installed capacity of power supply, the thermal power and hydropower projects which has been put into operation and under construction will be taken into account and the thermal power and hydropower projects of energy planning of the Pakistan will be considered, and wind power, photovoltaic power generation and biomass power generationwill not be involved in balance.

（4）参与平衡的电源容量：参照中巴经济走廊能源规划报告，现有电源利用容量按巴方提供的2013年实际情况考虑（约67%）。
Power supply capacity involved in balance: pursuant to the report on energy planning of the

China–Pakistan Economic Corridor, the existing power supply utilization capacity will be considered as per the actual situation of 2013 provided by Pakistan (about 67%).

信德省和卡拉奇地区是巴基斯坦未来主要火电基地，将重点发展塔尔煤田坑口电站项目、港口进口煤电项目和港口核电项目，2018年至2023年期间，信德省和卡拉奇地区存在部分电力盈余，2018年、2019年、2020年和2023年分别达到2340MW、3530MW、7980MW和10070MW。在满足地区用电的基础上，信德省和卡拉奇地区具有盈余电力，需要外送。

As Pakistan's future major thermal power bases, Sindh and Karachi will focus on the development of Thar Coal Field Pithead Power Plant project, port coal power project and port nuclear power project. During 2018-2023, there will be some power surplus in Sindh and Karachi, reaching 2340MW, 3530MW, 7980MW and 10070MW in 2018, 2019, 2020 and 2023 respectively. While meeting the regional demand for power, Sindh and Karachi will enjoy a power surplus,need the HVDC to output.

表3.3-1 信德省和卡拉奇地区电力平衡表
Table 3.3-1 Balance Sheet of Power in Sindh and Karachi

单位：10MW
Unit: 10MW

	2017	2018	2019	2020	2023
1、全社会最大负荷 Maximum load of the whole society	503	530	558	588	686
2、年末装机容量 Installed capacity at end of year	841	973	1120	1595	1903
（1）现有火电 Existing thermal power plant	634	634	634	634	634
（2）现有水电 Existing hydropower plant	0	0	0	0	0
（3）现有核电Existing nuclear power plant	0	0	0	0	0
（4）在建电源 Power supply in construction	75	75	75	185	295
1）古杜 Guddu Power Plant	75	75	75	75	75
2）核电 Nuclear Power Plant	0	0	0	110	220
（5）规划电源 Planned power supply	132	264	411	776	974
HUBCO Coal Power Project 胡布克燃煤电站	132	132	132	132	132
Port Qasim coal Power Project 卡西姆港燃煤电厂		132	132	132	132
Engro Thar Coal-fired Power Plant 安格鲁燃煤电厂			66	66	66

SSRL Thar Coal BlockI Mine Mouth Power Plant 塔尔煤田一区块坑口电站				132	132
TPS Jamshoro (Phase-1,2)			66	132	132
Grange Power Project			15	15	15
Lucky Coal Power Project				66	66
Siddiqsons Coal Power Project				35	35
HUB Power Project Thar Block-II				33	33
Thal NOVA Power Project, Thar Block-II				33	33
Thar Mine Mouth Oracle 塔尔 Oracle 坑口电站					132
Coal Plant at Lakhra					66
3、年末可用装机容量 Installed capacity available at end of year	632	764	911	1386	1694
4、电力外送需求 Electric power output demand	-129	-234	-353	-798	-1007

中方考虑新能源项目不参与电力平衡，输电规模未考虑新能源电力，但巴方表示巴国实行容量电价机制，外送需求需考虑风电大发时系统最大出力。根据巴方介绍，2018年除中巴经济走廊项目外，另新增风电1410MW，外送需求达3190MW，2023年外送需求达10920MW。考虑巴方规划风电大发情况下的信德省和卡拉奇地区电力平衡结果见表3.3-2。

China believes that new energy projects should not be involved in the power balance, so new energy power is excluded from the transmission capacity, while Pakistan expressed that since Pakistan implements a capacity price mechanism, it needs to take into account the maximum output in case of large-scale wind power generation when satisfying outward delivery demand. According to Pakistan's description, another 1,410MW wind power will be added in addition to Chine-Pakistan Economic Corridor project, with 3190MW to satisfy outward deliverydemand in 2018, and 10920MW in 2023. See Table 3.3-2 for the results of the power balance in Sindh and Karachi taking into account large-scale wind power generation.

表3.3-2 考虑巴方规划风电大发的外送需求

Table 3.3-2 Outward DeliveryDemand Taking into Account the Large-scale Wind Power Generation Planned by Pakistan

单位：10MW
Unit: 10MW

项目 Item	2017	2018	2019	2020	2023
1、中巴经济走廊风电 Wind power of China-Pakistan	35	35	35	35	35

Economic Corridor					
2、巴方新增风电 Pakistan's new wind power	141	141	141	141	141
3、巴方提出的风电外送需求（考虑同时率50%） Output demand for wind power station consider coincidence factor 50%	85	85	85	85	85
4、考虑风电的送出需求 Electric power output demand**consider wind power station**	-214	-319	-438	-883	-1092

3.4 工程建设必要性

Necessity of projectconstruction

A、 满足巴基斯坦负荷中心电力负荷发展需要。
To satisfy the need of developing power load of Pakistan's load centers.

本工程的建设可将巴基斯坦南部的大规模电力送至巴基斯坦负荷中心，满足巴基斯坦特别是旁遮普省及伊斯兰堡地区电力负荷供电需要，为经济的持续快速发展提供保障。
This project can deliver the large amounts of electricity in the southern region to Pakistan's load centers, satisfy the power supply needs of Pakistan, particularly Punjab and Islamabad regions and safeguard the sustained and rapid economic development.

B、 满足巴基斯坦南部电力外送需要。
To satisfy the need of outward delivery of electricity in southern Pakistan.

电力供应不足问题已严重制约了巴基斯坦经济的持续快速发展。巴基斯坦电源构成长期保持以油电、气电为主导地位的格局，发电成本高、出力不足、能源对外依存度高，严重影响电厂的发电效率，进一步加剧了网内缺电形势，电源结构亟待优化调整。为缓解巴基斯坦电力供应不足的问题，巴基斯坦将在南部塔尔煤田建设大型煤电电源，并在南部港口建设进口燃煤电站。由于项目距离负荷中心较远，本工程的建设可以满足巴基斯坦南部电力远距离送出的需要。

Pakistan's economy has long been restricted from sustainable and rapid development by its inadequate power supply problem. Since oil power and gas power, which cost much, generate less but rely heavily on external resources, have dominated the power market in Pakistan for a long time, seriously affected the power generation efficiency of the plant, and further exacerbated domestic power shortage, hence the power structure needs to be adjusted and optimized urgently. Pakistan will build a large coal power supply in the southern Thar Coal Field and a power plant using imported coal in the southern port to ease its shortage of power. In view of the fact that these projects are located far from the load center, this Project can meet Pakistan's needs on long-distance delivery of power in its southern region.

C、 满足巴基斯坦全国能源资源优化配置的需要
To satisfy the need of optimization and allocation of Pakistan's nationwide energy resources

满足国民经济和社会发展的电力供应需求是本阶段巴基斯坦电力工业发展的第一要务。能源资源与负荷分布不均衡的特点，决定了巴基斯坦电力供应问题的解决需依托电网、交通等平台实现最大范围内的能源资源优化配置，建立多元化能源供应渠道，提高用电安全可靠性。因此，本工程建设是实现巴基斯坦能源资源优化配置、满足缺能地区电力供应的需要。
It is the top priority for the development of power industry in Pakistan at this stage to satisfy the needs of national economy and social development on power supply. While the uneven distribution of energy resources and load determines that the solution to Pakistan's power supply problem should rely up the power grid, transportation and other platforms to achieve energy resources optimization and allocation to the largest extent, to establish diversified energy supply channels, and to improve energy security and

reliability. Hence this Project is necessary for Pakistan to achieve energy resources optimization and allocation and to satisfy the needs of energy-deficient areas on power supply.

4 送端换流站接入系统方案研究

Study on Access Schemesof Sending-end Converter Station

4.1 送端换流站选址及接入原则

Site selection and access principles of sending-end converter station

随着信德省塔尔煤电及沿海进口煤电开发规模的不断扩大，需要在更大范围内消纳送端电力。建设南电北送直流输电工程，有序引导送端电源的开发外送，可以促进地区经济发展，满足负荷中心发展需要。
With the continuous expanding of the development size of Sindh Thar Coal Power Plant and coastal power plant using imported coal, a larger market is needed to consume sending-end power. Hence the South-to-North DC Power Delivery Project can orderly guide the development and outgoing of sending-end power supply, promote economic development in the region, and meet the development needs of each load center.

本工程送端换流站的位置选择应综合考虑与系统连接点、接入电源点的相对位置，以及直流线路的路径走向等因素，具体原则如下：
The site selection of the sending-end converter station in this Project should take into account the position corresponding to the point in connection with the system and the point of access to power, the path of the DC line and other factors. The specific principles are as follows:

（1）便于换流站接入信德省500kV电网；
To facilitate converter station to access to Sindh 500kV power grid;

（2）便于本区域配套外送电源汇集；
To facilitate the collection of outgoing power supply in the region;

（3）尽量避免线路交叉；
To avoid line crossingto the largest extent;

（4）适当控制直流线路长度。
To controlthe length of DC line appropriately.

4.2 送端换流站选站范围及选站情况

Scope and circumstances of site selection of sending-end converter station

根据送端配套电源分布情况，安格鲁燃煤电厂和塔尔一区块坑口电厂位于信德省东南部塔尔煤田，卡西姆港电厂和胡布克电厂位于信德省南部卡拉奇附近。塔尔煤田近区尚无500kV电网覆盖，塔尔煤田电源项目与最近的Jamshoro500kV变电站距离超过300km。

According to the distribution of supporting sending-end power supply, Engro Coal Power Plant and Thar Coal Field Block I Pithead Coal Power Plant are located in the Thar Coal Field in the southeast of Sindh, while Port Qasim Coal Power Plant and Hubco Coal Power Plant are located near Karachi, a city in the south of Sindh. Thar Coal Field has no 500kV power grid close to it, and the distance between the power supply project of Thar Coal Field and nearest Jamshoro 500kV substation exceeds 300km.

送端换流站选址应综合考虑送端配套电源位置和信德省500kV电网情况，宜选址信德省500kV电网与塔尔煤田电源项目之间，兼顾电源汇集及换流站接入系统，同时尽量缩短直流线路长度。针对站址选择，中南电力设计院进行了现场踏勘并与巴方沟通，巴方建议站址位于默蒂亚里地区，中南院建议站址位于巴方站址以南约20公里处，由于在建的贾姆沙罗～摩洛线路路径已经兼顾巴方建议站址，且该站址相关工作巴方已经开展，最终确定了考虑海德拉巴市北部的默蒂亚里及周边地区作为本工程送端换流站选址范围。

The location of the sending-end supporting power supply and situations of Sindh 500k power grid should completely considered in the site selection of the sending-end converter station, a place between the Sindh 500kv power grid and Thar Coal Field power supply project should be appropriate in order to coordinate with power supply collection and converter station access system and shorten the length of

DC line as much as possible. The Central Southern China Electric Power Design Institute (CSEPDI) has conducted an site investigation and communicated with Pakistan with regard to the site selection. Pakistan proposed to select Matiari, while CSEPDI recommended that the place should be about 20 km away from Pakistan's station. Since the Jamshoro-Moro line in construction has already take into account the site proposed by Pakistan and Pakistan has already started relevant work, it is finally decided that Matiari and surrounding area in the northern of Hyderabad City should be the scope of site selection of the sending-end converter station in the Project.

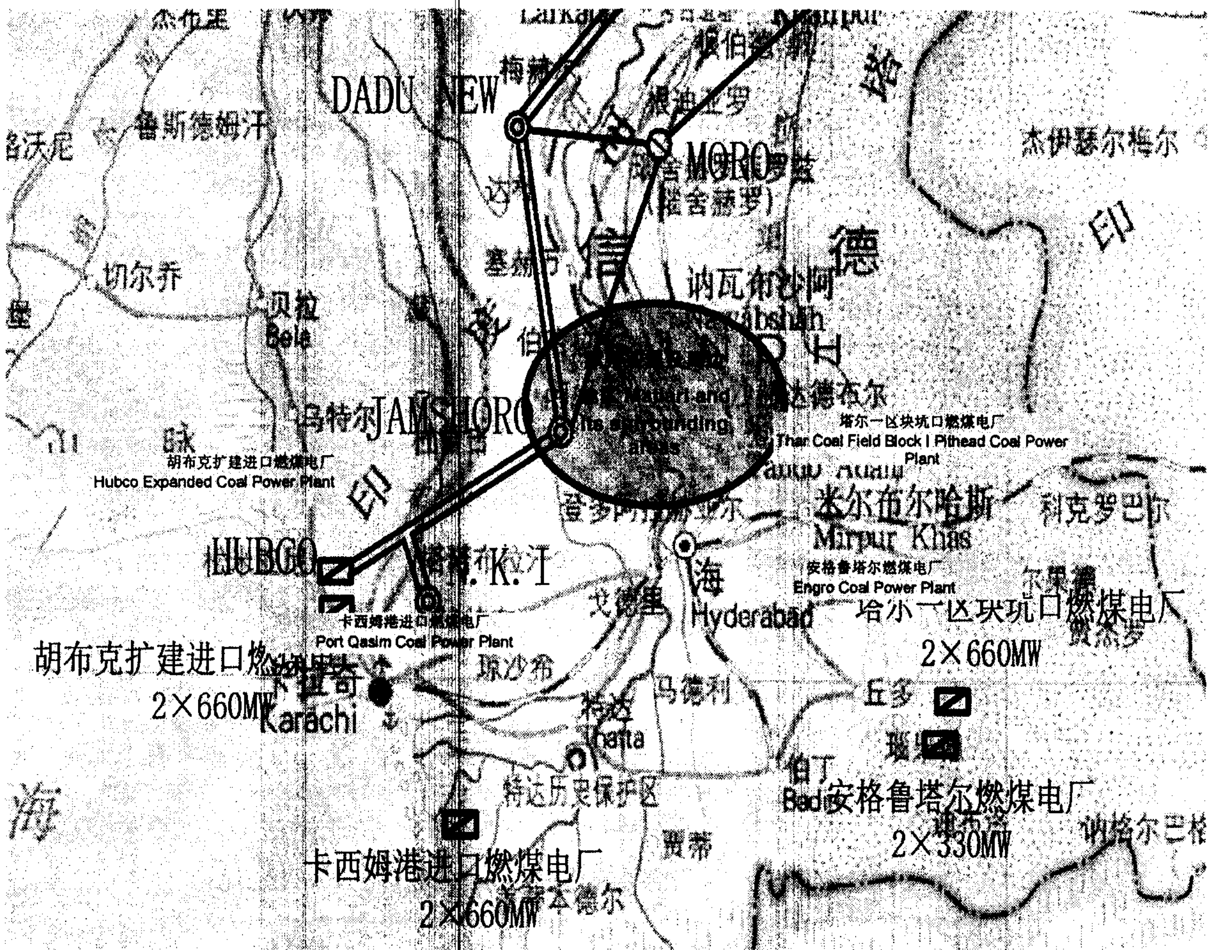

图4.2-1 送端换流站选址范围示意图

Fig.4.2-1 Scope of Site Selection of Sending-end Converter Station

根据送端默蒂亚里换流站选站情况，送端换流站选择赛卡德（Sekhat）站址。站址的中心坐标为：东经68°30' 32"，北纬25°38' 25"，位于N5国家干线公路（5号国道）东侧。站址地势开阔，地形平坦，大部分种植小麦，小部分为灌木丛荒地。站址以北有5户左右简易民房（单层土坯房）需要拆迁。进站道路可从连接N5国家干线公路的乡村公路引接，该乡村公路为沥青路面，路况一般，路面宽度可以满足工程建设及大件运输要求。换流站水源初步考虑采用地下水。站址位于印度河东岸，距印度河防洪堤约1.5km。

According to the site selection of Matiari sending-end converter station, the sending-end converter station chose Sekhat, with center coordinates: 68°30' 32" E, 25°38' 25" N, located at the east side of N5 national trunk road (No.5 National Road). The place is open and flat, mostly planted with wheat and covered by bushes in a small portion. About five simple private houses (single-floor adobe houses) in the north need to be relocated. The inbound road may be connected to the country road extending to N5 national trunk road. The country road has an asphalt surface, with ordinary road conditions, and a width wide enough to meet the requirements of construction and large transport. Groundwater is considered to be the water source of the converter station preliminarily. The place is located on the east bank of the Indus River, approximately 1.5km away from the Indian River levees.

4.3 送端电源组织方案

Sending-end power supply organization scheme

巴基斯坦信德省电网电压等级为500kV、220kV，直流工程配套火电电源点建设规模在660MW以上，不适合以220kV电压等级接入。同时，电源接入系统设计尽量满足N-1原则，提高送出电力的可靠性。送端电源考虑以500kV电压等级汇集，1个电厂出2回500 kV线路，或2个电厂串连后，出2回500kV线路接入换流站。

Although Sindh applies 500kV and 220kV in its power grid, 220kV is not suitable for access, because the installed capacity of the supporting thermal power plant of DC Transmission Project has exceeded 660MW. In the meantime, the design of power supply access system should satisfy N-1 principle in order to improve the reliability of outgoing power. Sending-end power supply may apply 500kV, with one power plant providingdouble-circuit 500kV outgoing lines, or two power plants connectingin series to provide double-circuit 500kV outgoing lineswhich connect to the converter station.

送端电源组织方案为：新胡布克燃煤电厂以2回500kV线路接入换流站；卡西姆港燃煤电厂以2回500 kV线路接入换流站；安格鲁电厂、塔尔一区块电厂分别以1回500kV线路接入换流站，安格鲁电厂通过1回500kV线路与塔尔一区块电厂相连。

Sending-end power supply organization scheme is: the new Hubco Coal Power Plant accesses to the converter station through double-circuit 500kV lines; Port Qasim Coal Power Plant accesses to the converter station through double-circuit 500kV lines; Engro Coal Power Plant and Thar Coal Field Block I Pithead Coal Power Plant access to the converter station through single-circuit 500kV lines; and Engro Coal Power Plant connects to Thar Coal Field Block I Pithead Coal Power Plant through single-circuit 500kV lines.

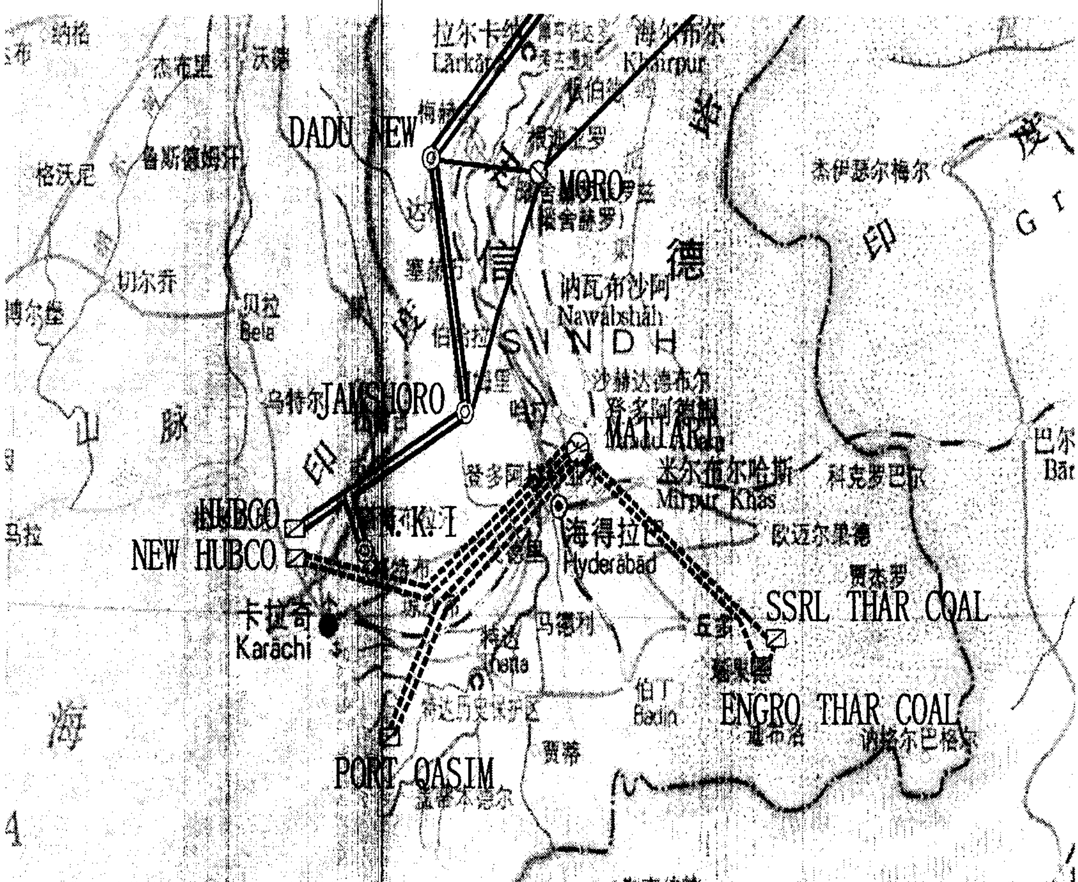

图4.3-1 送端电源组织方案示意图

Fig. 4.3-1 Schematic Diagram of Sending-end Power Supply Organization Scheme

4.4 换流站接入系统方案

Access schemes of converter station

考虑本工程2018年建成投产，在现有网架基础上，送端地区500kV电网新建贾姆沙罗（Jamshoro）～摩洛（Moro）单回500kV线路、摩洛（Moro）～新大都（Dadu New）单回500kV线路、摩洛（Moro）～R.Y.汉（R.Y.KHAN）单回500kV线路，南电北送能力进一步增强。信德省默蒂亚里及周边地区作为直流工程送端起点；由于送端配套电源均以500kV送出，为了提高交流系统对直流的支撑能力，减少损耗，送端换流站考虑以500kV电压等级接入，规划以下送端换流站接入系统方案：

Since this Project will be put into production at 2018, the sending-end regional 500kV power grid will have new Jamshoro-Moro single-circuit 500kV line, Moro-Dadu New single-circuit 500kV line and Moro-R.Y.KHAN single-circuit 500kV line in addition to existing power grid frame, and will further improve its South-to-North power transmission capacity. Sindh Matiari and its surrounding area will serve as the send-end starting point of the DC Transmission Project; since all the sending-end supporting power suppliesare delivered through 500kV line, the sending-end converter station intends to apply 500kV line in order to improve AC system's capacity to support DC transmissionand reduce power loss. The following access schemesof sending-end converter station are proposed:

方案1： 直流送端换流站π入贾姆沙罗（Jamshoro）～摩洛（Moro）500kV线路；π入贾姆沙罗～新大都（Dadu New）500kV线路。直流配套火电机组以500kV电压等级接入换流站。送端换流站形成10回出线，2回至贾姆沙罗，1回至摩洛，1回至新大都，6回至配套电源。。

Scheme1: DC sending-end converter station connects (π connection)toJamshoro-Moro 500kV line, with 2 new lines, and connects(π connection) to Jamshoro-Dadu New 500kV line, with 2 new lines. DC supporting thermal power generating units are connectedto the converter station through 500kV lines. The sending-end converter station will have 10-circuit outgoing lines, with 2to Jamshoro, 1 Moro and 1 Dadu New respectively, and 6 to supporting power supply.

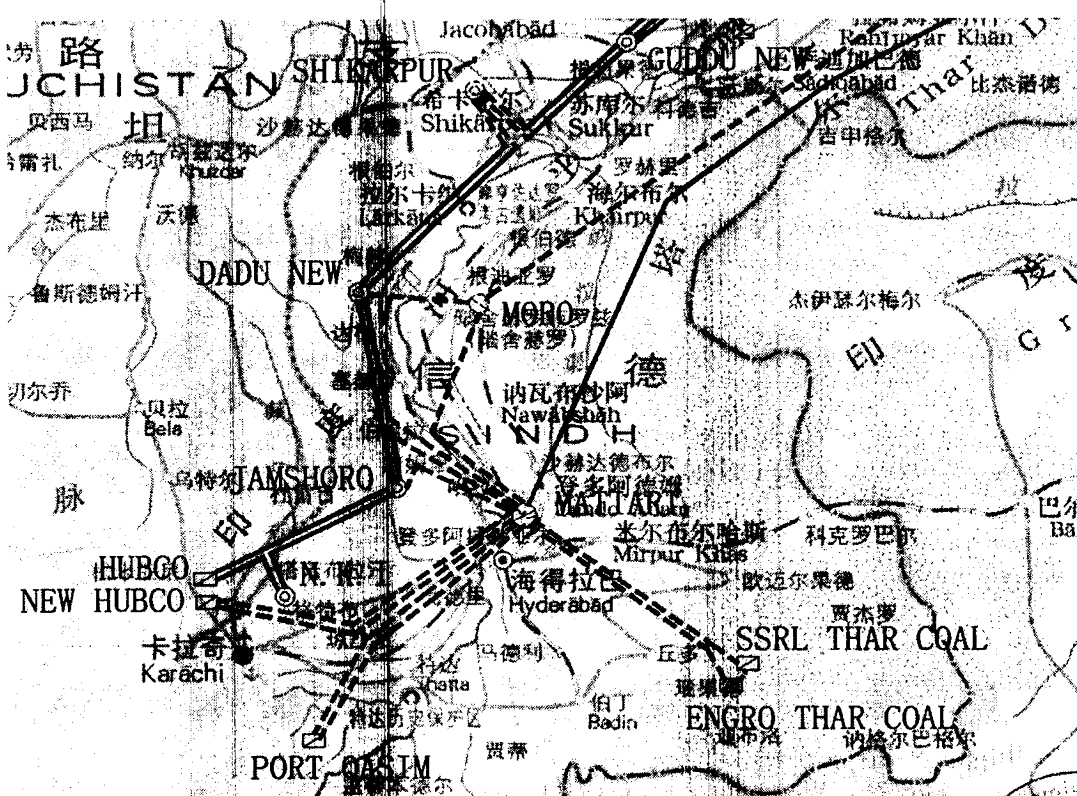

图4.4-1 送端换流站接入系统方案1

Fig.4.4-1 Access Scheme 1of Sending-end Converter Station

方案2：直流送端换流站π入贾姆沙罗（Jamshoro）～摩洛（Moro）500kV线路；新建送端换流站至贾姆沙罗（Jamshoro）500kV变电站的500kV线路；新建送端换流站至摩洛（Moro）500kV变电站的500kV线路。直流配套火电机组以500kV电压等级接入换流站。送端换流站形成10回出线，2回至贾姆沙罗，2回至摩洛，6回至配套电源。

Scheme2: DC sending-end converter station connects (π connection)toJamshoro-Moro 500kV line, with 2 new lines, connects1 line to Jamshoro 500kV substation and 1 line to Moro substation, with 2 new lines. DC supporting thermal power generating units are connectedto the converter station through 500kV lines. The sending-end converter station will have10-circuit outgoing lines, with 2 to Jamshoro, 2 to Moro and 6 to supporting power supply.

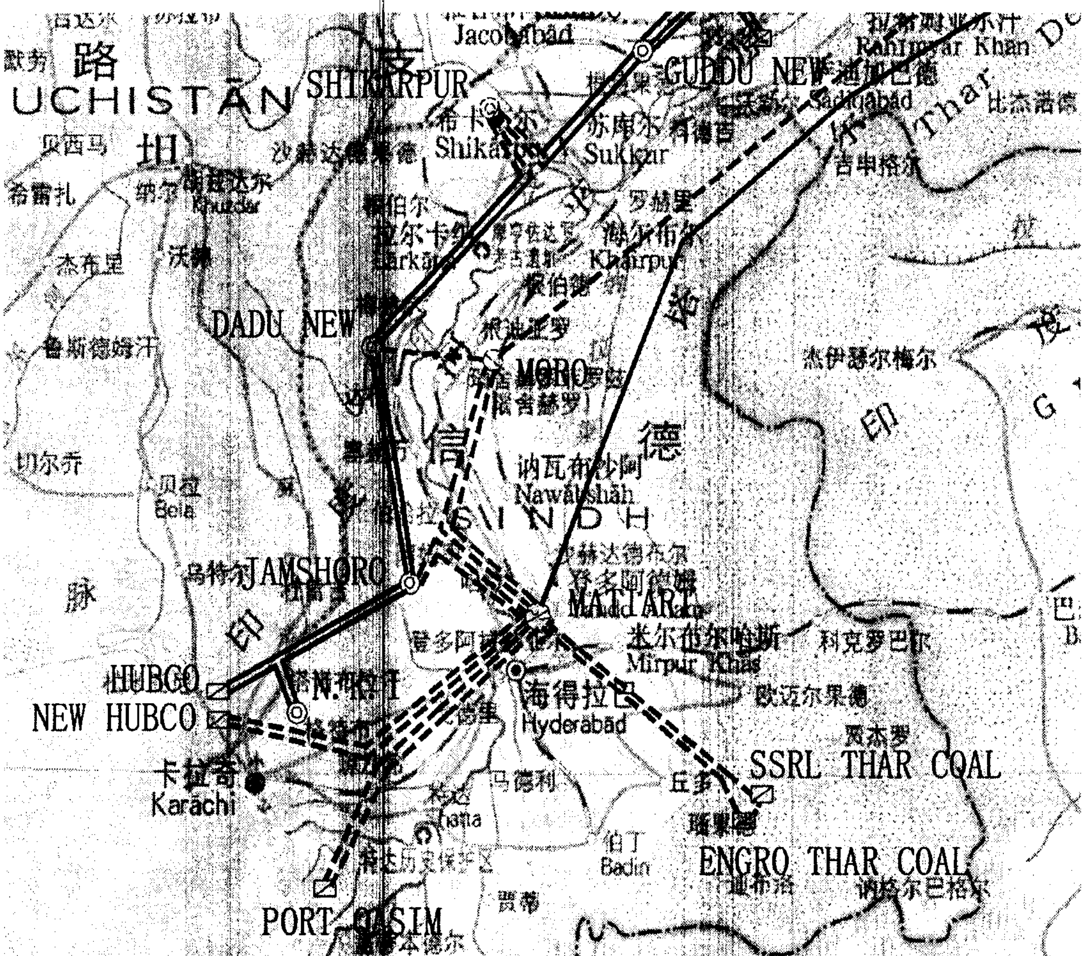

图4.4-2 送端换流站接入系统方案2
Fig.4.4-2 Access Scheme 2of Sending-end Converter Station

5 电气计算 Electrical calculation

5.1 计算条件 Calculation conditions

采用BPA潮流与稳定计算程序，对送端换流站接入系统方案进行电气计算分析，本工程2018年投产，计算水平年选取2018年。电气计算条件如下：

BPA load flow and stability calculation program is adopted to implement electrical calculation and analysis on sending-end converter station access scheme. The project goes into operation at the end of 2018. 2018 is chosen to be the level year for calculation. Electrical calculation conditions are listed below:

（1）计算负荷和装机

Calculation of load and installed capacity

在电气计算中，以巴基斯坦电网规划负荷和装机方案为基础，扣除部分接入220kV及以下电网的小机组和相应的负荷作为计算负荷和装机。

In electrical calculation, load and installed capacity will be calculated with the planned load and installed capacity of Pakistani power grid as the basis, subtracting small units and related loads connecting to power grids of 220kV or lower voltage.

（2）校核网架

Grid structure check

本期，采用巴基斯坦电网2018年规划网架，巴基斯坦电网建成南电北送第三回500kV交流通道，建成默蒂亚里～拉合尔±660kV直流，输电容量4000MW。

In this phase, 2018 Structure Plan of Pakistan Power Grid is adopted, and 3rd-circuit 500kV AC channel to transmit electricity from south to north is constructed in Pakistan power grid. Matiari-Lahore ±660kV DC is to be constructed, leading to transmission capacity of 4000MW.

5.2 潮流计算 Load flow calculation

计算采用巴基斯坦电网2018年夏大方式，默蒂亚里～拉合尔±660kV直流工程送电4000MW。潮流计算表明，各接入系统方案下送端500kV电网潮流分布均匀、电压水平满足要求，N-1方式下交流线路、变压器均不过载。各方案正常方式及主要的N-1方式潮流分布如下图所示。

Pakistan power grid 2018 summer maximum-load mode is adopted in the calculation. Matiari-Lahore ±660kV DC Transmission Project leads to a transmission capacity of 4000MW. According to load flow calculation, under all system accessing schemes, 500kV power grid load flow at the sending-end is evenly distributed, with voltage level complying with requirement, and there is no overloading with AC line, and transformer under N-1 mode. Load flow distribution under normal mode and main N-1 mode of the two schemes is shown in the below figure.

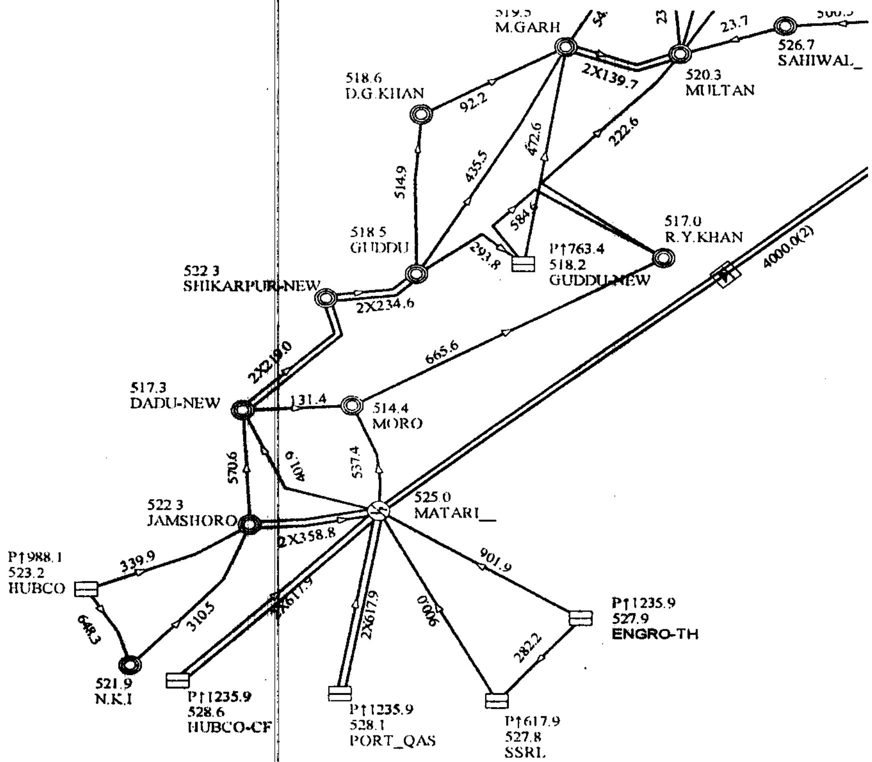

图5.2-1 方案1正常方式潮流图

Fig. 5.2-1 Scheme 1 Normal Mode Load Flow Diagram

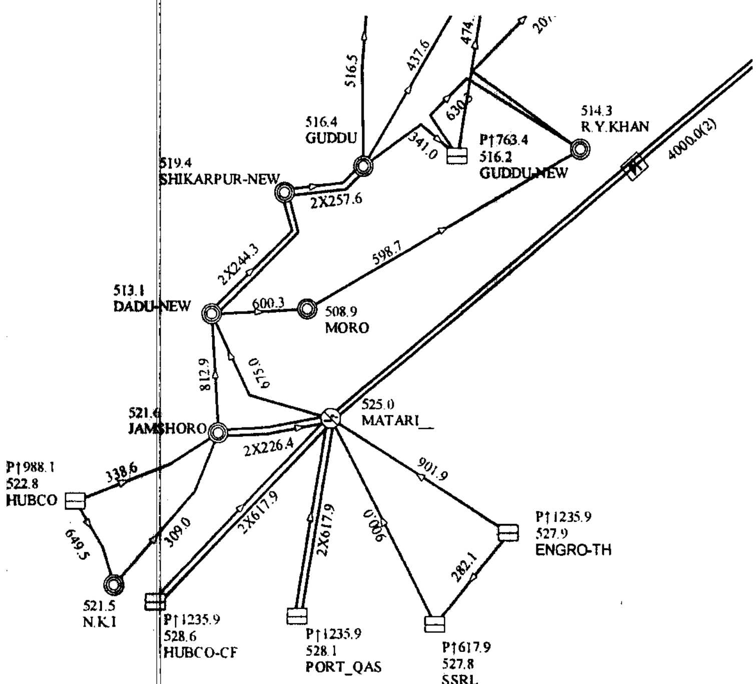

图5.2-2 方案1 MATIARI～MORO500kV线路N-1方式潮流图

Fig. 5.2-2 Scheme 1 MATIARI-MORO 500kV Line N-1 Mode Load Flow Diagram

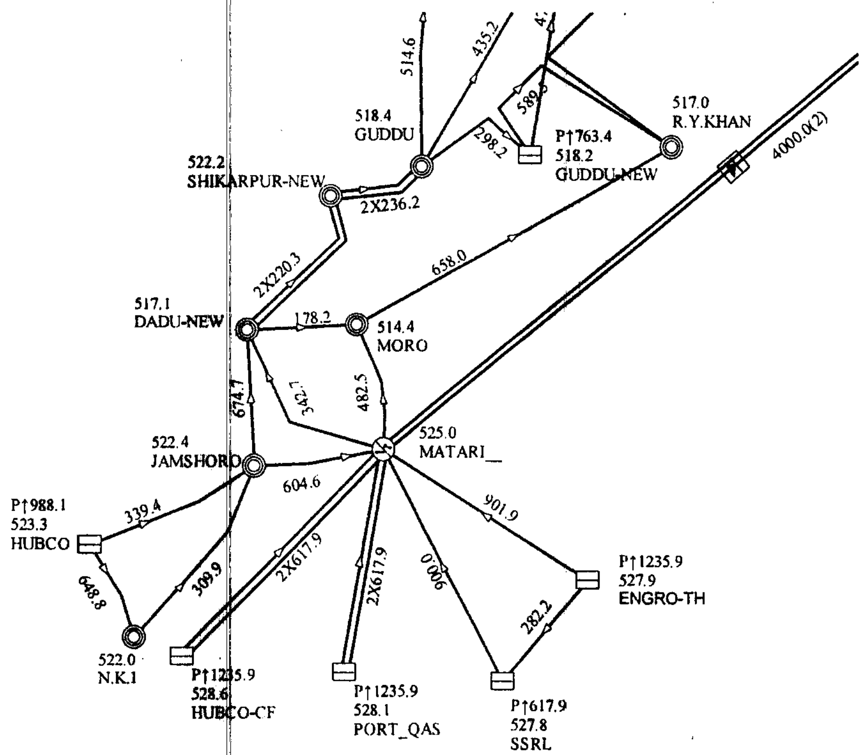

图5.2-3 方案1 MATIARI～JAMSHORO500kV线路N-1方式潮流图

Fig. 5.2-3 Scheme 1 MATIARI-JAMSHORO 500kV Line N-1 Mode Load Flow Diagram

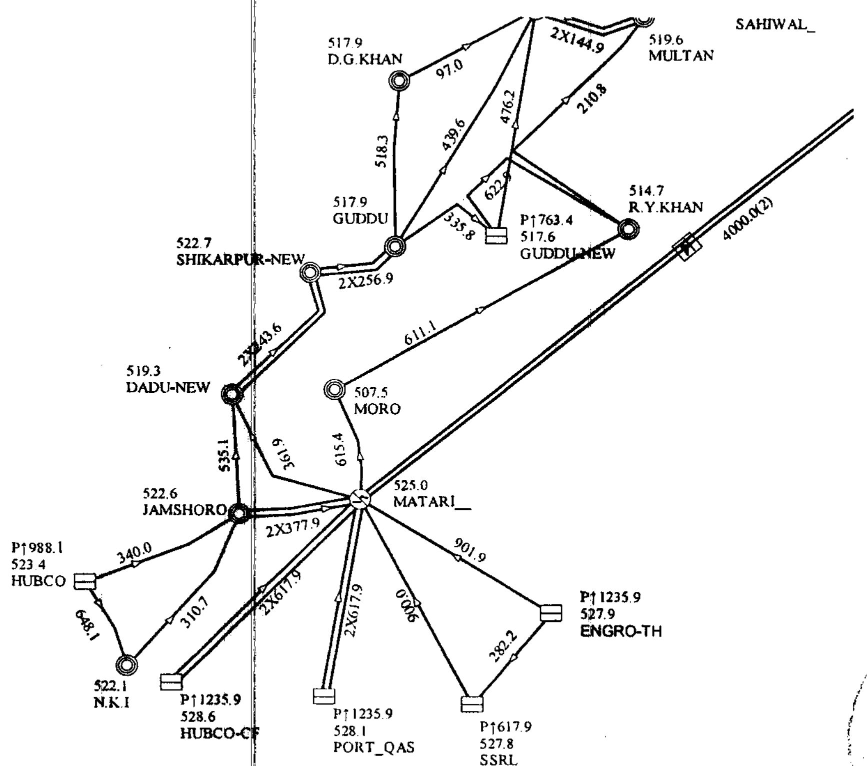

图5.2-4 方案1 MORO～DADU-NEW500kV线路N-1方式潮流图

Fig. 5.2-4 Scheme 1 MORO-DADU-NEW 500kV Line N-1 Mode Load Flow Diagram

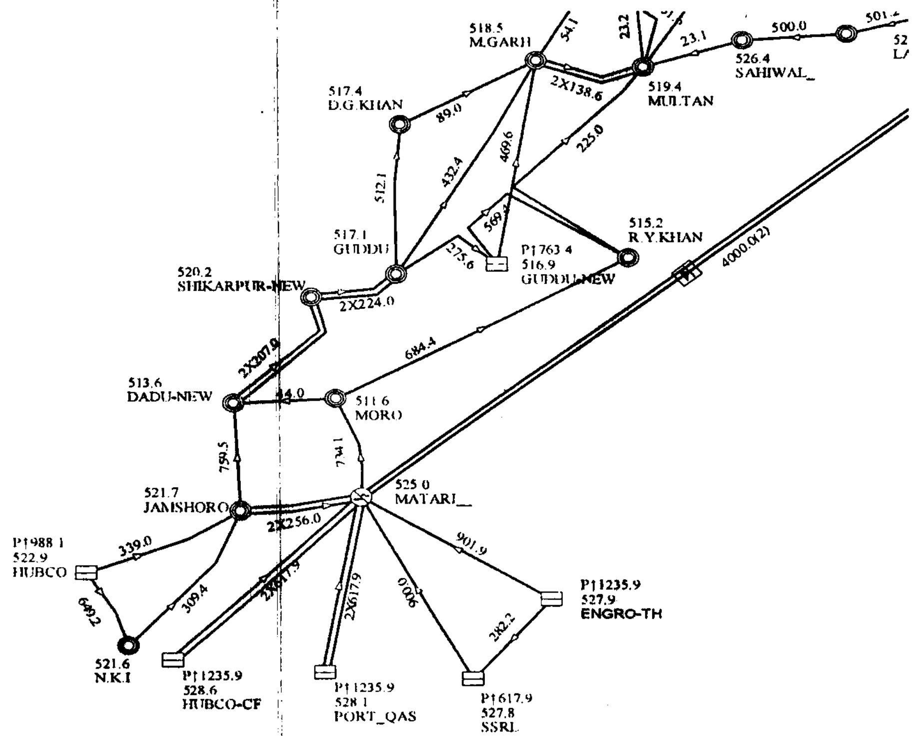

图5.2-5　方案1 MATIARI～DADU-NEW500kV线路N-1方式潮流图

Fig. 5.2-5 Scheme 1 MATIARI～DADU-NEW500kV Line N-1 Mode Load Flow Diagram

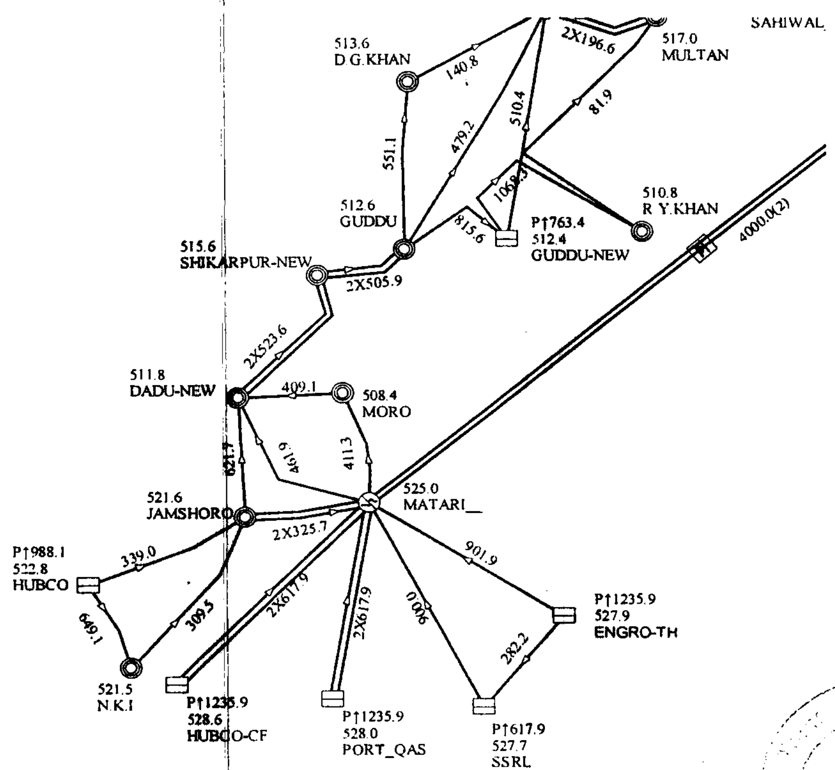

图5.2-6 方案1 MORO～R.Y.KHAN 500kV线路N-1方式潮流图

Fig. 5.2-6 Scheme 1 MORO～R.Y.KHAN 500kV Line N-1 Mode Load Flow Diagram

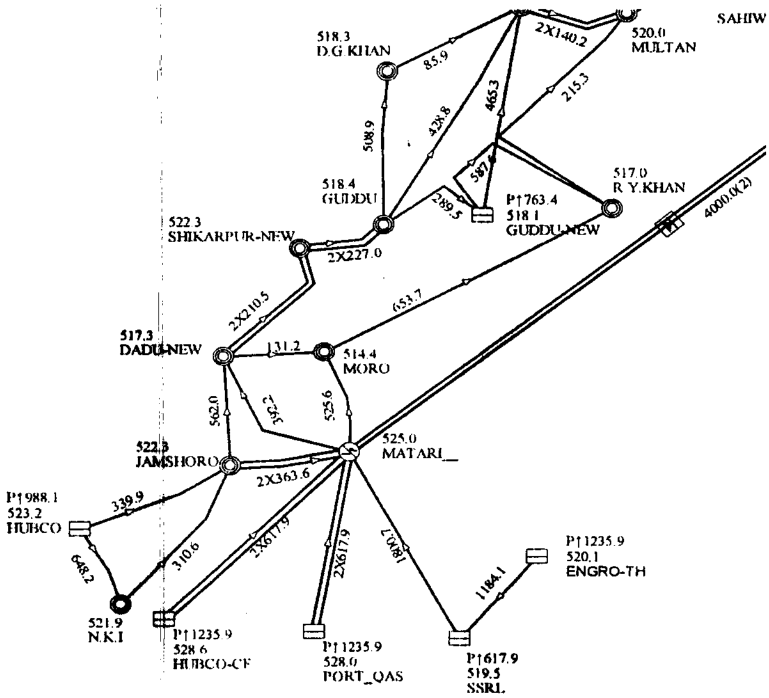

图5.2-7 方案1 MATIARI～THAR COAL PLANT 500kV线路N-1方式潮流图

Fig. 5.2-7 Scheme 1 MATIARI～THAR COAL PLANT 500kV Line N-1 Mode Load Flow Diagram

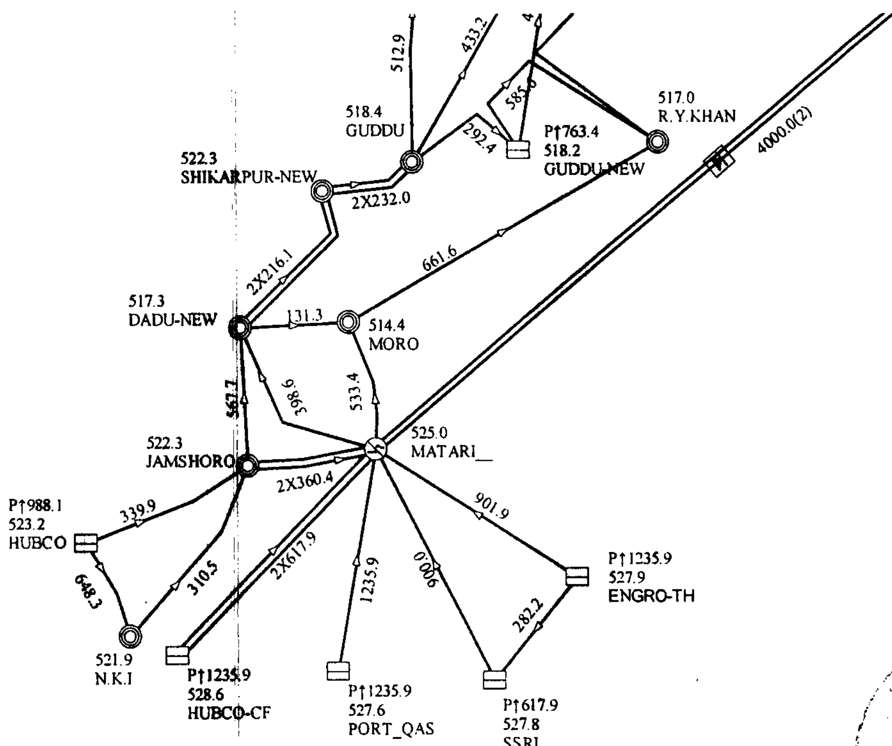

图5.2-8方案1 MATIARI～QASIM COAL PLANT 500kV线路N-1方式潮流图

Fig. 5.2-8 Scheme 1 MATIARI-QASIM COAL PLANT 500kV Line N-1 Mode Load Flow Diagram

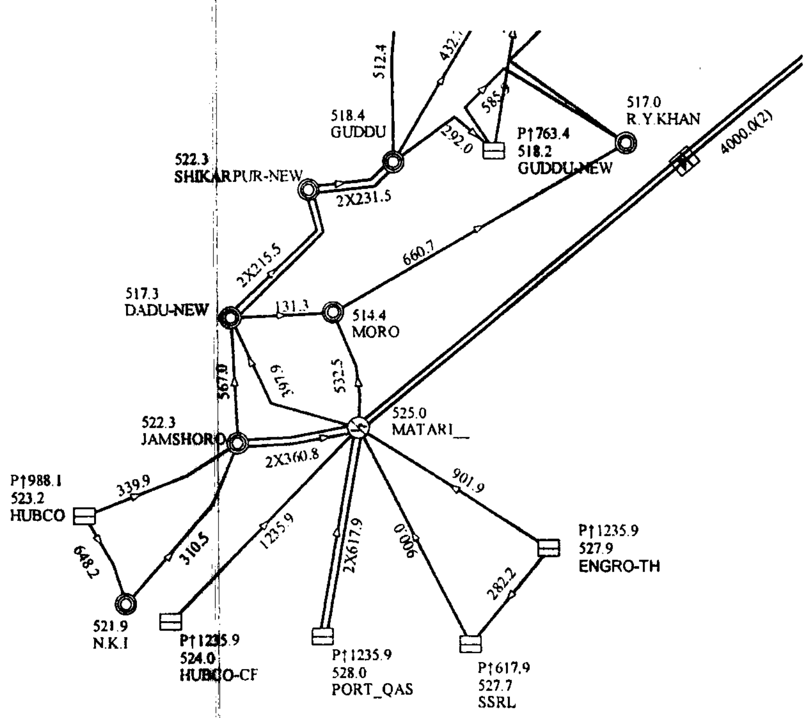

图5.2-9方案1 MATIARI~NEW HUBCO COAL PLANT 500kV线路N-1方式潮流图
Fig. 5.2-9 Scheme 1 MATIARI-NEW HUBCO COAL PLANT 500kV Line N-1 Mode Load Flow Diagram

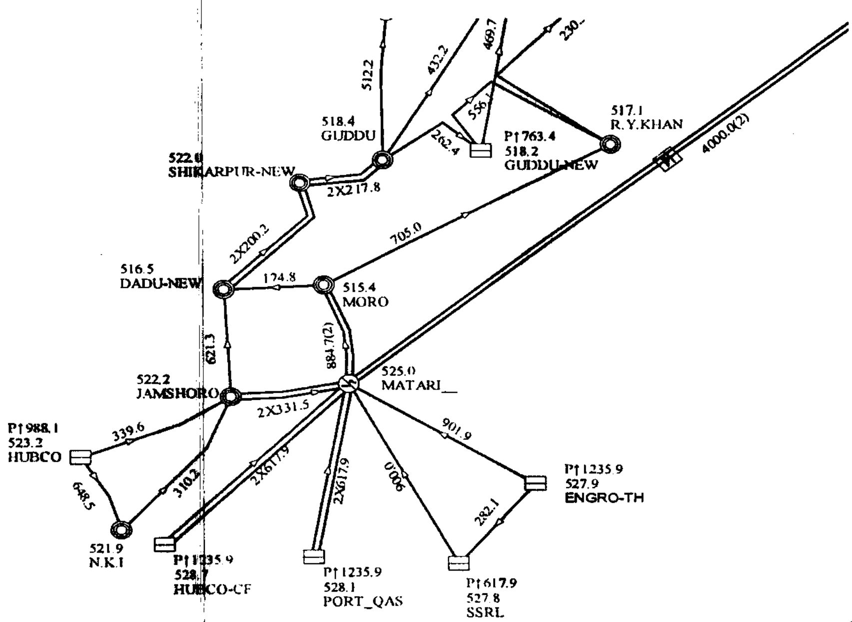

图5.2-10方案2正常方式潮流图
Fig. 5.2-10 Scheme 2 Normal Mode Load Flow Diagram

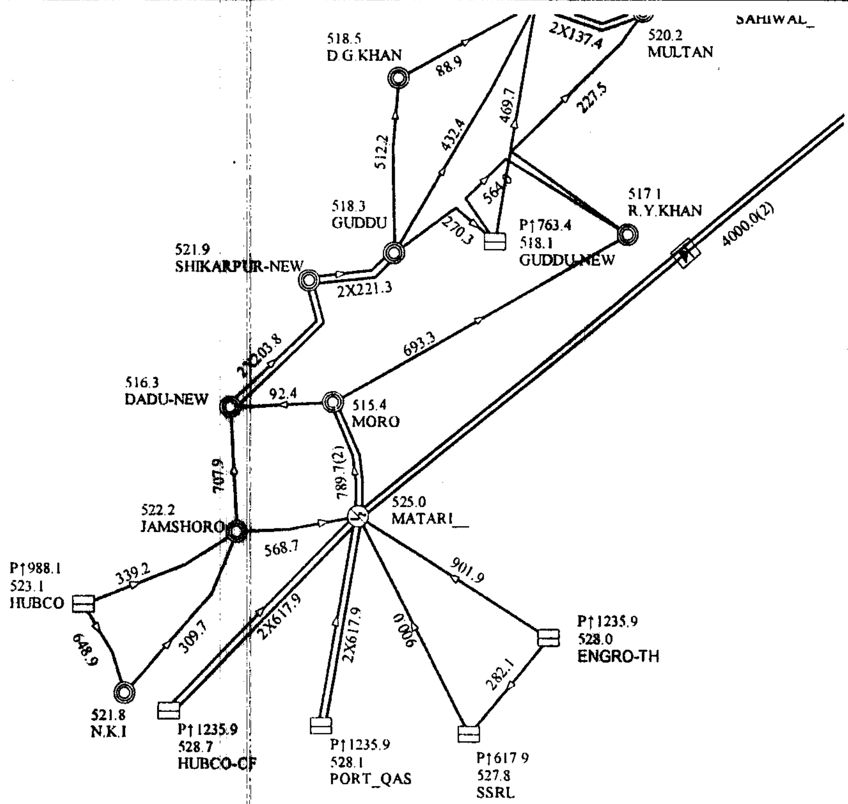

图5.2-11方案2 MATIARI～JAMSHORO 500kV线路N-1方式潮流图

Fig. 5.2-11 Scheme 2 MATIARI-JAMSHORO 500kV Line N-1 Mode Load Flow Diagram

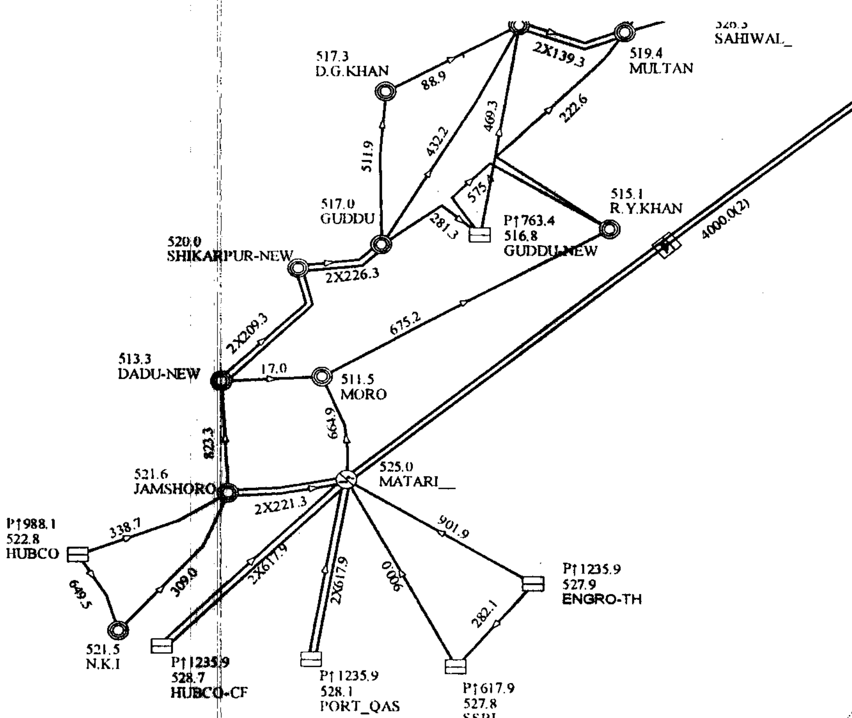

图5.2-12方案2 MATIARI～MORO 500kV线路N-1方式潮流图

Fig. 5.2-12 Scheme 2 MATIARI～MORO 500kV Line N-1 Mode Load Flow Diagram

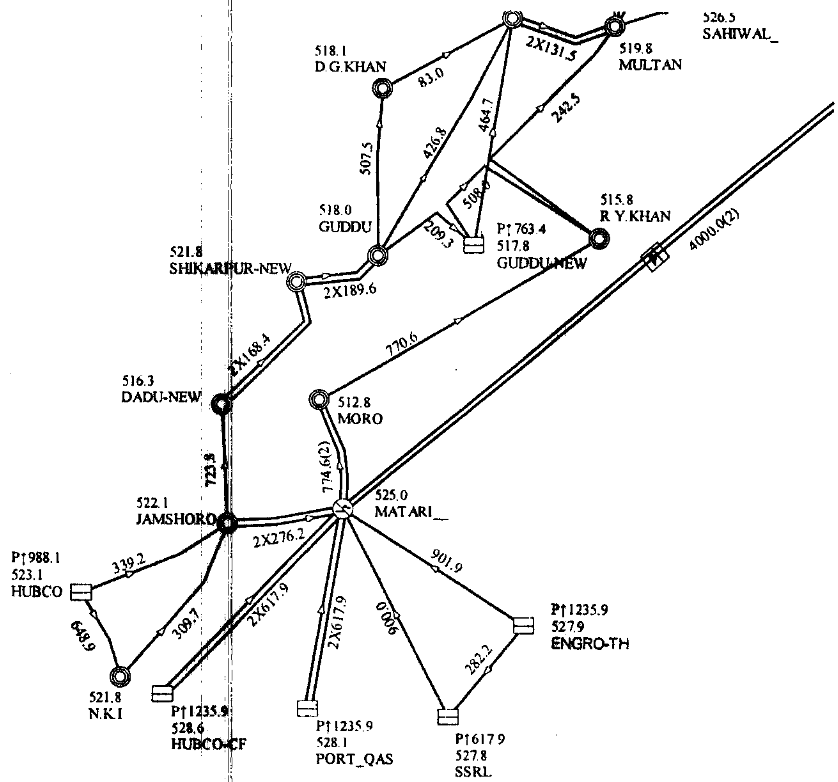

图5.2-13方案2 MORO～DADU-NEW500kV线路N-1方式潮流图
Fig. 5.2-13 Scheme 2 MORO-DADU-NEW 500kV Line N-1 Mode Load Flow Diagram

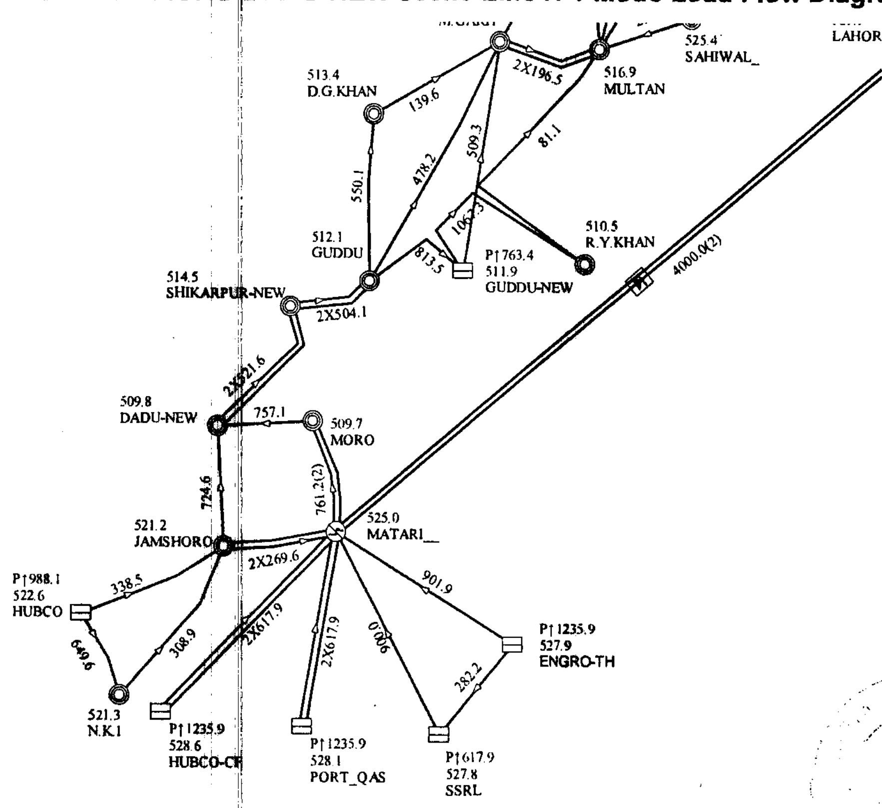

图5.2-14方案2MORO～R.Y.KHAN500kV线路N-1方式潮流图
Fig. 5.2-14 Scheme 2 MORO～R.Y.KHAN 500kV Line N-1 Mode Load Flow Diagram

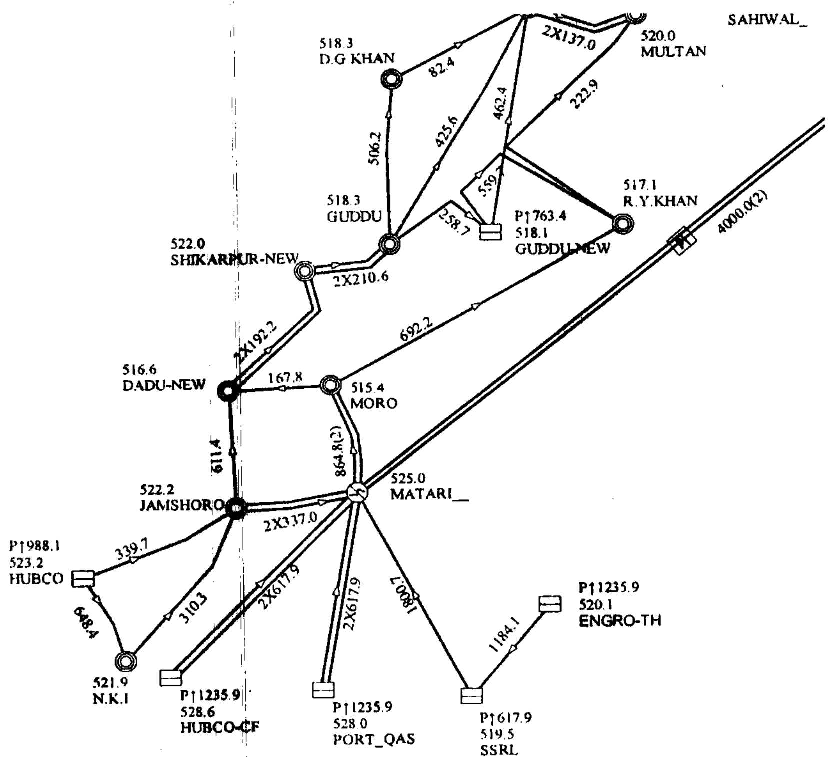

图5.2-15方案2 MATIARI～THAR COAL PLANT 500kV线路N-1方式潮流图
Fig. 5.2-15 Scheme 2 MATIARI-THAR COAL PLANT 500kV Line N-1 Mode Load Flow Diagram

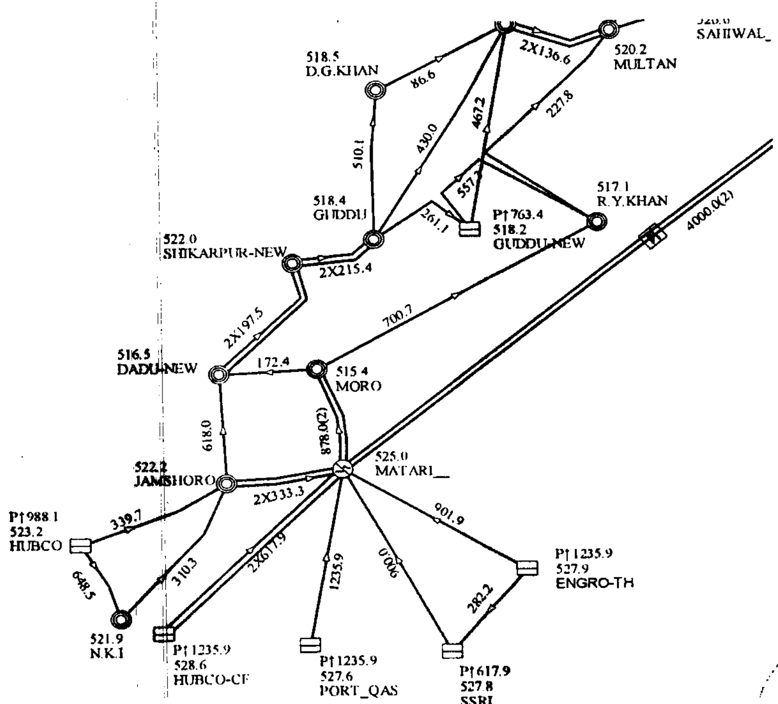

图5.2-16方案2 MATIARI～QASIM COAL PLANT 500kV线路N-1方式潮流图
Fig. 5.2-16 Scheme 2 MATIARI-QASIM COAL PLANT 500kV Line N-1 Mode Load Flow Diagram

表5.3-1 送端换流站接入系统方案投资估算表
Table 5.3-1 Investment Estimation for Sending-end Converter Station AccessSchemes

单位：km、万元
Unit: km, 10,000RMB Yuan

	方案1 Scheme 1 Difference		方案2 Scheme 2 Difference	
	规模 Scale	投资 Investment	规模 Scale	投资 Investment
线路 Line	0	0	142	32660
变电 Power transformation		0		3600
合计差值 Total Difference	0		36260	

综合考虑以上因素，推荐方案1为默蒂亚里～拉合尔直流工程送端接入系统方案，具体为：直流送端换流站π入贾姆沙罗（Jamshoro）～摩洛（Moro）500kV线路，新建线路长度分别约43km、165km；π入贾姆沙罗～新大都（Dadu New）500kV线路，新建线路长度分别约40km、172km。直流配套火电机组以500kV电压等级接入换流站。送端换流站形成10回出线：2回至贾姆沙罗，1回至摩洛，1回至新大都，6回至配套电源（NEW HUBCO 2回，新建线路长度为2×220km；PORT QASIM 2回，新建线路长度为2×180km；ENGRO THAR COAL 1回和SSRL THAR COAL 1回，新建线路长度分别为245km和245km）。

Considering the above factors, we recommend Scheme 1 for Matiari-Lahore DC Transmission Project sending-end to connect to thesystem:DC sending-end converter station connects (π connection)toJamshoro-Moro 500kV line, with new line about 43km and 165km long respectively, and connects(π connection) to Jamshoro-Dadu New 500kV line, with new line about 40km and 172km long respectively. DC supporting thermal power generating units areconnected to the converter station through 500kV lines. The sending-end converter station will have 10-circuit outgoing lines, with 2 to Jamshoro, 1 Moro and 1 Dadu New respectively, and 6 to supporting power supply（NEW HUBCO 2 circuits，New 500kV line2×220km.PORT QASIM 2 circuits，New 500kV line2×180km. ENGRO THAR COAL 1 circuit and SSRL THAR COAL 1 circuit， New 500kV line both 245km）..

6 主要结论

Main Conclusions

6.1 工程建设必要性

Necessity of projectconstruction

默蒂亚里～拉合尔±660kV直流输电工程的建设，将有利于满足旁遮普省和伊斯兰堡地区用电负荷增长需要，保障负荷中心电力供应，促进经济健康发展，有利于促进塔尔煤田坑口煤电及沿海进口煤电的开发，实现能源资源更大范围优化配置。

The construction of Pakistan Matiari-Lahore ±660kV DC Transmission Project will contribute to meeting the increasing demands for electrical loads of the area of Punjab and Islamabad, assuring the power supply for the load center, promoting the healthy development of economy, boosting the development of Thar Coal Field pithead coal power and imported coal power along the coast and realizing the optimal configuration of energy resources in a broader sense.

6.2 送端换流站接入系统方案

Access scheme of sending-end converter station

接入系统方案为：直流送端换流站落点默蒂亚里及周边地区，交流侧电压采用500kV，π入贾姆沙罗～摩洛500kV线路，π入贾姆沙罗～新大都500kV线路，直流配套火电机组以500kV电压等级接入换流站。送端换流站形成10回出线，2回至贾姆沙罗变电站，1回至摩洛变电站，1回至新大都变电站，6回至配套电源。根据电气计算分析，送端电网潮流分布合理，网架结构清晰，本期及远期送端电网暂态稳定和短路电流水平能够满足电网运行的要求。

The access scheme is: locate the DC sending-end converter station in Matiari and its surrounding areas, adopt 500kV voltage at the AC side, and connect (π connection) the converter station toJamshoro-Moro 500kV lines, and the DC supporting thermal power generating unit is connected to the converter station at the voltage of 500kV. The sending-end converter station will have10-circuit outgoing lines, with2to Jamshoro Substation, 1 to Moro Substaion, 1 to Dadu NewSubstaion and 6 to the supporting power supply. According to the electrical calculation analysis, the load flow of sending-end grid is distributed properly, the grid structure is clear, the transient state of current and long-term sending-end grid is stable and the short-circuit current level can meet the operating requirements of the grid.

国家电网公司
STATE GRID
CORPORATION OF CHINA

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巴基斯坦默蒂亚里～拉合尔±660kV 直流输电工程
±660kV HVDC Project from Matiari to Lahore in Pakistan

可行性研究
Feasibility Study

电力系统一次
Power System Primary Part

受端拉合尔换流站接入系统设计
Access System Design of Lahore Converter Station

中国电力技术装备有限公司

CHINA ELECTRIC POWER EQUIPMENT AND TECHNOLOGY CO., LTD.

国网北京经济技术研究院

STATE POWER ECONOMIC RESEARCH INSTITUTE

2016年

2016

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0 任务依据和主要原则

Task Basis and Main Principles

0.1 任务依据

Task basis

（1）中国电力技术装备有限公司关于巴基斯坦默蒂亚里～拉合尔±660kV直流输电工程可行性研究的合同（电力系统一次）。
The Contract on the Feasibility Study of Pakistan Matiari-Lahore ±660kV DC Transmission Project of China Electric Power Equipment & Technology Co., Ltd. (Power System Primary Part);

（2）巴基斯坦电网扩展规划（National Power System Expansion Plan），2011年，加拿大SNC-兰万灵集团公司。
National Power System Expansion Plan (2001), SNC-Lavalin Group Inc.

（3）2014年11月《中华人民共和国政府与巴基斯坦伊斯兰共和国政府关于中巴经济走廊能源项目合作的协议》、2015年4月中方领导人出访巴基斯坦中巴双方签署的51项合作协议。
The *Agreement on the Energy Project Cooperation of the China-Pakistan Economic Corridor between the Governments of the People's Republic of China and Islamic Republic of Pakistan* signed in November, 2014 and the cooperation agreements on 51 projects signed between China and Pakistan during Chinese leaders' visit to Pakistan in April, 2015.

0.2 技术标准

Technical standards

本工程应贯彻、引用的技术标准主要有：
The technical standards to be implemented and referenced for the Project mainly include:

（1）IEC 62001-2004 Guide to the specification and design evaluation of a.c. filters for HVDC systems（HVDC系统用交流滤波器的规范和设计评价指南）

（2）IEC 60909-02001-07 INTERNATIONL STANDARD: Short-circuit in three-phase a.c.system，Part 0 Calculation of currents交流系统三相短路电流计算

（3）电力系统设计规程 SDJ161-85
Code for Design of Power System (SDJ161-85)

（4）电力系统安全稳定导则DL755-2001
Guidelines for Power System Security and Stability(DL755-2001)

.（5）Pakistan Standard： NEPRA Grid Code 2005(《并网准则》巴基斯坦电力监管局)

0.3 设计水平年

Design level year

巴基斯坦默蒂亚里～拉合尔±660kV直流工程计划2018年双极投运。工程可研设计水平年考虑为2018年。
The Pakistan Matiari-Lahore ±660kV DC Transmission Project is planned to be put into double-pole operation in 2018, and the year of 2018 is considered as the design level year for the feasibility study of the Project.

1 电力系统概况

Power System Overview

目前，巴基斯坦输电网最高电压等级为500kV，已形成覆盖全国主要地区的主网架结构，形成南部、北部向伊斯兰堡、旁遮普省负荷中心供电的2～4回500kV输电通道，在负荷中心建成环网。巴基斯坦国家电网按输电区域划分为巴基斯坦国家输电公司（NTDC）及卡拉奇KESC工业园。

At present, the maximum voltage class of Pakistan transmission grid is 500kV. The main grid structure covering major regions throughout the country has been formed, the 2 to 4-circuit 500kV transmission channels for supplying power from southern and northern parts to the load centers in Islamabad and Punjab have been established, and a looped network has been built in the load centers. The State Grid of Pakistan is divided into National Transmission & Despatch Co. Ltd. (NTDC) and Karachi Electric Supply Co. Ltd. (KESC) Industrial Park by transmission areas.

巴基斯坦电网主网架电压等级为500kV、220kV，地方配电公司电压等级为132kV、66kV，其中66kV电压等级正初步向132kV过渡。目前巴基斯坦电网有500kV变电站12座，变电容量15750MVA，220kV变电站29座，变电容量1823.10MVA，500kV线路长度5144km，220kV线路长度8358km。

The voltage classes of the main grid of the Pakistan Power Grid are 500kV and 220kV, and that of local power distribution companies are 132kV and 66kV (66kV is being initially transformed to 132kV). Now, there are twelve 500kV substations (with capacity of 15750MVA) and twenty-nine 220kV substations (with capacity of 1823.10MVA) in the Pakistan Power Grid, with 500kV line and 220kV line being 5144km and 8358km long respectively.

按照地理位置，巴基斯坦地方配电公司包括旁遮普省和伊斯兰堡地区的IESCO、LESCO、GEPCO、FESCO、MEPCO配电公司、信德省和卡拉奇地区的SEPCO、HESCO配电公司及卡拉奇KESC工业园、俾路支省的QESCO、北部地区的PESCO、TESCO配电公司。

Based on the geographical position, the local power distribution companies of Pakistan include IESCO, LESCO, GEPCO, FESCO and MEPCO power distribution companies in Punjab and Islamabad, SEPCO and HESCO power distribution companies in Sindh and Karachi, KESC Industrial Park in Karachi, QESCO in Balochistan, and PESCO and TESCO power distribution companies in the northern part.

2014年巴基斯坦电网最大负荷需求23040MW，实际最大负荷18830MW，装机24110MW，电源利用容量约67%。用电结构中，以居民生活用电比重最大，约45%左右；工业用电比重其次，约29%；农业、商业及其它大用户用电比重分别在11%、8%和7%左右。巴基斯坦用电负荷主要集中在中部旁遮普省和伊斯兰堡地区，约占全国60%左右；信德省及卡拉奇地区约占20%，俾路支省约6%，开伯尔-普赫图赫瓦省及周边北部地区约占14%左右，目前巴基斯坦电网形成了北部水电、南部火电围绕负荷中心向中部供电的局面。

In 2014, the maximum load demand of the National Power System was 23040MW, the actual maximum load was 18830MW, the installed capacity was 24110MW, and the power utilization capacity was about 67%. In the electricity consumption structure, the household consumption by residents takes up the largest proportion, about 45%; the industrial electricity consumption comes second, about 29%; and the consumption by farming, commerce and other large users about 11%, 8% and 7%, respectively. The electrical load in Pakistan is concentrated in Punjab and Islamabad in the middle part, accounting for about 60% of the total of the country; Sindh and Karachi takes up about 20%, Balochistan about 6%, and Khyber Pakhtunkhwa and surrounding northern areas about 14%. At present, the Pakistan Power Grid has formed a power supply pattern with hydropower in the north and thermal power in the south supplying power to the central areas through the load centers.

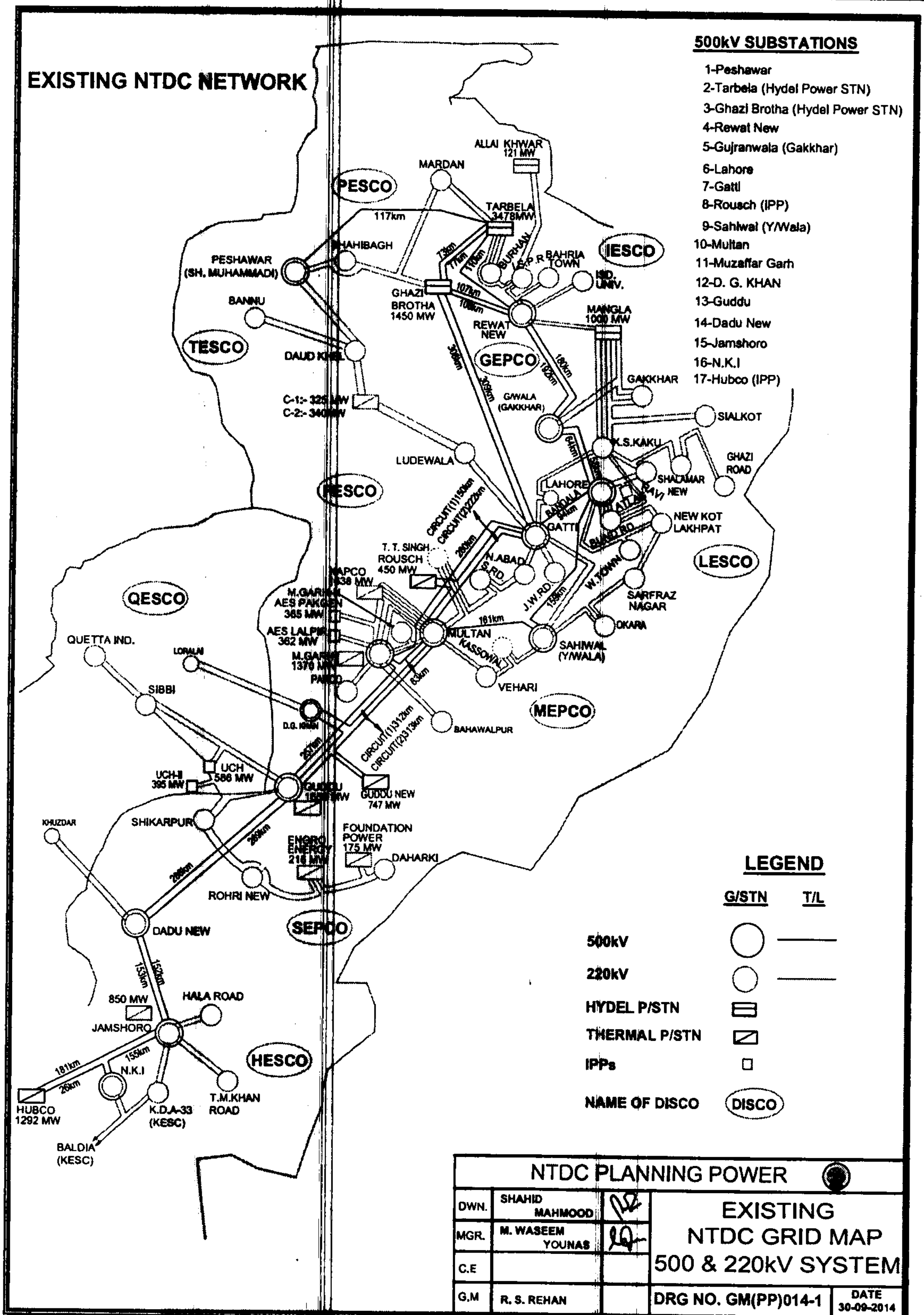

图1-1 2014年巴基斯坦220kV及以上电网地理接线图

Fig. 1-1 Geographical Connection Diagram of Pakistan Power Grid (220kV and Above) in 2014

2 电力系统发展规划

Power System Development Plan

2.1 电力需求预测

Power demand forecast

1971年以来，巴基斯坦用电量整体上呈持续上升趋势，在1998年、2008年出现回落，2010年以来至今用电增速放缓。1972～2012年期间，巴基斯坦全社会用电量年均增长率为6.9%。
The electricity consumption of Pakistan has been rising overall since 1971, but dropped in 1998 and 2008, and from 2010 to now, the increase of electricity consumption slows down. From 1972 to 2012, the average annual growth rate of total electricity consumption of Pakistan was up to 6.9%.

巴基斯坦国家电网按输电区域划分为巴基斯坦国家输电公司（NTDC）及卡拉奇KESC工业园负荷，根据巴方提供最新的负荷预测数据，巴基斯坦电网2017年、2018年、2020年和2023年最大负荷将分别达到26680MW、28020MW、30820MW和38250MW，2015～2020年年均增长率4.9%，2020～2023年年均增长率7.5%。
The State Grid of Pakistan is divided into NTDC and Karachi Electric Supply Co. Ltd. (KESC) Industrial Park loads according to the transmission areas, and in accordance with the latest load forecast data provided by Pakistan, the maximum loads of the National Power System will be respectively up to 26680MW, 28020MW, 30820MW and 38250MW in 2017, 2018, 2020 and 2023, the average annual growth rate will be 4.9% from 2015 to 2020 and the average annual growth rate will be 7.5% from 2020 to 2023.

表2.1-1 巴基斯坦电力需求预测表
Table 2.1-1 Pakistan Power Demand Forecast

单位：10MW
Unit: 10MW

年份 Year	2015	2017	2018	2020	2015～2020年年均增长率 Average annual growth rate from 2015 to 2020	2023	2010～2023年年均增长率 Average annual growth rate from 2010 to 2023
全国 Nationwide	2422	2668	2802	3082	4.9%	3825	7.5%
其中：NTDC Incl.: NTDC	2121	2335	2449	2685	4.8%	3364	7.6%
KESC	301	333	353	397	5.7%	461	6.4%

2.2 电源安排

Power supply arrangement

根据巴基斯坦提供的电源规划有关情况，安排规划电源的投产时序。电源项目2016年、2017年、2018年、2019年、2020年、2021年、2022年投产规模分别达到635 MW、6425.5 MW、5419MW、5419MW、3572MW、5390MW、2730MW。
According to the power generations planning which advised by Pakistan, the planning of the power generations COD time for 2016, 2017, 2018, 2019, 2020, 2021, 2022, is 635 MW, 6425.5 MW, 5419MW, 5419MW, 3572MW, 5390MW and 2730MW respectively.

表2.2-1 巴基斯坦电网规划电源建设安排表

Table 2.2-1 Construction Arrangement for Planned Power Supply Projects of Pakistan Power Grid

单位：MW
Unit: MW

Sr. #	Fiscal Year	Name of Project	Fuel	Location	Installed Capacity (MW)	Expected Comissioning Date
		Existing capacity				
1	2015-16	CHASNUPP-III	Nucl	Chashma, KPK	340	May-16
2		Zonergy-II	Solar	Lal Sohnra (Cholistan), Punjab	100	May-16
3		M/s Hamza Sugar Mills Ltd.	Baggase	Khanpur, Punjab	15	May-16
4		M/s Yunus Energy Ltd.	Wind	Jhimpir, Sindh	50	Jun. 2016
5		M/s Metro Power Co. Ltd.	Wind	Jhimpir, Sindh	50	Jun. 2016
6		M/s Gul Ahmed Energy Limited	Wind	Jhimpir, Sindh	50	Jun. 2016
7		M/s Tapal Wind Energy (Pvt.) Limited	Wind	Jhimpir, Sindh	30	Jun. 2016
8	2016-17	Zonergy-III, IV & V	Solar	Lal Sohnra (Cholistan), Punjab	300	Jul. 2016
9		M/s Tenaga Generasi Limited	Wind	Gharo/Bhambore/Kuttikun, Sindh	49.5	Sep. 2016
10		M/s Master Wind Energy Limited	Wind	Jhimpir, Sindh	49.5	Sep. 2016
11		M/s HydroChina Dawood Power Ltd.	Wind	Gharo, Sindh	49.5	Sep. 2016
12		M/s United Energy Pakistan Limited	Wind	Jhimpir, Sindh	99	Sep. 2016
13		M/s Tenaga Generasi Limited		Gharo, Sindh	49.5	Sep. 2016
14		M/s Layyah Sugar Mills Ltd.	Baggase	Layyah, Punjab	41	Dec. 2016
15		CHASHNUPP-IV	Nucl	Chashma, KPK	340	Dec. 2016
16		Zonergy-VI	Solar	Lal Sohnra (Cholistan), Punjab	100	Dec. 2016
17		Zonergy-VII	Solar	Lal Sohnra (Cholistan), Punjab	100	Jan. 2017
18		Zonergy-VIII & IX	Solar	Lal Sohnra (Cholistan), Punjab	200	Feb. 2017

19		LNG Based Plants (2*GT)	LNG	Bhikki, Punjab	800	Mar. 2017
20		Patrind HPP	Hydel	Kunhar River, KPK/AJK	147	Mar. 2017
21		LNG Based Plants (2*GT)	LNG	Haveli Bahadur Shah (Jhang), Punjab	800	Apr. 2017
22		Gas Based Power Plants	LNG	Existing Plant Sites	1000	Apr. 2017
23		LNG Based Plants (2*GT)	LNG	Baloki, Punjab	800	May. 2017
24		M/s Alliance Sugar Mills Ltd.	Baggase	Ghotki, Sindh	19	Feb. 2017
25		M/s Chanar Sugar Mills Ltd.	Baggase	Tandlianwala, Punjab	22	Jun. 2017
26		M/s Sachal Energy Development (Pvt.) Limited	Wind	Jhimpir, Sindh	49.5	Jun. 2017
27		Tarbela 4th Ext. Project	Hydel	Tarbela, KPK	1410	Jun. 2017
28	2017-18	Neelum Jhelum Hydel	Hydel	Nauseri/Muzaffarabad, AJK	969	Aug. 2017
29		M/s Etihad Power Generation Ltd.	Baggase	Rahim Yar Khan, Punjab	67	Feb. 2017
30		M/s Almoiz Industries Ltd.	Baggase	Mianwali, Punjab	36	Dec. 2017
31		M/s Safina Sugar Mills	Baggase	Lalian, Sagodha	20	Dec. 2017
32		M/s Shahtaj Sugar Mills Ltd.	Baggase	Mandi Bahauddin, Punjab	32	Dec. 2017
33		M/s RYK Energy Ltd.	Baggase	Rahim Yar Khan, Punjab	32	Dec. 2017
34		M/s SSJD Bioenergy	Baggase	Mirpurkhas, Sindh	12	Dec. 2017
35		M/s Lumen Energia Pvt Ltd	Baggase	Jhang, Punjab	12	Dec. 2017
36		Shandong Imported Coal Based Power Project	Coal	Sahiwal, Punjab	1320	Dec. 2017
37		LNG Based Plants (1*ST)	LNG	Bhikki, Punjab	400	Dec. 2017
38		LNG Based Plants (1*ST)	LNG	Baloki, Punjab	400	Dec. 2017
39		LNG Based Plants (1*ST)	LNG	Haveli Bahadur Shah (Jhang), Punjab	400	Dec. 2017

40		M/s Jhampir Wind Power (Pvt.) Limited	Wind	Jhimpir, Sindh	50	Feb. 2018
41		M/s Hawa Energy (Pvt.) Limited	Wind	Jhimpir, Sindh	50	Mar. 2018
42		M/s Hartford Alternative Energy (Pvt.) Limited	Wind	Jhimpir, Sindh	50	Apr. 2018
43		M/s Tricon Boston Consulting Corporation (Pvt.) Limited (A)	Wind	Jhimpir, Sindh	50	Apr. 2018
44		M/s Tricon Boston Consulting Corporation (Pvt.) Limited (B)	Wind	Jhimpir, Sindh	50	May. 2018
45		M/s Tricon Boston Consulting Corporation (Pvt.) Limited (C)	Wind	Jhimpir, Sindh	50	May. 2018
46		M/s Three Gorges Second Wind Fram Pakistan Ltd (Wind Eagle Limited)	Wind	Jhimpir, Sindh	49.5	Jun. 2018
47		M/s Three Gorges Second Wind Fram Pakistan Ltd (Wind Eagle Limited)	Wind	Jhimpir, Sindh	49.5	Jun. 2018
48		Port Qasim Power Project	Coal	Port Qasim Karachi, Sindh	1320	Jun. 2018
49	2018-19	Golen Gol HPP	Hydel	Chitral, KPK	106	Jul. 2018
50		Engro Powergen Project	Coal	Thar, Sindh	660	Oct. 2018
51		Gulpur Poonch river	Hydel	Poonch River/Gulpur, AJK	102	Oct. 2018
52		M/s Zephyr Power Pvt. Ltd.	Wind	Gharo, Sindh	50	Nov. 2018
53		Coal Plant at Salt Range	Coal	Salt Range, Punjab	300	Jan. 2019
54		Shanghai Electric Power Project	Coal	Thar, Sindh	1320	Jan. 2019
55		Grange Holding	Coal	Arifwala, Punjab	163	Jan. 2019
56		HUB Power Company Ltd.	Coal	HUB, Baluchistan	1320	Jan. 2019
57		Lucky Electric	Coal	Port Qasim, Sindh	660	Mar. 2019

		Power Company Ltd.				
58		Siddiqsons Limited	Coal	Port Qasim, Sindh	350	Mar. 2019
59	2019-20	TPS Jamshoro (Phase-1)	Coal	Jamshoro, Sindh	660	Jun. 2019
60		CASA	Import	Cross Border Interconnection	1000	Jul. 2019
61		Coal Plant at Muzaffargarh	Coal	Muzaffargarh, Punjab	600	Sep. 2019
62		TPS Jamshoro (Phase-2)	Coal	Jamshoro, Sindh	660	Dec. 2019
63		Keyal Khwar	Hydel	Dasu District, KPK	128	Jan. 2020
64		Other Wind Power Plants	Wind	Sindh	524	Feb. 2020
65	2020-21	Karachi Coastal Power Plant (unit-1)	Nucl	Karachi	1100	Nov. 2020
66		Dasu HPP (Phase-1)	Hydel	7km upstream of Dasu Village on Indus River, KPK	2160	Feb. 2021
67		Karot HPP	Hydel	Jehlum River, Distt. Rawalpindi, Punjab	720	Jun. 2021
68		Tarbela 5th Ext. Project	Hydel	Tarbela, KPK	1410	Jun. 2021
69	2021-22	Suki Kinari HPP	Hydel	Kunhar River/Mansehra, KPK	870	Jul. 2021
70		Karachi Coastal Power Plant (unit-2)	Nucl	Karachi	1100	Oct. 2021
71		Kotli	Hydel	Poonch River/Kotii, AJK	100	Jun. 2022
72		Coal Plant at Lakhra	Coal	Lakhra, Sindh	660	Jun. 2022

3 工程概况

Project overview

3.1 默蒂亚里～拉合尔直流工程概况

Overview of Matiari-Lahore DC Transmission Project

为促进信德省塔尔煤田及沿海煤电的开发外送，满足旁遮普省及伊斯兰堡地区用电负荷增长的需求，规划建设默蒂亚里～拉合尔±660kV直流输电工程。工程起点巴基斯坦南部信德省默蒂亚里，途径信德、旁遮普2省，落点中部旁遮普省拉合尔地区，直流线路长度约891km，输电容量4000MW，规划2018年底投产。

To promote the development and transmission of Thar Coal Field in Sindh and the coastal coal power and meet the requirements for the increase of electrical loads in Punjab and Islamabad, the Matiari-Lahore ±660kV DC Transmission Project shall be planned and constructed. The Project starts from Matiari, Sindh (in the south of Pakistan) to Lahore, Punjab (in the central area) via Sindh and Punjab, and the DC line is about 891km long, the power transmission capacity is 4000MW and it is to be put into operation at the end of 2018.

3.2 受端市场空间分析

Analysis on receiving-end market space

（1）计算水平年：2017～2020年及2022年；
Calculation level year: 2017-2020 and 2022;

（2）旁遮普省和伊斯兰堡电网备用容量按最大负荷的10%或660MW考虑；旁遮普省和伊斯兰堡地区包括IESCO、LESCO、GEPCO、FESCO、MEPCO 5家配电公司，最大负荷同时率按0.85或0.8考虑。
The spare capacity of Punjab and Islamabad grid shall be considered at 10% of the maximum load or 660MW; 5 power distribution companies, i.e. IESCO, LESCO, GEPCO, FESCO and MEPCO, exist in the area of Punjab and Islamabad and the maximum load coincidence factor will be determined at 0.85 or 0.8.

（3）电源装机考虑已投及在建火电、水电项目，考虑巴基斯坦规划火电、水电项目，风电、光伏、生物质发电不参与平衡。
For the installed capacity of power supply, the thermal power and hydropower projects which has been put into operation and under construction will be taken into account and the thermal power and hydropower projects of energy planning of the Pakistan will be considered, and wind power, photovoltaic power generation and biomass power generation will not be involved in balance.

（4）参与平衡的电源容量：参照中巴经济走廊能源规划报告，现有电源利用容量按巴方提供的2013年实际情况考虑（约67%）。
Power supply capacity involved in balance: pursuant to the report on energy planning of the China–Pakistan Economic Corridor, the existing power supply utilization capacity will be considered as per the actual situation of 2013 provided by Pakistan (about 67%).

（5）送受电情况：计算电力市场空间时，暂不考虑与国外电网的送受电。
Status of power sending and receiving: the power market space is calculated, without sending to, and receiving from, the foreign grids,

旁遮普省和伊斯兰堡地区为巴基斯坦最大的负荷中心，负荷约占全国的60%，2017～2023年，旁遮普省和伊斯兰堡地区负荷发展较快，考虑现有、在建及规划电源项目后，电力平衡表明，2017年、2018年、2020年及2023年旁遮普省及伊斯兰堡地区逐年电力缺额最大分别达到4746 MW、3166MW、4043 MW和11045 MW。旁遮普省和伊斯兰堡电网具备消纳默蒂亚里～拉合尔±660kV直流工程的市场空间，工程的建设有利于缓解旁遮普省和伊斯兰堡地区电力短缺的局面。

The area of Punjab and Islamabad is the largest load center throughout Pakistan and its loads account for about 60% of the country, and from 2017 to 2023, the area will develop faster, so after the power supply projects are carried out preferentially for the existing projects, projects under construction and the Pakistan planning generations, the electric power balance shows that the maximum power deficits of the area of Punjab and Islamabad are separately up to 4746 MW, 3166 MW, 4043MW and 11045MW in 2017, 2018, 2020 and 2023. The grid of Punjab and Islamabad is provided with the market space to absorb the Matiari-Lahore ±660kV DC Transmission Project, and the construction of the Project contributes to alleviate the situation of power deficit in the area of Punjab and Islamabad.

表3.2-1 旁遮普省和伊斯兰堡地区市场空间表

Table 3.2-1 Market Space in Punjab and Islamabad Region

单位：MW

Unit: MW

	2017	2018	2019	2020	2023
1-1.Peak load (Coincidence Factor 85%)	16014	16864	17731	18641	28642
1-2.Peak load (Coincidence Factor 80%)	15072	15872	16688	17544	26957
2-1.system backup (Peak load 10%)	1601	1686	1773	1864	2864
2-2.system backup (660MW)	660	660	660	660	660
3.Installed capacity	14301	19521	19521	21111	25376
（1）Existing Thermal Power Plant	7550	7550	7550	7550	7550
（2）Existing hydropower Plant	1790	1790	1790	1790	1790
（3）Existing nuclear Power Plant	650	650	650	650	650
（4）Constructing and Planning Power Plant	3201	8421	11061	12651	14276
Gas Based Power Plants(Existing Plant Sites)燃气电厂	1000	1000	1000	1000	1000
Bhikki、Balloki& H.B. Shah 燃气电厂	2400	3600	3600	3600	3600
Neelum Jhelum 水电	969	969	969	969	969
Tarbela 4th extension 水电	1410	1410	1410	1410	1410
patrind 水电	147	147	147	147	147
Suki Kinari Hydropower Station 苏克[illegible]瑞水电站	0	0	0	0	870
Karot Hydropower Station 卡洛特水电站	0	0	0	0	720
Golen Gol HPP(Chitral, KPK)水电		106	106	106	106
Gulpur Poonch river(Poonch River/Gulpur, AJK)水电		102	102	102	102
Keyal Khwar(Dasu District, KPK)水电				128	128

Dasu HPP (Phase-1)(7km upstream of Dasu Village on Indus River, KPK)水电						2160
Tarbela 5th Ext. Project(Tarbela, KPK)水电						1410
Kotli(Poonch River/Kotli, AJK)水电						100
Sahiwal 2×660MW Coal-fired Power Plant 萨希瓦尔燃煤电厂		0	1320	1320	1320	1320
岩盐矿带坑口电站（Salt Range Mine Mouth）		0	0	300	300	300
Muzaffargarh coal Power Project 穆扎法格燃煤电站		0	0	600	600	600
Grange Holding(Arifwala, Punjab)火电				163	163	163
4. Power Marker Space scope						
Coincidence Factor 85%	system backup 10% hydropower work capacity 80%	4746	3166	3140	4043	11045
	system backup 10% hydropower work capacity 95%	4587	2977	2951	3836	10087
	system backup 660MW hydropower work capacity 80%	3805	2140	2027	2839	8841
	system backup 660MW hydropower work capacity 95%	3242	1469	1326	2116	7221
Coincidence Factor 80%	system backup 10% hydropower work capacity 80%	3710	2075	1993	2837	9191
	system backup 10% hydropower work capacity 95%	3148	1404	1292	2114	7572
	system backup 660MW hydropower work capacity 80%	2863	1148	984	1743	7156
	system backup 660MW hydropower work capacity 95%	2300	477	283	1020	5536

3.3 工程建设必要性

Necessity of project construction

1） 满足巴基斯坦负荷中心电力负荷发展需要。
To satisfy the need of developing power load of Pakistan's load centers.

旁遮普省和伊斯兰堡地区为巴基斯坦最大的负荷中心，负荷约占全国的60%，根据电力平衡分析，2017年、2018年、2020年及2023年旁遮普省及伊斯兰堡地区逐年电力缺额最大分别达到4746 MW、3166MW、4043 MW和11045 MW。本工程的建设可将巴基斯坦南部的大规模电力送至巴基斯坦负荷中心，满足巴基斯坦特别是旁遮普省及伊斯兰堡地区电力负荷供电需要，为经济的持续快速发展提供保障。

As the two largest load centers in Pakistan, Punjab and Islamabad take up 60% of the total load nationwide, while the analysis on balance of electric power shows that a power shortage of 4746 MW, 3166 MW, 4043MW and 11045MW will appear in Punjab and Islamabad in 2017, 2018, 2020 and 2023 respectively. This project can deliver the large amounts of electricity in the southern region to Pakistan's load centers, satisfy the power supply needs of Pakistan, particularly Punjab and Islamabad regions and safeguard the sustained and rapid economic development.

2） 满足巴基斯坦南部电力外送需要。
To satisfy the need of outward delivery of electricity in southern Pakistan.

电力供应不足问题已严重制约了巴基斯坦经济的持续快速发展。巴基斯坦电源构成长期保持以油电、气电为主导地位的格局，发电成本高、出力不足、能源对外依存度高，严重影响电厂的发电效率，进一步加剧了网内缺电形势，电源结构亟待优化调整。为缓解巴基斯坦电力供应不足的问题，巴基斯坦将在南部塔尔煤田建设大型煤电电源，并在南部港口建设进口燃煤电站。由于项目距离负荷中心较远，本工程的建设可以满足巴基斯坦南部电力远距离送出的需要。

Pakistan's economy has long been restricted from sustainable and rapid development by its inadequate power supply problem. Since oil power and gas power, which cost much, generate less but rely heavily on external resources, have dominated the power market in Pakistan for a long time, seriously affected the power generation efficiency of the plant, and further exacerbated domestic power shortage, hence the power structure needs to be adjusted and optimized urgently. Pakistan will build a large coal power supply in the southern Thar Coal Field and a power plant using imported coal in the southern port to ease its shortage of power. In view of the fact that these projects are located far from the load center, this Project can meet Pakistan's needs on long-distance delivery of power in its southern region.

3） 满足巴基斯坦全国能源资源优化配置的需要
To satisfy the need of optimization and allocation of Pakistan's nationwide energy resources

满足国民经济和社会发展的电力供应需求是本阶段巴基斯坦电力工业发展的第一要务。能源资源与负荷分布不均衡的特点，决定了巴基斯坦电力供应问题的解决需依托电网、交通等平台实现最大范围内的能源资源优化配置，建立多元化能源供应渠道，提高用电安全可靠性。因此，本工程建设是实现巴基斯坦能源资源优化配置、满足缺能地区电力供应的需要。

It is the top priority for the development of power industry in Pakistan at this stage to satisfy the needs of national economy and social development on power supply. While the uneven distribution of energy resources and load determines that the solution to Pakistan's power supply problem should rely up the power grid, transportation and other platforms to achieve energy resources optimization and allocation to the largest extent, to establish diversified energy supply channels, and to improve energy security and reliability. Hence this Project is necessary for Pakistan to achieve energy resources optimization and allocation and to satisfy the needs of energy-deficient areas on power supply.

4 受端换流站接入系统方案研究

Study on Access Schemes of Receiving-end Converter Station

4.1 受端换流站选址及接入原则

Site selection and access principles of receiving-end converter station

本工程受端换流站接入原则主要考虑满足直流受端的安全可靠运行，有利于形成坚强受端电网，兼顾地区电网规划，具体原则如下：

The safe and reliable operation of DC receiving end, the formation of robust receiving-end power grid and coordination with regional power grid planning are mainly considered in the access of the receiving-end converter station of the Project, and the specific principles are as follows:

（1）便于换流站接入受端500kV电网；

To facilitate converter station to access to receiving-end 500kV power grid;

（2）尽量避免线路交叉；

To avoid line crossing to the largest extent;

（3）适当控制直流线路长度。

To control the length of DC line appropriately.

4.2 受端换流站选站范围及选站情况

Scope and circumstances of site selection of receiving-end converter station

根据电力市场空间分析，2017年～2020年旁遮普省和伊斯兰堡地区缺电最大情况约7537MW、3557MW、4511MW、4425MW，因此，巴基斯坦南电北送直流工程考虑落点旁遮普省和伊斯兰堡地区。根据巴方规划，伊斯兰堡负荷主要由北部水电满足，巴基斯坦第一回南电北送直流输电工程考虑落点旁遮普省主要负荷中心拉合尔地区。同时，为便于换流站接入当地500kV电网，同时尽量缩短直流线路长度，考虑拉合尔南部地区作为本工程受端换流站选址范围。

According to the analysis of electricity market space, the maximum shortage of power in Punjab and Islamabad will reach about 7537MW, 3557MW, 4511MW, 4425MW during 2017-2020, hence Pakistan intends to locate its South-to-North DC Power Transmission Project in Punjab and Islamabad. According to Pakistan's plan, the load in Islamabad will be satisfied by hydropower generated in the northern area, while the first circuit of South-to-North DC Power Transmission Project will be located in Lahore region, a major load center in Punjab. In the meantime, it is considered that the southern region of Lahore will be the location of the receiving-end converter station in order to facilitate the access of the converter station to local 500kV power grid while reducing the length of DC line as much as possible.

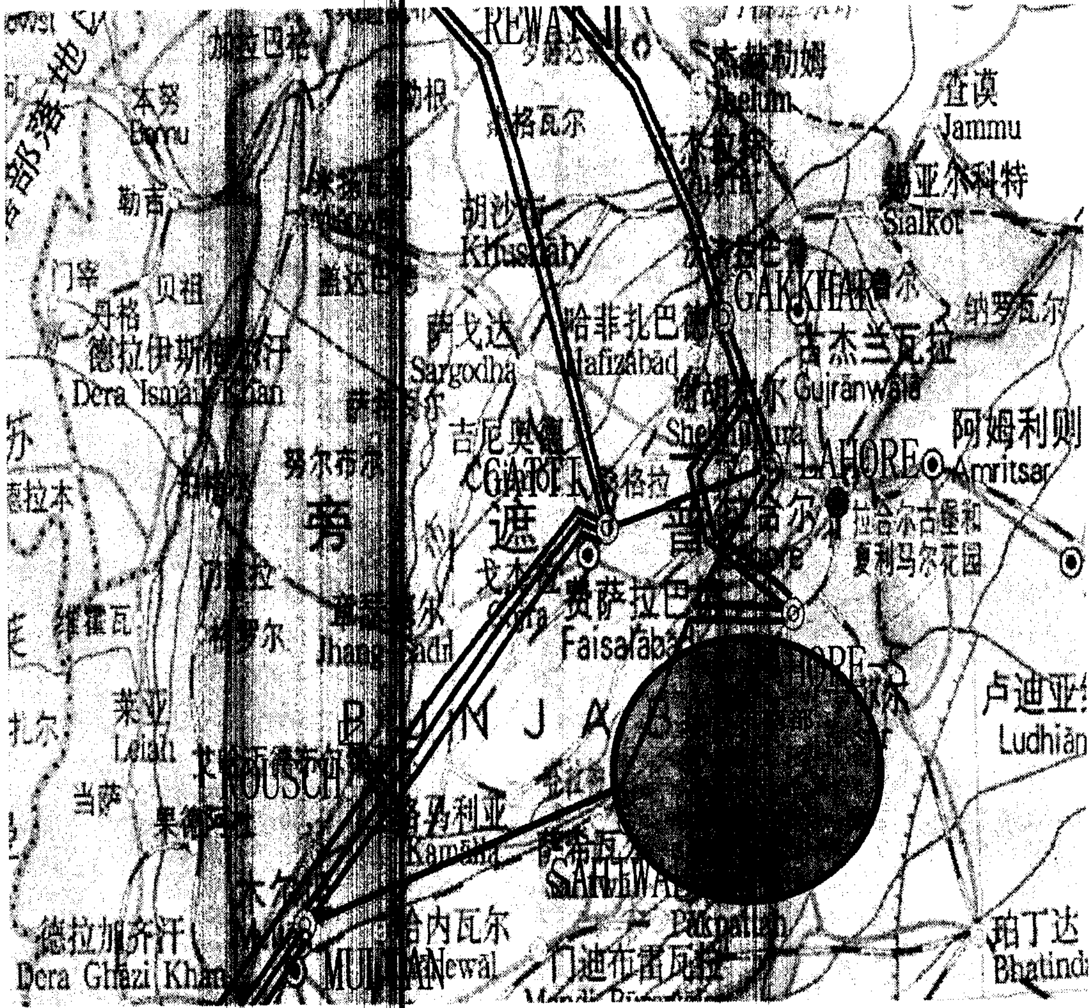

图4.2-1 受端换流站选址范围示意图
Fig.4.2-1 Scope of Site Selection of Receiving-end Converter Station

根据受端拉合尔换流站选站情况，送端换流站选择萨卡塔巴德（Shakatabad）站址。站址的中心坐标为：东经73° 50' 18"，北纬31°15' 13"，位于Bhai Pheru-Mor Khunda公路西侧。站址地势开阔，地形平坦，地表植被较为茂盛，大部分种植小麦，站址范围内有5户左右居民房屋需拆迁。进站道路可从Bhai Pheru-Kot Radha Kishan公路引接，该公路为沥青路面，路况良好，路面宽度可以满足工程建设及大件运输要求。换流站水源初步考虑采用地下水。

According to the site selection of Lahore receiving-end converter station, the sending-end converter station is located in Shakatabad on the west side of Bhai Pheru-Mor Khunda road, with center coordinates: 73°50'18" E, 31° 15' 13" N. This place is open and flat, with lush ground vegetation, and mostly planted with wheat. About 5 residential houses need be demolished. The inbound road may be connected to Bhai Pheru-Kot Radha Kishan road, an asphalt road with good road conditions, and a width wide enough to meet the requirements of construction and large transport. Groundwater is considered to be the water source of the converter station preliminarily.

4.3 换流站接入系统方案

Access schemes of converter station

考虑旁遮普省拉合尔南部地区作为直流工程受端落点，并结合直流的工程定位和消纳方向，提出以下受端换流站接入系统方案：

The following access schemes of the receiving-end converter station are proposed by taking into account the location of the receiving end of DC Transmission Project in the southern region of Punjab Lahore as well as the DC project location and load flow direction:

方案1：直流受端换流站交流侧电压采用500kV，分别π入拉合尔（Lahore）～拉合尔南（Lahore South）双回500kV线路；建设拉合尔北（Lahore North）500kV变电站，建设受端换流站～拉合尔北～古杰兰瓦拉（Gakkhar）双回500kV线路。受端换流站形成6回出线，2回至拉合尔，2回至拉合尔南，2回至拉合尔北。受端换流站接入系统方案1见图4.3-1中虚线所示。

Scheme 1: Adopt 500kV voltage at the AC side of DC receiving-end converter station and connect (π connection) the converter station to the Lahore-Lahore South double-circuit 500kV lines; build the Lahore North 500kV substation, and the receiving-end converter station-Lahore North-Gakkhar double-circuit 500kV lines. The receiving-end converter station will have 6-circuit outgoing lines, with 2 to Lahore, 2 to Lahore South and 2 to Lahore North. See the dotted line in Fig.4.3-1 for Access Scheme 1 of receiving-end converter station.

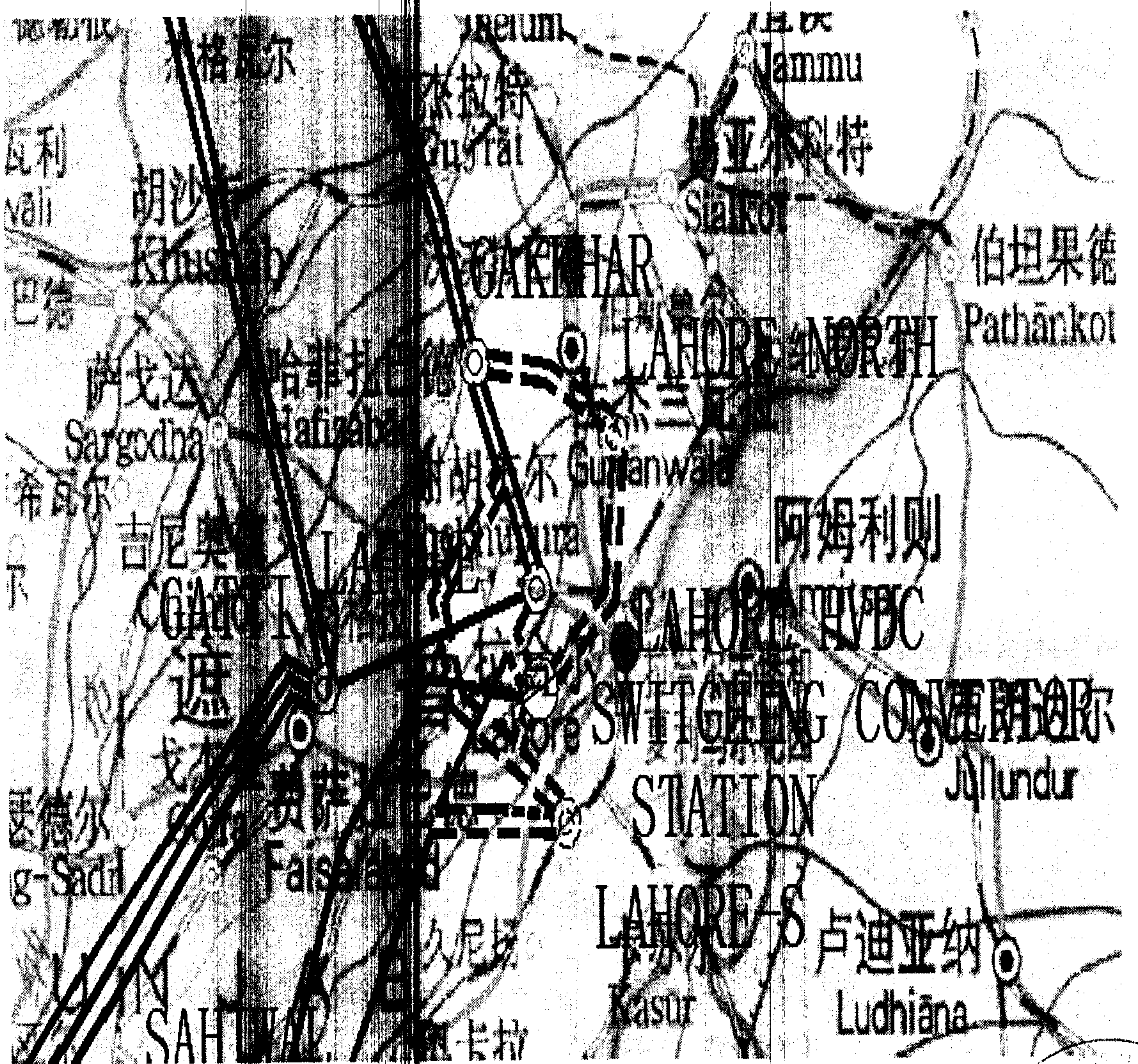

图4.3-1 受端换流站接入系统方案1
Fig.4.3-1 Access Scheme 1 of Receiving-end Converter Station

方案2：直流受端换流站交流侧电压采用500kV，出线2回至拉合尔（Lahore）500kV变电站；出线2回至拉合尔南（Lahore South）500kV变电站；建设拉合尔北（Lahore North）500kV变电站，建设受端换流站～拉合尔北～古杰兰瓦拉（Gakkhar）双回500kV线路。受端换流站形成6回出线，2回至拉合尔，2回至拉合尔南，2回至拉合尔北。受端换流站接入系统方案2见图4.3-2中虚线所示。

Scheme 2: Adopt 500kV voltage at the AC side of DC receiving-end converter station, with 2-circuit outgoing lines to Lahore 500kV substation, and 2-circuit outgoing lines to Lahore South 500kV substation; build the Lahore North 500kV substation, and the receiving-end converter station-Lahore North-Gakkhar double-circuit 500kV lines. The receiving-end converter station will have 6-circuit outgoing lines, with 2 to Lahore, 2 to Lahore South and 2 to Lahore North. See the dotted line in Fig.4.3-2 for Access Scheme 2 of receiving-end converter station.

图4.3-2　受端换流站接入系统方案2

Fig.4.3-2 Access Scheme 2 of Receiving-end Converter Station

5 电气计算

Electrical calculation

5.1 计算条件

Calculation conditions

采用BPA潮流与稳定计算程序，对受端换流站接入系统方案进行电气计算分析，本工程2018年投产，计算水平年选取2018年。电气计算条件如下：
BPA load flow and stability calculation program is adopted to implement electrical calculation and analysis on receiving-end converter station access scheme. The project goes into operation at 2018. 2018 is chosen to be the level year for calculation. Electrical calculation conditions are listed below:

（1）计算负荷和装机
Calculation of load and installed capacity

在电气计算中，以巴基斯坦电网规划负荷和装机方案为基础，扣除部分接入220kV及以下电网的小机组和相应的负荷作为计算负荷和装机。
In electrical calculation, load and installed capacity will be calculated with the planned load and installed capacity of Pakistani power grid as the basis, subtracting small units and related loads connecting to power grids of 220kV or lower voltage.

（2）校核网架
Grid check

本期，采用巴基斯坦电网2018年规划网架，巴基斯坦电网建成南电北送第三回500kV交流通道，建成默蒂亚里～拉合尔±660kV直流，输电容量4000MW。
In this phase, 2018 Structure Plan of Pakistan Power Grid is adopted, and 3rd-circuit 500kV AC channel to transmit electricity from south to north is constructed in Pakistan power grid. Matiari-Lahore ±660kV DC is to be constructed, leading to transmission capacity of 4000MW.

5.2 潮流计算

Load flow calculation

计算采用巴基斯坦电网2018年夏大方式，默蒂亚里～拉合尔±660kV直流工程送电4000MW。潮流计算表明，方案1默蒂亚里～拉合尔直流电力主要通过换流站～拉合尔南、换流站～拉合尔、换流站～拉合尔北3个通道送出，3个通道潮流分别为1520MW、1800MW、532MW。受端500kV电网潮流分布均匀、电压水平满足要求，N-1方式下交流线路、变压器均不过载。
Pakistan power grid 2018 summer maximum-load mode is adopted in the calculation. Matiari-Lahore ±660kV DC Transmission Project leads to a transmission capacity of 4000MW. Shown by the load flow calculation, in Scheme 1, DC electricity of Matiari-Lahore is mainly transmitted via three channels: converter station-Lahore South, converter station-Lahore, and converter station-Lahore North, separately 1520MW, 1800MW, 532MW. 500kV power grid at the receiving-end is evenly distributed, with voltage level complying with requirement, and there is no overloading with AC line, and transformer under N-1 mode.

方案2默蒂亚里～拉合尔直流电力同样通过换流站～拉合尔南、换流站～拉合尔、换流站～拉合尔北3个通道送出，3个通道潮流分别为1520MW、1800MW、532MW。受端500kV电网潮流分布均匀、电压水平满足要求，N-1方式下交流线路、变压器均不过载。
In Scheme 2, DC electricity of Matiari-Lahore is also transmitted via three channels: converter station-Lahore South, converter station-Lahore, and converter station-Lahore North, separately 1520MW, 1800MW, 532MW. 500kV power grid at the receiving-end is evenly distributed, with voltage level complying with requirement, and there is no overloading with AC line, and transformer under N-1 mode.

各方案正常方式及主要的N-1方式潮流分布如下图所示。
Load flow distribution under normal mode and main N-1 mode of the two schemes is shown in the below figure.

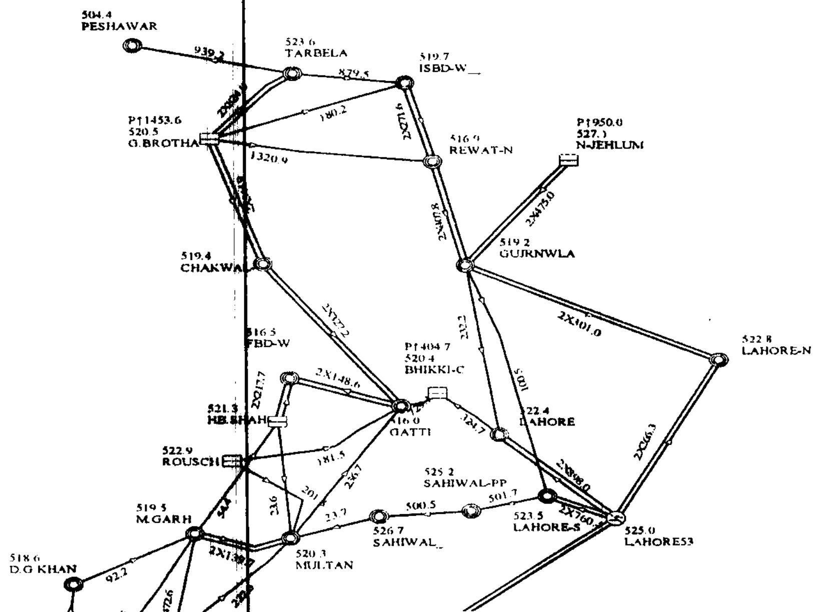

图5.2-1 方案1正常方式潮流图
Fig. 5.2-1 Scheme 1 Normal Mode Load Flow Diagram

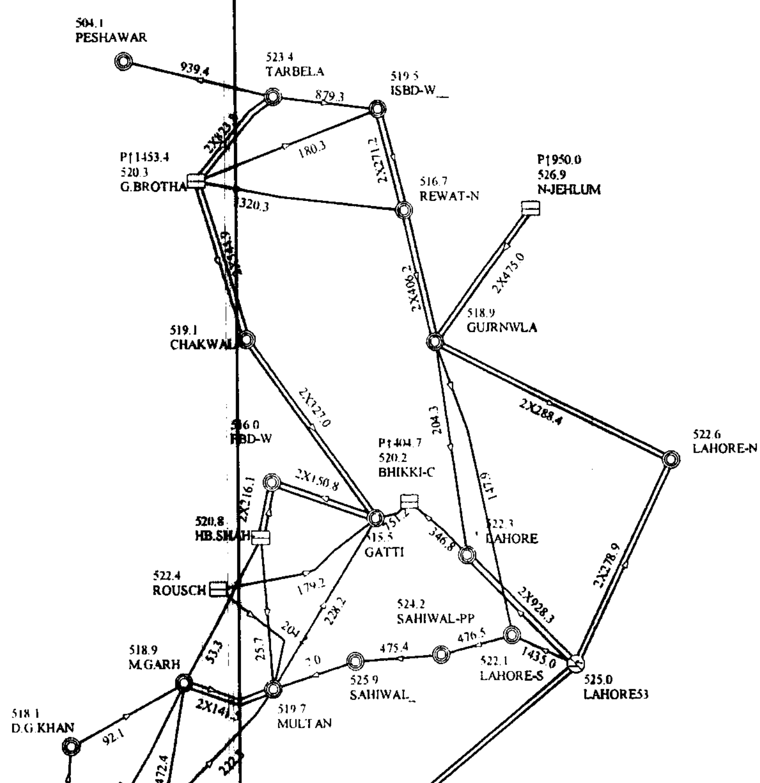

图5.2-2 方案1换流站~LAHORE SOUTH 500kV线路N-1方式潮流图
Fig. 5.2-2 Scheme 1 Converter Station-LAHORE SOUTH 500kV Line N-1 Mode Load Flow Diagram

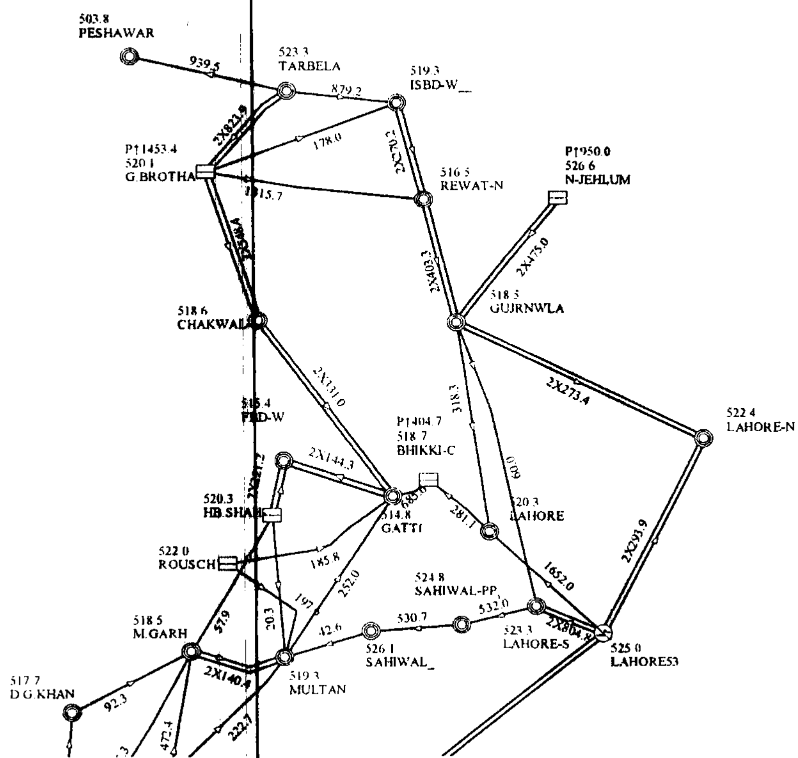

图5.2-3 方案1换流站～LAHORE 500kV线路N-1方式潮流图
Fig. 5.2-3 Scheme 1 Converter Station-LAHORE 500kV Line N-1 Mode Load Flow Diagram

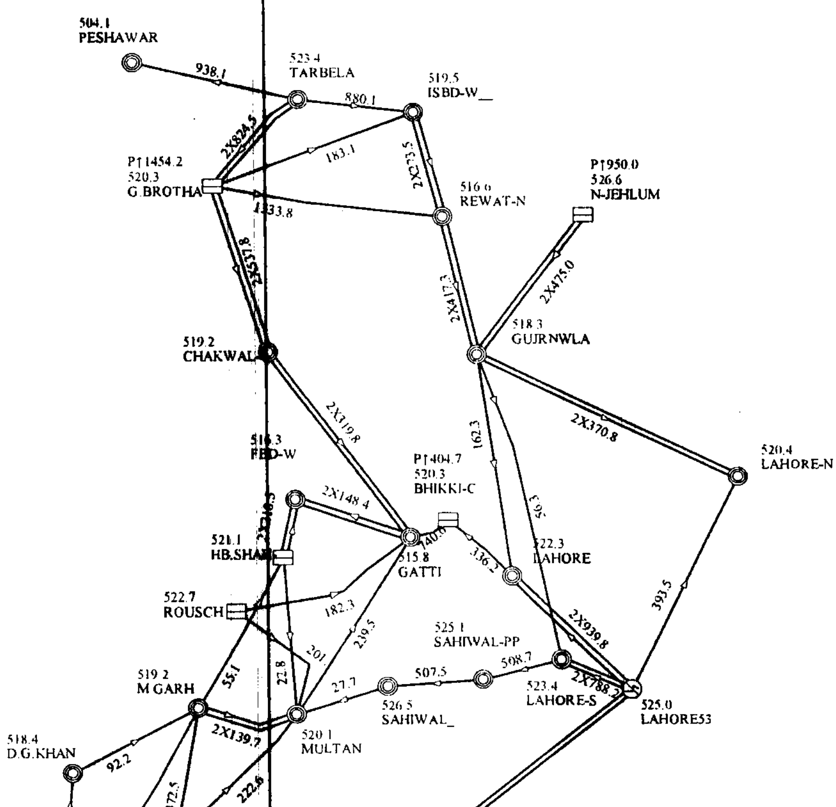

图5.2-4 方案1换流站～LAHORE NORTH 500kV线路N-1方式潮流图
Fig. 5.2-4 Scheme 1 Converter Station-LAHORE NORTH 500kV Line N-1 Mode Load Flow Diagram

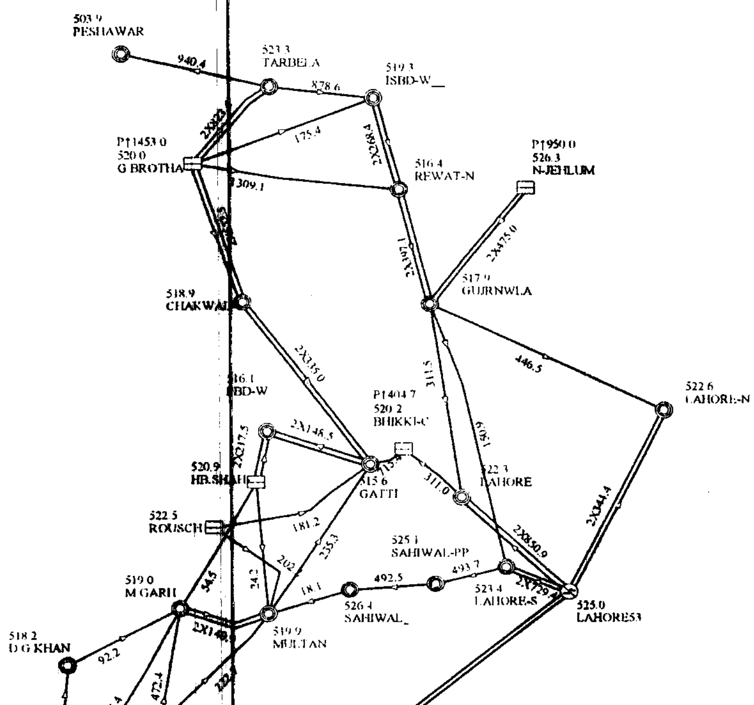

图5.2-5 方案1 LAHORE NORTH～GAKKHAR 500kV线路N-1方式潮流图

Fig. 5.2-5 Scheme 1 LAHORE NORTH-GAKKHAR 500kV Line N-1 Mode Load Flow Diagram

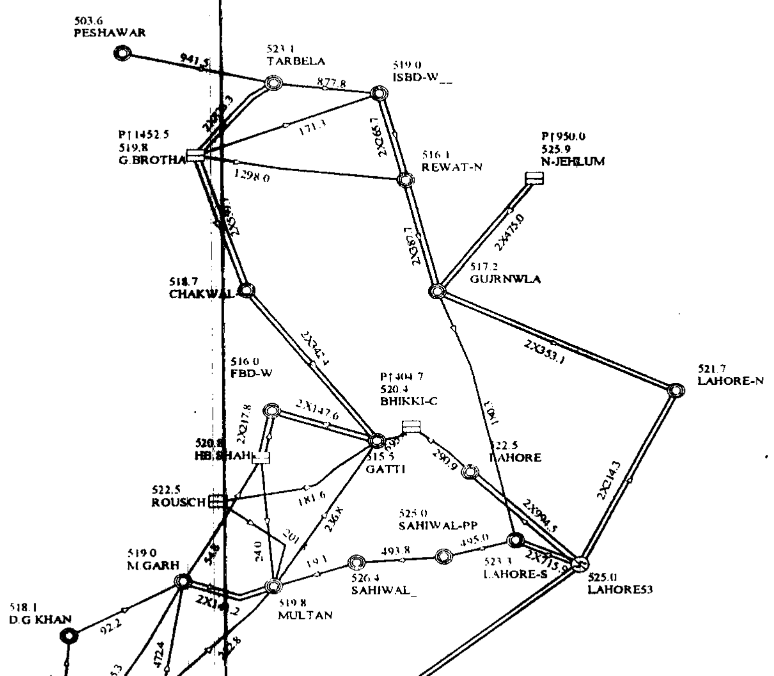

图5.2-6 方案1GAKKHAR～LAHORE 500kV线路N-1方式潮流图

Fig. 5.2-6 Scheme 1 GAKKHAR-LAHORE 500kV Line N-1 Mode Load Flow Diagram

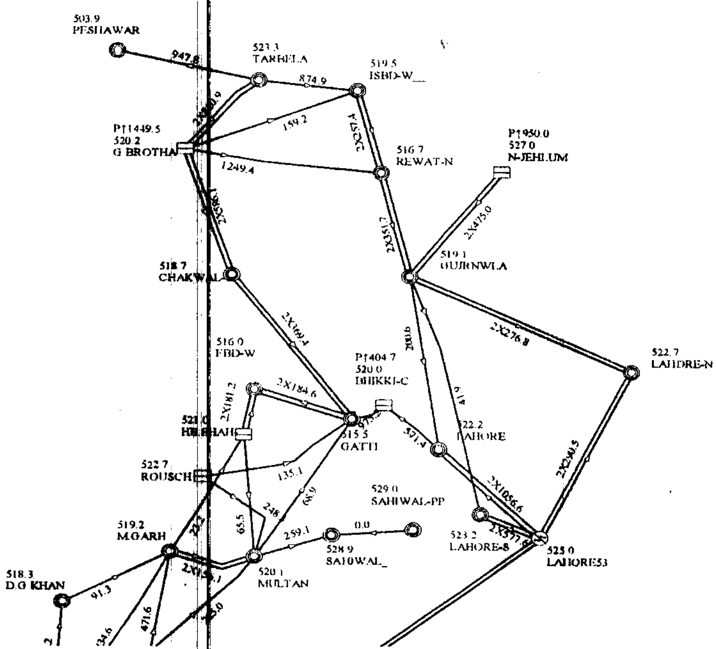

图5.2-7 方案1 LAHORE SOUTH～SAHIWAL 500kV线路N-1方式潮流图
Fig. 5.2-7 Scheme 1 LAHORE SOUTH-SAHIWAL 500kV Line N-1 Mode Load Flow Diagram

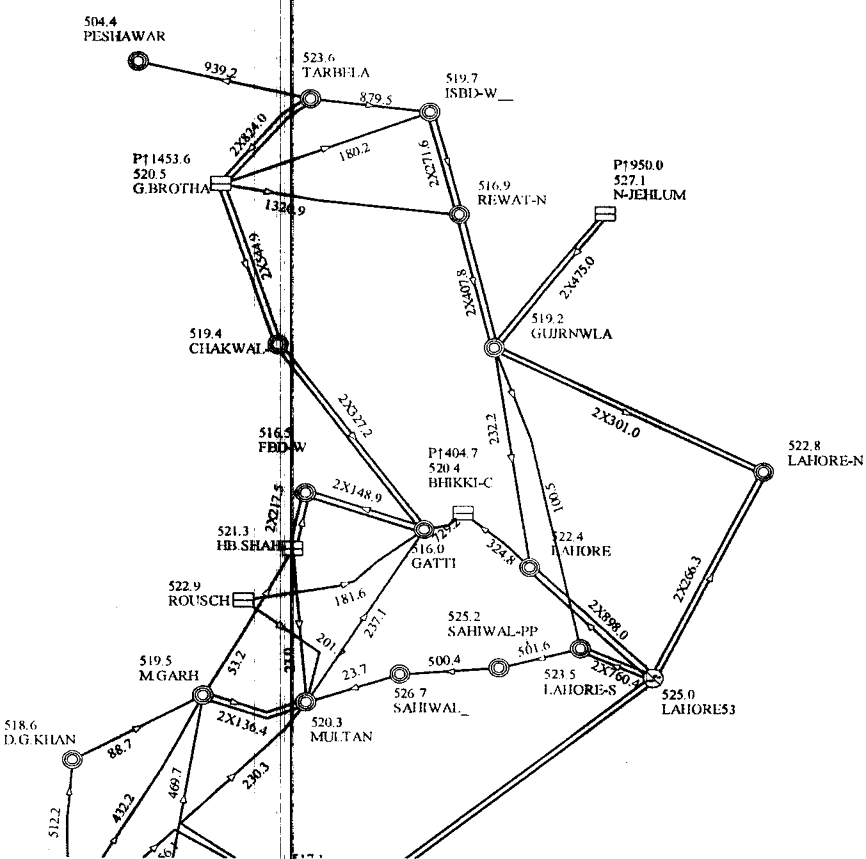

图5.2-8 方案2正常方式潮流图
Fig. 5.2-8 Scheme 2 Normal Mode Load Flow Diagram

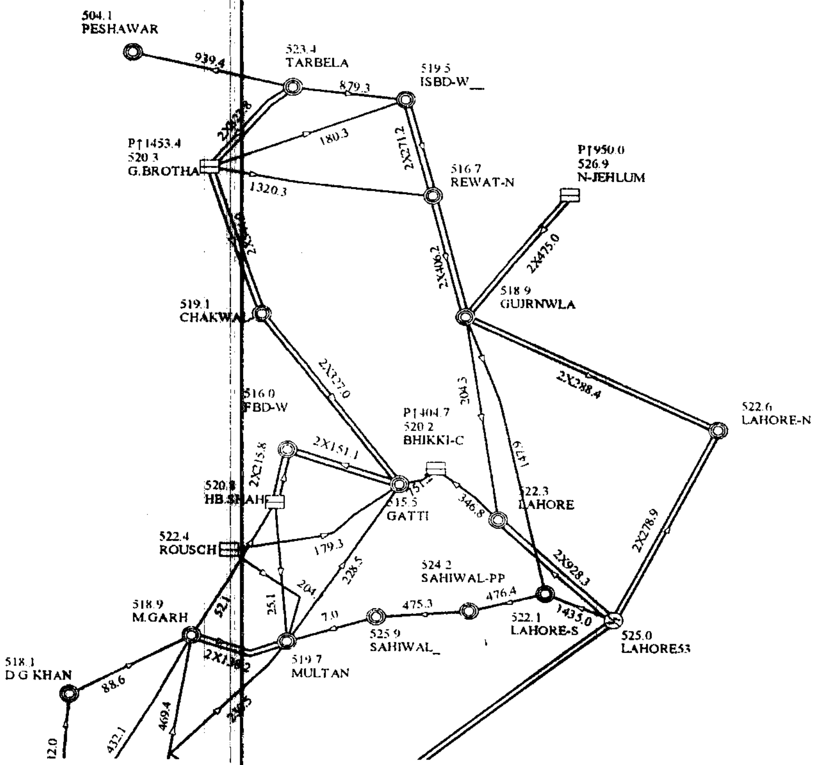

图5.2-9 方案2换流站～LAHORE SOUTH 500kV线路N-1方式潮流图

Fig. 5.2-9 Scheme 2 Converter Station-LAHORE SOUTH 500kV Line N-1 Mode Load Flow Diagram

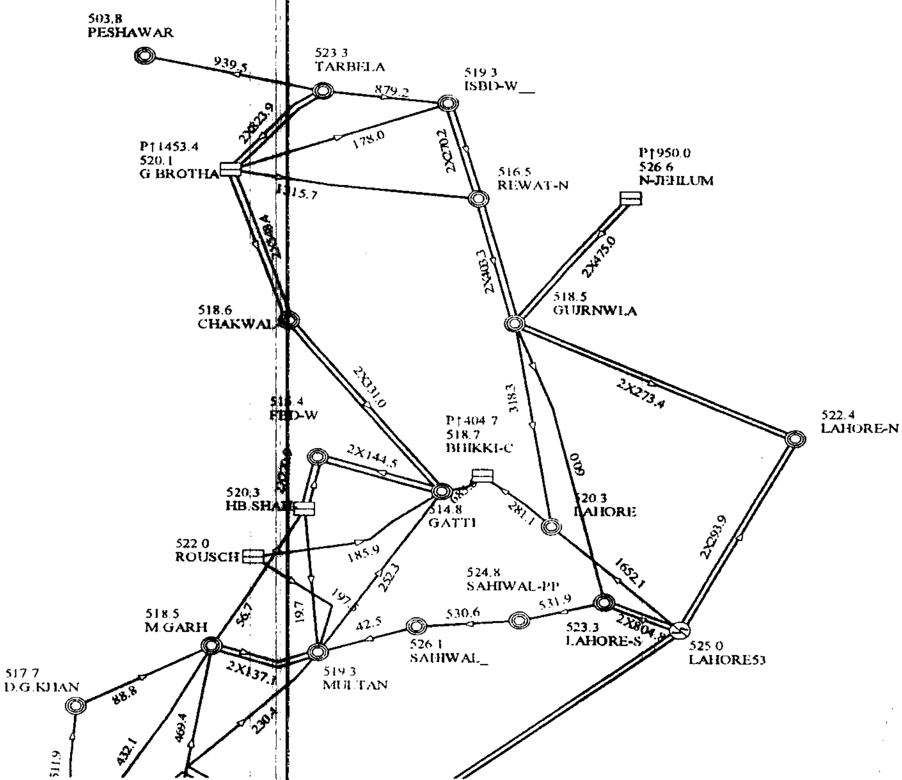

图5.2-10 方案2换流站～LAHORE 500kV线路N-1方式潮流图

Fig. 5.2-10 Scheme 2 Converter Station-LAHORE 500kV Line N-1 Mode Load Flow Diagram

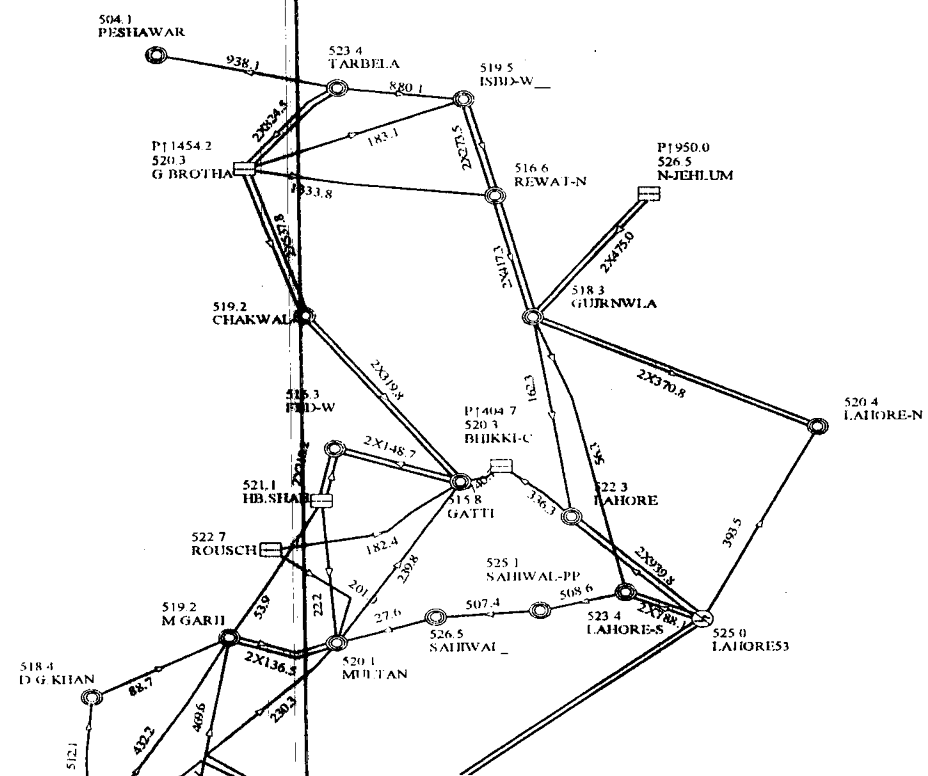

图5.2-11 方案2换流站～LAHORE NORTH 500kV线路N-1方式潮流图

Fig. 5.2-11 Scheme 2 Converter Station-LAHORE NORTH 500kV Line N-1 Mode Load Flow Diagram

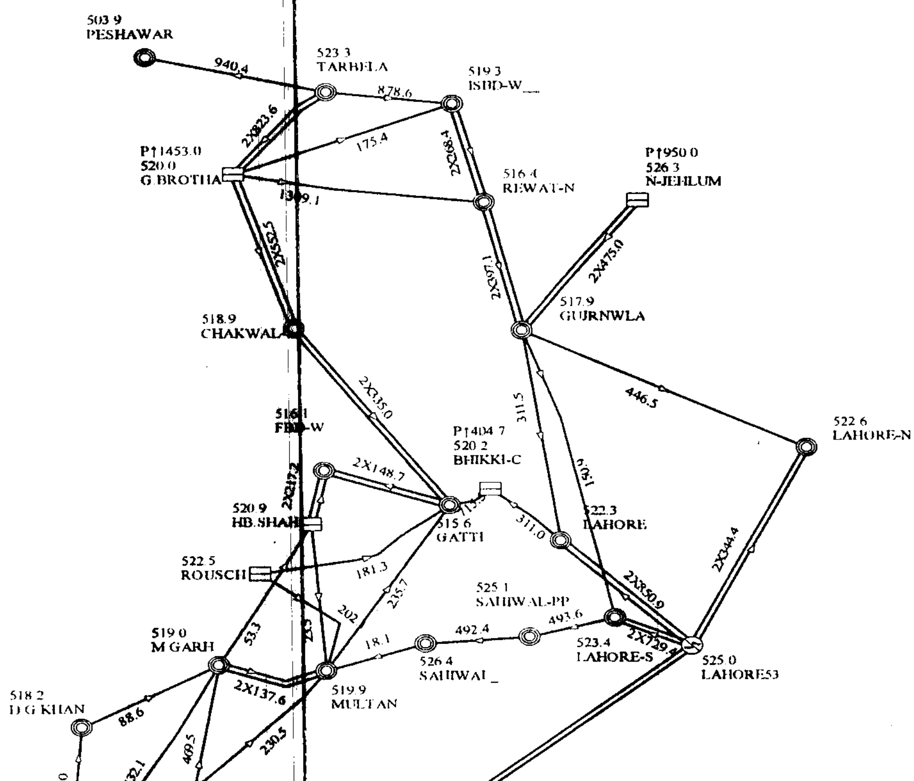

图5.2-12 方案2 LAHORE NORTH～GAKKHAR 500kV线路N-1方式潮流图

Fig. 5.2-12 Scheme 2 Converter Station-LAHORE NORTH-GAKKHAR 500kV Line N-1 Mode Load Flow Diagram

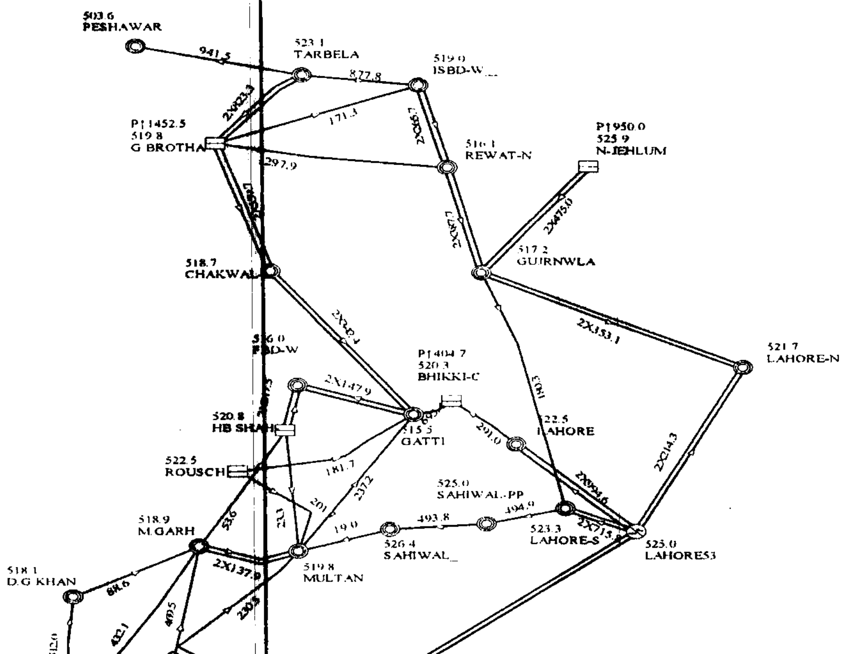

图5.2-13 方案2 GAKKHAR～LAHORE 500kV线路N-1方式潮流图

Fig. 5.2-13 Scheme 2 GAKKHAR-LAHORE 500kV Line N-1 Mode Load Flow Diagram

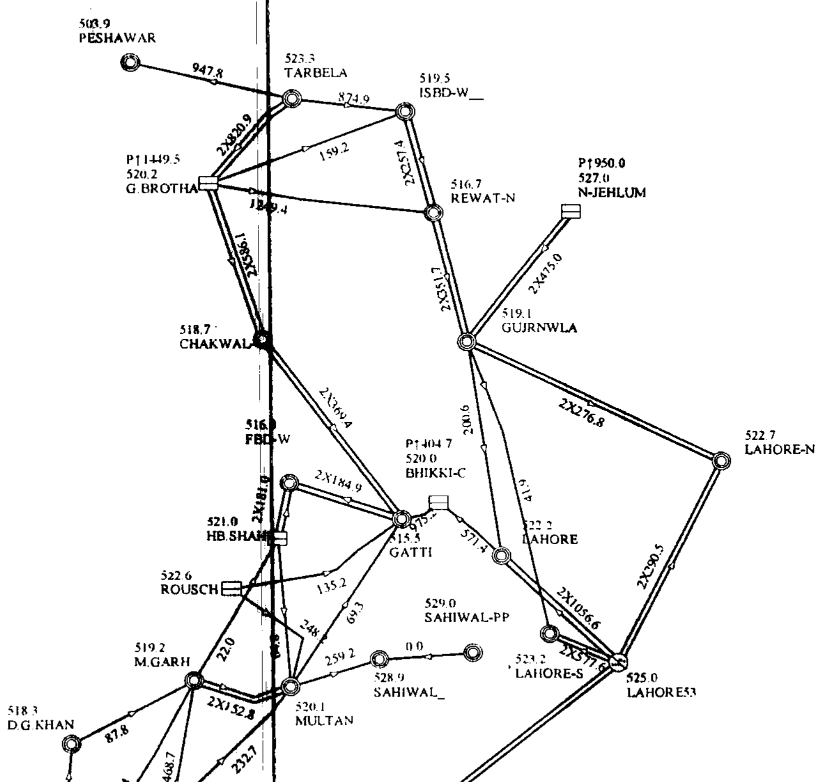

图5.2-14 方案2 LAHORE SOUTH～SAHIWAL 500kV线路N-1方式潮流图

Fig. 5.2-14 Scheme 2 LAHORE SOUTH-SAHIWAL 500kV Line N-1 Mode Load Flow Diagram

5.3 方案比较及推荐

Scheme comparison and recommendation

从潮流计算结果来看，各受端接入系统方案电网潮流分布均匀、电压水平满足要求，N-1方式下交流线路、变压器均不过载。

According to load flow calculation, power grid load flow of respective schemes at the receiving-end is evenly distributed, with voltage level complying with requirement, and there is no overloading with AC line, and transformer under N-1 mode.

从工程经济性来看，方案1新建交流线路较短，需扩建2个500kV间隔；方案2新建交流线路较长，需扩建6个500kV间隔。因此，方案1受端换流站接入电网配套交流系统投资最省。各方案换流站接入电网配套交流系统投资估算如下表所示。

In aspect of economical efficiency, Scheme 1 needs shorter newly constructed AC line, and 2 500kV bays shall be expanded. Scheme 2 needs longer newly constructed AC line, while 6 500kV bays shall be expanded. As for this, power grid accessing AC system for receiving-end converter station in Scheme 1 saves investment. Estimated investment of AC system for receiving-end converter station in respective schemes is shown in the below table.

表5.3-1 受端换流站接入系统方案投资估算表
Table 5.3-1 Investment Estimation for Receiving-end Converter Station Access Schemes

单位：km、万元
Unit: km, 10,000 RMB yuan

	方案1 Scheme 1 Difference		方案2 Scheme 2 Difference	
	规模 Scale	投资 Investment	规模 Scale	投资 Investment
线路 Line	0	0	31	7130
变电 Power transformation		0		5400
合计差值 Total Difference	0		12530	

综合考虑以上因素，推荐方案1为默蒂亚里～拉合尔直流工程受端接入系统方案，具体为：直流受端换流站交流侧电压采用500kV，换流站分别π入拉合尔（Lahore）～拉合尔南（Lahore South）的双回500kV线路，换流站至拉合尔南的2回新建线路长度分别为21km、20km，换流站至拉合尔的2回新建线路长度分别为36km、53km；建设拉合尔北（Lahore North）500kV变电站，建设受端换流站～拉合尔北～古杰兰瓦拉（Gakkhar）双回500kV线路，线路长度分别约60km，50km。受端换流站出线6回，各通过2回至拉合尔、拉合尔南及拉合尔北。

Considering the above factors, we recommend Scheme 1 for Matiari-Lahore DC Transmission Project receiving-end to connect to the system: Adopt 500kV voltage at the AC side of DC receiving-end converter station and connect (π connection) the converter station to the Lahore-Lahore South double-circuit 500kV lines, with the new lines being 21km and 20km for converter station to the Lahore-Lahore South, 36 and 53km for converter station to the Lahore-Lahore(old) long respectively; build the Lahore North 500kV substation, and the receiving-end converter station-Lahore North-Gakkhar double-circuit 500kV lines with a length of about 60, 50km respectively. The receiving-end converter station will have 6-circuit outgoing lines, with 2 to Lahore, 2 to Lahore South and 2 to Lahore North.

6 主要结论

Main Conclusions

6.1 工程建设必要性

Necessity of project construction

默蒂亚里～拉合尔±660kV直流输电工程的建设，将有利于满足旁遮普省和伊斯兰堡地区用电负荷增长需要，保障负荷中心电力供应，促进经济健康发展，有利于促进塔尔煤田坑口煤电及沿海进口煤电的开发，实现能源资源更大范围优化配置。

The construction of Pakistan Matiari-Lahore ±660kV DC Transmission Project will contribute to meeting the increasing demands for electrical loads of the area of Punjab and Islamabad, assuring the power supply for the load center, promoting the healthy development of economy, boosting the development of Thar Coal Field pithead coal power and imported coal power along the coast and realizing the optimal configuration of energy resources in a broader sense.

6.2 受端换流站接入系统方案

Access scheme of receiving-end converter station

接入系统方案为：直流受端换流站落点拉合尔南部地区，交流侧电压采用500kV，分别π入拉合尔～拉合尔南双回500kV线路，建设拉合尔北500kV变电站，建设受端换流站～拉合尔北～古杰兰瓦拉双回500kV线路。受端换流站形成6回出线，2回至拉合尔，2回至拉合尔南，2回至拉合尔北。根据电气计算分析，受端电网潮流分布合理，网架结构清晰，本期及远期受端电网暂态稳定和短路电流水平能够满足电网运行的要求。

The access scheme is: locate the DC receiving-end converter station in the southern area of Lahore, adopt 500kV voltage at the AC side, and connect (π connection) the converter station to Lahore-Lahore South double-circuit 500kV lines; build Lahore North 500kV Substation, and the receiving-end converter station-Lahore North-Gakkhar double-circuit 500kV lines. The receiving-end converter station will have 6-circuit outgoing lines, with 2 to Lahore, 2 to Lahore South and 2 to Lahore North. According to the electrical calculation analysis, the load flow of receiving-end grid is distributed properly, the grid structure is clear, the transient state of current and long-term receiving-end grid is stable, and the short-circuit current level can meet the operating requirements of the grid.

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巴基斯坦默蒂亚里—拉合尔±660kV 直流输电工程

±660kV HVDC Project from Matiari to Lahore in Pakistan

可行性研究

Feasibility Study

电力系统一次

Power System Primary Part

系统短路电流水平研究

Study of System Short Circuit Characteristics

中国电力技术装备有限公司

CHINA ELECTRIC POWER EQUIPMENT AND TECHNOLOGY CO., LTD

南京南瑞继保电气有限公司

NR Electrical Co., Ltd.

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摘要

报告主要依据 NTDC 提供的巴基斯坦电网各种水平年运行方式及短路电流计算数据，计算默蒂亚里-拉合尔直流接入系统后，直流线路换流站的最大及最小短路电流水平，最小短路比及最小有效短路比，为设备选型做参考及衡量交直流互联系统强度。

Abstract

The maximum short circuit current, the minimum short circuit current, the minimum short circuit ratio (SCR) and the effective short circuit ratio (ESCR)are calculated based on the scenarios and data provided by NTDC with the Matiari-Lahore DC link accessed into the system. The calculation results are used used to choose the equipment and evaluate the strength contrast between AC system and DC system.

目录/CONTENTS

1 前言

Introduction

巴基斯坦默蒂亚里-拉合尔±660kV 直流输电工程起点巴基斯坦南部信德省默蒂亚里，途经信德、旁遮 2 省，落点中部旁遮普省拉合尔地区，直流线路长度约 878km，输电容量 4000MW，规划 2018 年投产。默蒂亚里换流站和拉合尔换流站都含有双极，每极一个 12 脉动换流器，采用单相双绕组换流变压器。额定输送功率为双极 4000MW、单极 2000MW。

Pakistan Matiari-Lahore ±660kV DC Transmission Project starts from Matiari, Sindh (in the south of Pakistan) to Lahore, Punjab (in the central area) via Sindh and Punjab, and the DC line is about 878km long, the power transmission capacity is 4000MW and it is to be put into operation in 2018.

Both Matiari Converter Station and Lahore Converter Station are bipolar, every pole has a 12-pulse converters and the converter transformer of single phase double winding is used.

The rated transmitting power is 4000MW for bipole and 2000MW for monopole.

1.1 计算目的及采用的标准

The Calculation Object and Standard Adopted

通常的变电站设计过程中只需要计算电力系统可预见年份的最大短路电流水平，用于选择开关等设备。

而 HVDC 工程中除了计算最大短路电流水平外，还需计算 HVDC 工程投运年的最小短路电流水平，以便于计算 HVDC 接入系统之后，换流站的最小短路比 SCR 及最小有效短路比 ESCR，并以此来评估 HVDC 所接入的 AC 系统的强弱。

Usually in the process of substation design, only the maximum short circuit current in the predictable year is necessary to be calculated, which is used to choose equipment such as switches.

In HVDC project, the minimum short circuit current of the year HVDC project put into operation is also required to be calculated besides the maximum short circuit current. It is used to calculate the minimum short circuit ratio (SCR) and the minimum effective short circuit ratio (ESCR) after the HVDC project is accessed into the system. The strength of AC system is evaluated based on SCR and ESCR.

计算采用的标准为 IEC60909《三相交流系统短路电流》;
The standard adopted in this report is IEC 60909 *Short Circuit Currents in Three-Phase A.C. Systems*.

1.2 短路比及有效短路比的定义

The definition of SCR and ESCR

对于单回直流输电线路而言，通常用短路比(Short Circuit Ratio, SCR)或者是有效短路比(Effective Short Circuit Ratio, ESCR)来衡量所接入的交流系统相对于直流系统的强弱。直流系统的稳态特性和暂态特性很大程度上是由有效短路比决定，因此需要研究及计算有效短路比。

For a DC link, Short Circuit Ratio(SCR) or Effective Short Circuit Ratio(ESCR) are usually used to evaluate the strength contrast between AC system and DC system. The steady state and transient state characteristics of the DC system are largely determined by the effective short circuit ratio. So it is necessary to analyze and calculate the value of ESCR.

短路比 SCR 定义为换流站交流母线的短路容量 S_{sc} 与额定直流功率 P_{dN} 的比值，即：
The short circuit ratio is defined as the ratio of short circuit capacity S_{sc} of converter AC busbar and the rating power of DC link P_{dN}, i.e.:

$$SCR=\frac{S_{sc}}{P_{dN}}$$

为了同时考虑交流系统等效阻抗 Z 与换流站滤波器及无功补偿电容器的作用，引入了有效短路比 ESCR 的概念，有效短路比的定义为换流站交流母线的短路容量 S_{sc} 减去当换流站交流母线电压 U 取 U_N 时，交流滤波器和无功补偿电容器所产生的无功功率 Q_{cN} 后与额定直流功率 P_{dN} 的比值：
Considering the impact of equivalent impedance of AC system, AC filters and reactive compensation capacitors, the effective short circuit ratio is defined as the ratio of short circuit capacity S_{sc}minus the reactive power Q_{cN}generated by AC filters and reactive compensation capaticors when the voltage of converter AC busbar is rating voltage U_N and the rating power of DC link P_{dN}, i.e.:

$$ESCR=\frac{S_{sc}-Q_{cN}}{P_{dN}}$$

根据 WA00191K-SS-06《换流站无功补偿及配置研究》的报告，默蒂亚里站总无功补偿为 2610Mvar，其中备用为一组 180 Mvar；拉合尔站总无功补偿为 2480 Mvar，其中备用一组 150 Mvar。因此：在本报告计算中，整流侧 Q_{cNR} 为 2430 Mvar，逆变侧 Q_{cNI} 为 2330 Mvar。
According to Report WA00191K-SS-06*Study of Reactive Power Compensation and configuration of converter station*, the total reactive compensation of Converter Station Matiari is 2610 Mvar, including backup compensation capacity of one group 180 Mvar; the total reactive compensation of Converter Station Lahore is 2480 Mvar, including backup compensation capacity of one group 150 Mvar. So, in this report, the $Q_{cNR}$of the rectifier side is 2430 Mvar, the Q_{cNI} of the inverter side is 2330 Mvar.

1.3 关于系统阻抗 X/R 的说明

The Expain of System Impedance X/R

在 IEEE/ANSI 的短路电流计算标准中，规定如果短路电流高于断路器额定开断电流的 80%，即 50 kA，则必须考虑系统 R/X 的比。这是因为在 IEEE 标准的短路电流计算中，未考虑 R 元件，其计算基本公式为：

$$I_k^{''}=\frac{E}{X}$$

其中，E 取故障点最高典型运行电压；计算等值阻抗 X 时，忽略系统各元件电阻、忽略所有并联无功补偿设备、负荷及线路电容。

In IEEE/ANSI Standard of short circuit calculation, if the fault current is greater than 50kA (80% of the breaker rated interruping current), X/R ratio should be taken into consideration. This is becausethe calculation of short current in IEEE/ANSI C37.010 has not taken R into consideration.The equation is as (2-1). The *E* is the highest typical operating voltage of the fault position. All the resistance of the system, parallel reactive compensation, capacitor of the transmission lines and load are all ignored when calculating the equivalent impedance X.

根据 IEEE 标准，利用计算得到的 $I_k^{''}$校验电流开断能力时，如果 $I_k^{''}$低于断路器额定开断电流的 80%，则以 $I_k^{''}$为准。如果 $I_k^{''}$高于断路器额定开断电流的 80%，则必须考虑系统的 R/X 比。根据比值对 $I_k^{''}$做出修正。

Based on the IEEE standard, if $I_k^{''}$ is less than 80% of the rated interrupting current, the election of the circuit breakershould be based on $I_k^{''}$.If $I_k^{''}$exceed 80% of the rated interrupting current, then the X/R should be taken into consideration to modify the $I_k^{''}$.

但是，在 IEC 标准（IEC60909-2001）中及中国标准（《三相交流系统短路电流计算（GB/T 15544)》）中，短路电流（有效值）计算时采用的是系统阻抗 Z_k，也就是说既考虑了 X 元件因数，也考虑了 R 元件因数，基本计算公式为：

$$I_k^{''}=\frac{cU_n}{\sqrt{3}Z_k}$$

X/R 变化对于短路电流周期分量（有效值）影响较小。X/R 不是为了修正短路电流 $I_k^{''}$，其主要作用为：

In the standard of China (GB/T 15544) and IEC 60909-2001, the X and R are both taken into account in the calculation of short circuit current. The equation is shown as (2-2).In such condition, the range of X/R has small influence on the periodic component of short circuit (effective value) and is not used to modify the short circuit current $I_k^{''}$. Its main function is:

- 用于判断距离电厂的远近：
  to evaluate the distance from power plant;

- 用于判断直流分量的衰减：
  to evaluate the damping period of DC component of short circuit current.

当按照上述中国标准及 IEC 标准设计开关设备时，已经考虑了 X/R 对于冲击电流及直流分量的影响，目前中国国内电网尚未发现因为 X/R 值需要特殊设计开关设备或者选择另外一档开关标称容量的情况。

As the design of switch equipment in China is based on Chinese standard and IEC standard mentioned above, the influence of X/R has on impulse current and DC component has been taken into consideration. At present, special design of switching equipment or choosing another rating capacity because of X/R value haven't been found in China grid.

2. 计算边界条件及方式

Boundary Conditions of Calculation And Scenarios

2.1 计算边界条件

Boundary Conditions of Calculation

短路电流研究中主要用到了两个方式，分别用来计算 2018 年最小短路电流水平以及 2021-22 年最大短路电流水平。这些计算文件是 PSS/E 文件，由 NTDC 提供。短路电流的计算软件为 PSS/E，33 版本，系统网架绘制软件为南瑞潮流图程序。短路电流水平的计算边界条件有：

There are two scenarios used for short circuit study. One is for minimum short circuit level in the year 2018 and another is for maximum short circuit level in the year 2021-22. Both of these files are provided by NTDC in PSS/E. The software used to calculate the short circuit current is PSS/E and the software used to draw the system topology is NR Power Flow Chart. The calculation assumption of short circuit level includes as below:

- 南部 6 个电厂（塔尔安格鲁、塔尔坑口一区、胡布克燃煤电厂、卡西姆港、Lucky 燃煤电站、Sidqsns 燃煤电站）发电机的次暂态电抗为饱和值，报告中也提供采用不饱和值的计算结果；
  The sub-transient reactance of the generators of the power plants in the south which are EngroThar, SSRL, Hubco CFPP, Port Qasim, Lucky CFPP and Sidqsns CFPP aresaturated value, the calculation results with unsaturated values are also provided in the report；
- 在本报告的计算中不考虑线路容抗、无功补偿和负荷；
  The capacitive reactance of the line, the reactive compensation and the load are not taken into consideration in this report；
- 计算最大短路电流水平时，分别计算了电压水平为 1.1pu、1.05pu、1.0pu 时的短路电流水平。
  In the calculation of the maximum short circuit current, the values are calculated with different voltage levels, i.e. 1.1 pu, 1.05 pu, 1.0 pu.
- 计算最小短路电流水平时，电压水平为 0.95 pu。
  The voltage level for minimum short circuit level is set to 0.95 pu.

本工程所使用的最大短路电流水平计算水平年为 NTDC 提供的 2022 年规划远景水平年，并在计算中选取：

The scenario used to calculate the maximum short circuit current should be the longest-term year had been planned now, i.e. the year 2022. The boundary conditions of this calculation are:

- 开机水平最大；
  The amount of generation is maximum;

- 负荷水平最大；
  The amount of generation is maximum;
- 系统网架最强；
  The topology of the system is the strongest.

本工程所使用的最小短路电流水平计算水平年为 NTDC 提供的 2018 年规划投运水平年，并在计算中选取：

The scenario used to calculate the minimum short circuit current is the year when the HVDC put into operation. The boundary conditions of this calculation are:

- 开机水平最小；
  The amount of generation is minimum;
- 负荷水平最低；
  The amount of load is minimum;
- 网络拓扑结构最弱，如考虑 N-2；
  The topology of the system is the weakest, for example considering N-2.

2.2 计算方式

Scenarios Calculated

用来计算最大短路电流水平的方式网络拓扑图如图 2.1 所示。该方式下，系统电源总出力为 45973.88 MW，K2 和 K3 核电机组不在其中。其余南部电厂，包括塔尔安格鲁、塔尔坑口一区、卡西姆港、胡布克燃煤电站、Lucky 燃煤电站、Sidqsns 燃煤电站都考虑在内。另外，北部 LNG 电厂（包括 Bhikki、Balloki、H.B.Shah）出力水平最大。

The topology of the scenario used to calculate the maximum short circuit current is shown in Figure 2.1.The total generation is 45973.88 MW. K2 & K3 is not taken into consideration. The other plants in the south including Engro char, SSRL, Port Qasim, Hubco CFPP, Lucky CFPP and Sidqsns CFPP are all taken into consideration. Also, the generation of the LNG power plants (Bhikki, Balloki and H.B.Shah) is at the maximum level.

用来计算最小短路电流水平的方式网络拓扑图如图 2.2 所示。此方式基于冬季最小方式，在该方式中，默蒂亚里进出线共有 10 回，南部电厂开机水平高；拉合尔站出线共有 6 回，拉合尔站附近的电源开机为最低水平，北部 LNG 电厂（包括 Bhikki、Balloki、H.B.Shah）关闭。计算最小短路电流时需要考虑 N-2，即图中所示拉合尔站-拉合尔北之间无 2 回交流线路。

The topology of the scenario used to calculate the minimum short circuit current is shown in Figure 2.2. This scenario is based on the winter off peak operation conditions. In this scenario, there are 10 in and out AC lines of converter station Matiari. The generation in the south part is high to support the transmission power of HVDC. There are 6 out AC lines of converter station Lahore.The near generation of Lahore Converter has been kept for minimumand the impact of LNG power plants (Bhikki, Balloki and H.B.Shah) has been eliminated. Line N-2 is taken into consideration in the minimum short circuit current calculation. So, in Figure 2.2 there is no line between Lahore and Lahore North.

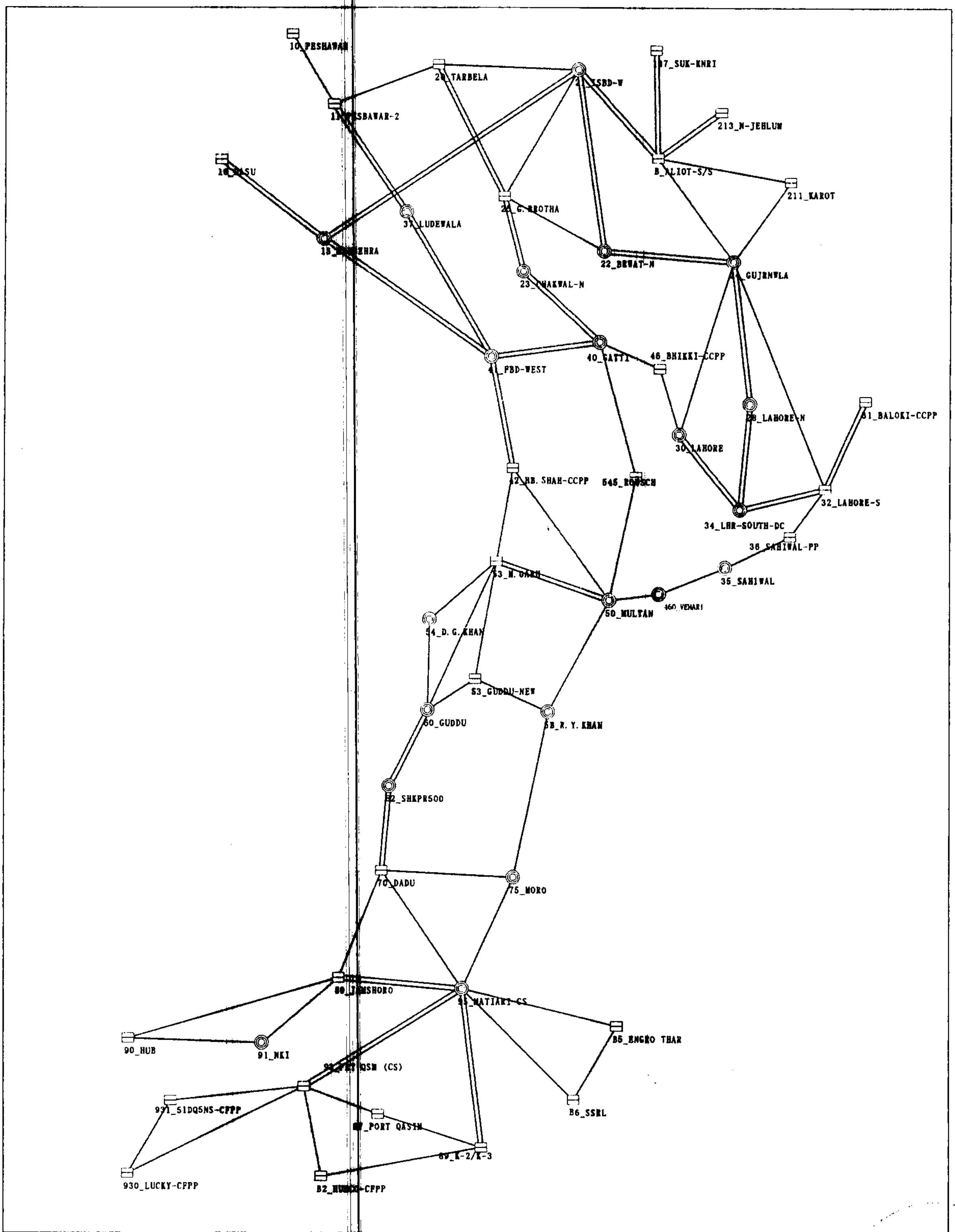

图 2.1 最大短路电流计算方式的拓扑结构

Figure 2.1 The topology of the scenario used for the maximum short circuit current

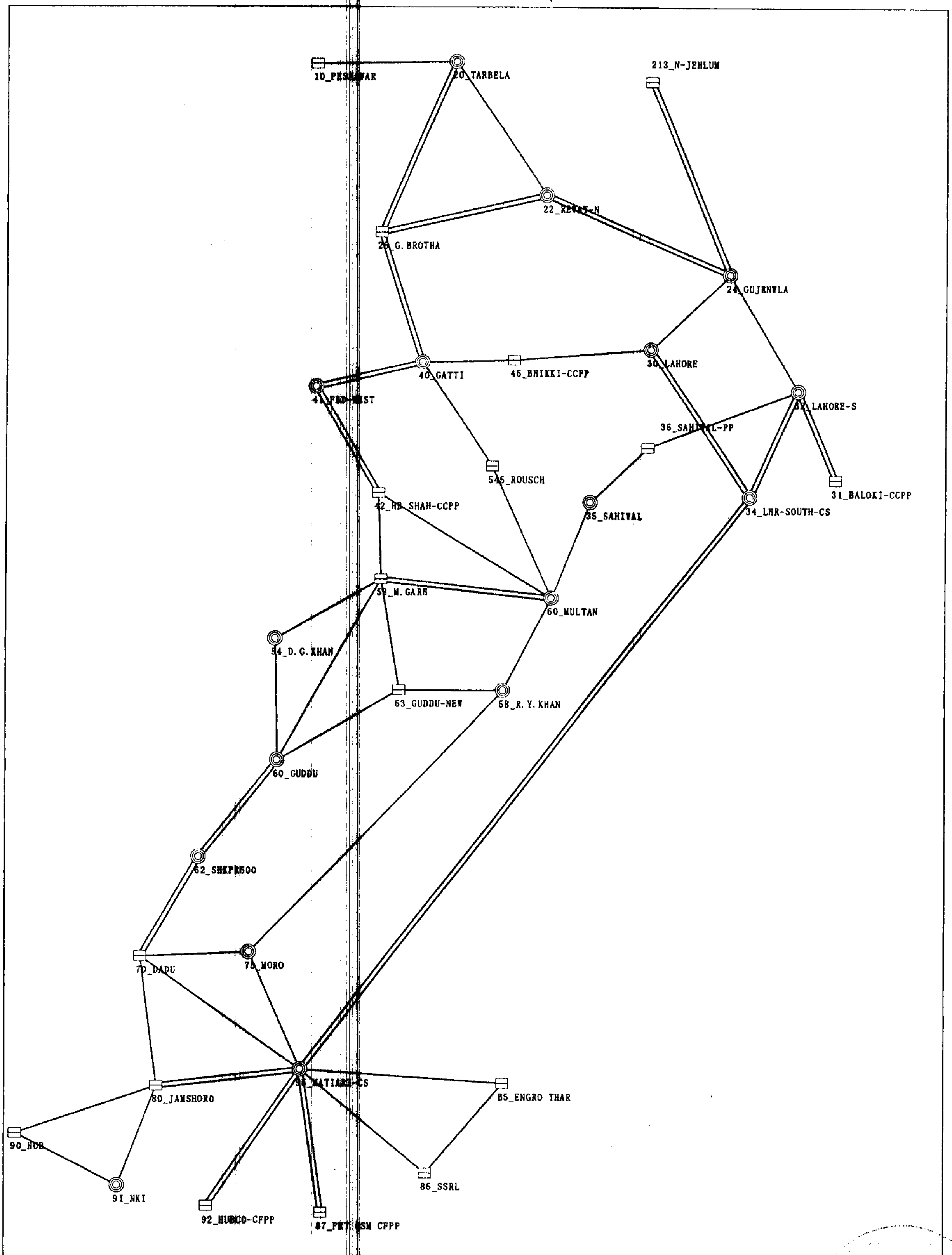

图 2.2 最小短路电流计算方式的拓扑结构

Figure 2.2 The topology of the scenario used for the minimum short circuit current

3. 换流站短路电流及短路比计算

Short Circuit Results

3.1 莫里亚蒂换流站母线短路电流及短路比计算

Calculation of short circuit current and short circuit ratio of bus of Matiari Converter Station

使用 NTDC 提供的最小短路电流计算文件，计算莫里亚蒂换流站母线短路电流及短路比，并计算在关停机组、线路检修时的母线短路电流和短路比。表 3-1 中为南部 4 座电厂次暂态电抗为饱和值时的计算结果，表 3-2 中为南部 4 座电厂次暂态电抗为非饱和值时的计算结果：

The short circuit current and short circuit ratio of converter Matiari is calculated based on the minimum short circuit calculation file provided by NTDC. Besides this, the short circuit current , SCR and ESCR with outage of generators and lines are calculated. Table 3-1 is the calculation results when the parameters of the four power plants (EngroThar, SSRL, Hubco CFPP and Port Qasim plant) in the south are saturated ones and Table 3-2 are the results with unsaturated ones.

表 3-1 2018 年默蒂亚里换流站母线短路电流及短路比（饱和值）
Table 3-1 Short circuit current and short circuit ratio of bus of Matiari Converter Station in 2018 (Saturated Value)

运行方式 Operation mode	三相短路电流(kA)/短路容量（MVA） Three-phase short circuit current (kA)/Short circuit capacity (MVA)	短路比 SCR	有效短路比 ESCR
正常 Normal	25.94/22466	5.62	5.01
塔尔电厂关机 1 台 Thar Power Plant-One Unit Shut Down	24.84/21561	5.39	4.78
胡布克电厂关机 1 台 Hubco Power Plant-One Unit Shut Down	24.55/21264	5.32	4.71
卡西姆电厂关机 1 台	24.42/21149	5.29	4.68

Qasim Power Plant-One Unit Shut Down			
默蒂亚里换流站～贾姆沙罗线路 N-1 Matiari Converter Station-Jamshoro N-1	24.83/21504	5.38	4.77
默蒂亚里换流站～摩洛线路 N-1 Matiari Converter Station-Moro N-1	25.28/21893	5.47	4.87
默蒂亚里换流站～新大都线路 N-1 Matiari Converter Station- Dadu New N-1	25.04/20776	5.42	4.81
塔尔电厂～默蒂亚里换流站线路 N-1 Thar Power Plant-Matiari Converter Station N-1	23.99/20845	5.19	4.59
卡西姆电厂～默蒂亚里换流站线路 N-1 Port Qasim Coal Power Plant-Matiari Converter Station N-1	25.14/21768	5.44	4.83
胡布克电厂～默蒂亚里换流站线路 N-1 Hubco power plant-Matiari Converter Station N-1	25.08/21715	5.43	4.82

表 3-2 2018 年默蒂亚里换流站母线短路电流及短路比（不饱和值）
Table 3-1 Short circuit current and short circuit ratio of bus of Matiari Converter Station in 2018 (Unsaturated Value)

运行方式 Operation mode	三相短路电流(kA)/短路容量（MVA） Three-phase short circuit current (kA)/Short circuit capacity (MVA)	短路比 SCR	有效短路比 ESCR
正常 Normal	25.06/21701	5.43	4.82
塔尔电厂关机 1 台 Thar Power Plant-One Unit Shut Down	23.96/20749	5.19	4.58
胡布克电厂关机 1 台 Hubco Power Plant-One Unit Shut Down	24.45/21172	5.29	4.69
卡西姆电厂关机 1 台	23.51/20358	5.09	4.48

Qasim Power Plant-One Unit Shut Down			
默蒂亚里换流站～贾姆沙罗线路 N-1 Matiari Converter Station-Jamshoro N-1	23.95/20741	5.19	4.58
默蒂亚里换流站～摩洛线路 N-1 Matiari Converter Station-Moro N-1	24.40/21128	5.28	4.67
默蒂亚里换流站～新大都线路 N-1 Matiari Converter Station- Dadu New N-1	24.16/20924	5.23	4.62
塔尔电厂～默蒂亚里换流站线路 N-1 Thar Power Plant-Matiari Converter Station N-1	23.19/20201	5.05	4.44
卡西姆电厂～默蒂亚里换流站线路 N-1 Port Qasim Coal Power Plant-Matiari Converter Station N-1	24.21/20967	5.24	4.63
胡布克电厂～默蒂亚里换流站线路 N-1 Hubco power plant-Matiari Converter Station N-1	24.55/21260	5.32	4.71

从表 3-1 及 3-2 可见：南部 4 台电厂参数采用饱和值与采用不饱和值时有效短路比 (ESCR) 计算结果相比，大约相差 0.81-4.31%，不饱和值计算出来的最小短路电流水平更低，所以对于最小有效短路比的计算，推荐采用不饱和值得计算结果，即 ESCR 取 4.44。

From Table 3-1 and 3-2, the difference of ESCR results is about 0.08-4.31% when the parameters of 4 power plants are saturated ones compared with unsaturated ones. The ESCR with unsaturated parameters are lower than that with saturated ones. So it is recommended that the ESCR with unsaturated ones should be adopted, i.e. 4.44.

3.2 拉合尔换流站母线短路电流及短路比计算

Calculation of short circuit current and short circuit ratio of bus of Lahore Converter Station

使用 NTDC 提供的最小短路电流文件计算最小短路电流、SCR 及 ESCR，此文件中拉合尔-拉合尔北无线路连接，为 N-2 方式。同时计算拉合尔-拉合尔北站线路运行（全接线方式）以及线路检修时的母线短路电流和短路比。北部机组参数现使用不饱和参数，暂无饱和参数，计算结果如表 3-3 及 3-4 所示（饱和参数结果未计算）。

The short circuit current, SCR and ESCR of converter Lahore is calculated based on the minimum short circuit calculation file provided by NTDC. In this file, there is no line between Lahore- Lahore North. It is treated as an N-2 scenario. Besides this, the short circuit current, SCR and ESCR in full connection scenario and outage of lines are calculated. The parameters of power plants in the north are unsaturated ones and the saturated values haven't been provided. The calculation results are shown in Table 3-3 and 3-4 (The results with saturated ones are not provided).

表 3-3 2018 年拉合尔换流站母线短路电流及短路比（饱和值）
Table 3-3 Short circuit current and short circuit ratio of bus of Lahore Converter Station in 2018 (Saturated Value)

运行方式 Operation mode	三相短路电流(kA)/短路容量（MVA） Three-phase short circuit current (kA)/Short circuit capacity (MVA)	短路比 SCR	有效短路比 ESCR

注：NTDC 暂时未提供北部机组饱和参数，故暂未计算。
Note：NTDC has not provided the Saturated Value of North Units yet, so it can not be calculated.

表 3-4 2018 年拉合尔换流站母线短路电流及短路比（不饱和值）
Table 3-4 Short circuit current and short circuit ratio of bus of Lahore Converter Station in 2018 (Unsaturated Value)

运行方式 Operation mode	三相短路电流(kA)/短路容量（MVA） Three-phase short circuit current (kA)/Short circuit capacity (MVA)	短路比 SCR	有效短路比 ESCR
正常 Normal	17.53/15188	3.80	3.21
拉合尔换流站～拉合尔线路 N-1 Lahore Converter Station-Lahore line N-1	16.69/14456	3.61	3.03
拉合尔换流站～拉合尔南线路 N-1 Lahore Converter Station-Lahore south line N-1	17.05/14769	3.69	3.11
拉合尔换流站～拉合尔北线路 N-1 Lahore Converter Station-Lahore north line N-1	17.09/14800	3.70	3.12
拉合尔换流站附近 3 台燃气机未投运 Without 3 LNG Power Plants near Lahore	15.14/13111	3.28	2.70
受端 4 回接入交流系统(无拉合尔北) Access AC system of receiving-end 4-circuit (no Lahore north)	13.87/12127	3.03	2.45

从表 3-4 可见：无拉合尔北时，即 N-2 方式时，短路电流、SCR 及 ESCR 最低，所以 ESCR 取 2.45。

From table 3-4, the minimum short circuit current, minimum SCR and ESCR are obtained without Lahore North station, i.e. N-2 scenario. Therefore, the minimum ESCR is 2.45.

4. 最大短路电流

Maximum Short Current Circuit

最大短路电流是根据 NTDC 提供的文件，方式描述见 2.3。表 4-1 为南部 6 个电厂参数采用饱和参数时的计算结果，6 个电厂为塔尔安格鲁、塔尔坑口一区、胡布克燃煤电厂、卡西姆港、Lucky 燃煤电站、Sidqsns 燃煤电站；表 4-2 为南部 6 个电厂采用不饱和参数时的计算结果。北部电厂的参数均采用饱和值，不饱和值未提供。表 4-3 为采用饱和值时的计算结果。

The calculation of maximum short circuit current is based on the file provided by NTDC, its description is in Chapter 2.3. Table 4-1 is the calculation results when the parameters of the four power plants (EngroThar, SSRL, Hubco CFPP, Port Qasim, Lucky CFPP and Sidqsns CFPP) in the south are saturated ones and Table 4-2 are the results with unsaturated ones. The parameters of power plants in the north part are saturated ones and the unsaturated values are not provided. Table 4-3 are the results with saturated ones.

表 4-1 默蒂亚里最大短路电流水平（饱和值）

Table 4-1Maximum Short Circuit levels of Converter Matiari(Saturated Value)

Voltage Level / Short Circuit Levels	1.1 p.u.		1.05 p.u.		1.0 p.u.	
	3 ø kA / MVA	1 ø kA / MVA	3 ø kA / MVA	1 ø kA / MVA	3 ø kA / MVA	1 ø kA / MVA
Without Jamshoro - Dadu Circuit #2 In-out at Matiari	37.48 /32460	29.35/25419	36.03 /31206	24.43/28218	34.61 /29976	27.11 /23474
With Jamshoro - Dadu Circuit #2 In-out at Matiari	40.37/34963	33.13/28693	38.81/33609	31.85/ 27582	37.27/32281	30.59/26492

表 4-2 默蒂亚里最大短路电流水平（不饱和值）

Table 4-2Maximum Short Circuit levels of Converter Matiari (Unsaturated Value)

Voltage Level / Short Circuit Levels	1.1 p.u.		1.05 p.u.		1.0 p.u.	
	3 ø kA / MVA	1 ø kA / MVA	3 ø kA / MVA	1 ø kA / MVA	3 ø kA / MVA	1 ø kA / MVA
Without Jamshoro - Dadu Circuit #2 In-out at Matiari	37.00 /32045	29.29/25365	35.57 /30805	28.16/24382	34.17 /29588	27.04 /23419

With Jamshoro - Dadu Circuit #2 In-out at Matiari	39.28 /34014	32.61/28290	37.75 /32697	31.40/ 27195	36.27/31406	30.16/26121

表 4-3 拉合尔最大短路电流水平（饱和值）

Table 4-3 Maximum Short Circuit levels of Converter Lahore (Saturated Value)

Voltage Level / Short Circuit Levels	1.1 p.u.		1.05 p.u.		1.0 p.u.	
	3 φ kA / MVA	1 φ kA / MVA	3 φ kA / MVA	1 φ kA / MVA	3 φ kA / MVA	1 φ kA / MVA
Without Jamshoro - Dadu Circuit #2 In-out at Matiari	34.86 /30192	27.54/23852	33.57 /29071	26.52 /22966	32.30 /27974	25.52 /22099
With Jamshoro - Dadu Circuit #2 In-out at Matiari	34.86/30192	27.54/23852	33.57 /29071	26.52 /22966	32.30 /27974	25.52 /22099

表 4-4 拉合尔最大短路电流水平（不饱和值）

Table 4-4 Maximum Short Circuit levels of Converter Lahore (Unsaturated Value)

Voltage Level / Short Circuit Levels	1.1 p.u.		1.05 p.u.		1.0 p.u.	
	3 φ kA / MVA	1 φ kA / MVA	3 φ kA / MVA	1 φ kA / MVA	3 φ kA / MVA	1 φ kA / MVA

注：NTDC 暂时未提供不饱和参数，故暂未计算。

Note：NTDC has not provided the Unsaturated Value yet, so it can not be calculated.

从表 4-1 及 4-2 可见：南部 6 座电厂参数采用饱和值与不饱和值得计算结果相比，大约相差 2.75-2.8%，采用饱和值计算出来的最大短路电流水平更高，所以对于最大短路电流水平的计算，推荐采用饱和值得计算结果，即默蒂亚里站为 40.37 kA，拉合尔站为 34.86 kA。

From Table 4-1 and 4-2, the difference of ESCR results is about 2.75-2.8% when the parameters of 6 power plants are saturated ones compared with unsaturated ones. The short circuit currents with saturated parameters are higher than that with unsaturated ones. So it is recommended that the short circuit current with saturated ones should be adopted, i.e. the maximum short circuit current of Matiari is 40.37 kA, the maximum short circuit current of Lahore is 34.86 kA.

5. 短路电流计算结论

Conclusions

- 在系统小方式下，考虑线路 N-1 运行方式，发电机参数为不饱和值时，默蒂亚里换流站 500kV 母线侧短路比及有效短路比最小，分别为 5.05、4.44。
  The minimum SCR and ESCR of 500kV bus of Matiari Converter Station are 5.05 and 4.44 respectively when N-1 scenario is taken into consideration and the parameters of power plants are unsaturated ones in small operation means.
- 在系统小方式下，拉合尔北不接入拉合尔换流站，拉合尔换流站 500 kV 母线侧短路比及有效短路比最小，分别为 3.03、2.45。
  The minimum SCR and ESCR of 500kV bus of Lahore Converter Station are 3.03 and 2.45 respectively when N-2 scenario is taken into consideration and the parameters of power plants are unsaturated ones in small operation means.
- 在系统大方式下，使用发电机饱和参数，贾姆沙罗～新大都线路 π 入默蒂亚里换流站时，默蒂亚里换流站 500 kV 母线侧短路电流水平最大，为 40.37 kA；拉合尔换流站 500 kV 母线侧最大短路电流水平为 34.86 kA。
  The maximum short circuit current of the side of Matiari Converter Station 500 kV bus is obtained when the line Jamshoro- Dadu is π connected to Matiari Converter Station and the parameters of generators are saturated ones. The maximum short circuit current of Matiari Converter side is 40.37 kA. The maximum short circuit current of Lahore Converter side is 34.86 kA.

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巴基斯坦默蒂亚里—拉合尔±660kV直流输电工程

±660kV HVDC Project From Matiari to Lahore in Pakistan

可行性研究

Feasibility Study

电力系统一次

Power System Primary Part

换流站无功补偿及配置研究

Study of Reactive Power Compensation and configuration of converter station

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摘 要

对默蒂亚里换流站和拉合尔换流站的无功补偿装置（包括交流滤波器和并联电容器）分组进行了全面研究。研究结果推荐：默蒂亚里换流站采用16组无功补偿装置，小组容量采用150Mvar×9+180Mvar×7，总补偿容量2610Mvar。拉合尔换流站采用16组无功补偿装置，小组容量采用150Mvar×8+160Mvar×8，总补偿容量2480Mvar。

Abstract

A comprehensive study of reactive power compensation device（AC filter grouping or shunt capacitor） of Matiari Converter Station and Lahore Converter Station is conducted. The results recommend:

For Matiari Converter Station, 16 groups of reactive power compensation device are used, the subgroup capacity is 150Mvar×9+180Mvar×7 and the total compensation capacity is 2610Mvar.

For Lahore Converter Station, 16 groups of reactive power compensation device are used, the subgroup capacity is 150Mvar×8+160Mvar×8 and the total compensation capacity is 2480Mvar.

目录/CONTENTS

1 工程概况 Project overview

1.1 输送能力 Transmission capacity

巴基斯坦默蒂亚里-拉合尔 ±660kV 直流输电工程起点巴基斯坦南部信德省默蒂亚里，途径信德、旁遮普 2 省，落点中部旁遮普省拉合尔地区，直流线路长度约 878km，输电容量 4000MW，规划2018年投产。默蒂亚里换流站和拉合尔换流站都含有双极，每极一个 12 脉动换流器，采用单相双绕组换流变压器。额定输送功率为双极 4000MW、单极 2000MW。

Pakistan Matiari-Lahore ±660kV DC Transmission Project starts from Matiari, Sindh (in the south of Pakistan) to Lahore, Punjab (in the central area) via Sindh and Punjab, and the DC line is about 878km long, the power transmission capacity is 4000MW and it is to be put into operation in 2018.

Both Matiari Converter Station and Lahore Converter Station are bipolar, every pole has a 12-pulse converters and the converter transformer of single phase double winding is used.

The rated transmitting power is 4000MW for bipole and 2000MW for monopole.

默蒂亚里-拉合尔±660kV 直流输电工程功率正送方式时，从默蒂亚里换流站向拉合尔换流站传输功率能力如下：

While the power of Matiari-Lahore ±660kV DC Transmission Project is transmitted positively, the transmission power capacity from Matiari Converter Station to Lahore Converter Station is as below:

双极运行输送 4000MW；

Transmission of 4000MW under the bipolar operation;

单极金属回线运行方式输送 2000MW；

Transmission of 2000MW under mode of monopole metallic return;

单极大地回线运行方式输送 2000MW。

Transmission of 2000MW under mode of monopole ground return;

1.2 直流电压 DC voltage

默蒂亚里换流站的直流额定运行电压为±660kV，定义为平波电抗器出线侧直流极母线与直流中性点的电压。

The DC rated operating voltage of Matiari Converter Station is ±660kV, and it is defined as the voltage between DC pole bus at the side of outgoing line of smoothing reactor and DC neutral point.

当功率从默蒂亚里送往拉合尔换流站时，两端交流母线电压在连续稳态运行范围内(默蒂亚里 475～540kV，拉合尔 475～530kV)，直流电压降压至额定电压的 70%~100%，每一极都应能够连续运行。

When the power is transmitted from Matiari Converter Station to Lahore Converter Station, the AC bus voltage at both ends is within the scope of continuous steady-state operation (475～540kV for Matiari and 475～530kV for Lahore), DC voltage drop is 70%~100% of rated voltage and every pole shall be able to operate continuously.

1.3 运行方式 Operation mode

默蒂亚里-拉合尔 ±660kV 直流输电工程能够实现下列运行方式：

Matiari-Lahore ±660kv DC Transmission Project can achieve the operation mode as below:

当默蒂亚里换流站作为整流站，拉合尔换流站作为逆变站运行时，称为功率正送运行方式，这是常规运行方式；当默蒂亚里换流站作为逆变站，拉合尔换流站作为整流站运行时，称为功率反送运行方式。

When Matiari Converter Station operates as the rectifier station and Lahore Converter Station operates as the inverter station, it is called positive power output operation mode that is a conventional operation mode; when Matiari Converter Station operates as the inverter station and Lahore Converter Station operates as the rectifier station, it is called inverse power output operation mode.

1.4 直流电阻 DC resistance

默蒂亚里-拉合尔 ±660kV 直流输电工程直流线路路径总长 878km，采用 4×1250 mm^2 导线。

The DC line of Matiari-Lahore ±660kV DC Transmission Project is about 878km long, and the conductor type is 4×1250 mm^2

本工程根据 CET 现场实地调研及与 NTDC 确认：年平均环境温度取 25°，最低环境温度取-5°，最高环境温度取 52.5°（见 2015 年 7 月与 NTDC 会议纪要《Comments of Design》）。表 2-1 分别给出了本工程的最小，额定及最大直流线路电阻值。表中电阻值用于计算换流站无功总消耗，最大无功消耗采用最小值，最小无功消耗采用最大值。

CET did field research and confirmed with NTDC: The annual averaged environmental temperature is 25° , while its minimum and maximum value are respectively -5° and 52.5° (*Comments of Design*,MOM with NTDC, 2015 July). Table 2-1 shows the minimum, rated and maximum values of DC line resistance, in order to calculate the reactive power consumption in the converter station.

表 2-1 直流线路电阻

Table 2-1 DC line resistance

ITEM	**电阻 (Ω) Resistance (Ω)**		
	最小值 Minimum value	**额定值 Rated value**	**最大值 Maximum value**
环境温度 environmental temperature	-5°	25°	52.5°
直流线路电阻 DC line resistance	5.056	5.646	6.18

1.5 交流系统条件 AC system conditions

默蒂亚里-拉合尔 ±660kV 直流输电工程送端换流站接入南部信德省 500kV 交流电网，受端换流站接入旁遮普省拉合尔地区 500kV 交流电网。 两端换流站接入交流系统的电压及频率如表 2-2、2-3 所示。

The sending-end converter station of Matiari-Lahore ±660kV DC transmission project is connected to 500kV AC power grid of Sindh in the south of Pakistan, and the receiving-end converter station is connected to 500kV AC power grid of Lahore, Punjab.

The voltage and frequency of access AC system of converter station of both ends is shown as Table 2-2 and Table 2-3.

表 2-2 两端换流站接入交流系统的电压

Table 2-2 Voltage of access AC system of converter station of both ends

换流站 Converter station	默蒂亚里 Matiari	拉合尔 Lahore
额定运行电压 Rated operating voltage	510kV	510kV
最高稳态电压 Maximum steady voltage	540kV	530kV
最低稳态电压 Minimum steady voltage	475kV	475kV
最高极端电压 Maximum extreme voltage	550kV	550kV
最低极端电压 Minimum extreme voltage	450kV	450kV

表 2-3 两端换流站接入交流系统的频率

Table 2-3 Frequency of access AC system of converter station of both ends

换流站 Converter station	默蒂亚里 Matiari	拉合尔 Lahore
额定频率 Rated frequency	50	50
稳态频率偏差 Steady frequency deviation	±0.1	±0.1
故障清除后 10 分钟频率偏差 Frequency deviation for 10min upon clearing of fault	±0.2	±0.2
事故情况下频率偏差 Frequency deviation under accident conditions	49.4-50.5	49.4-50.5

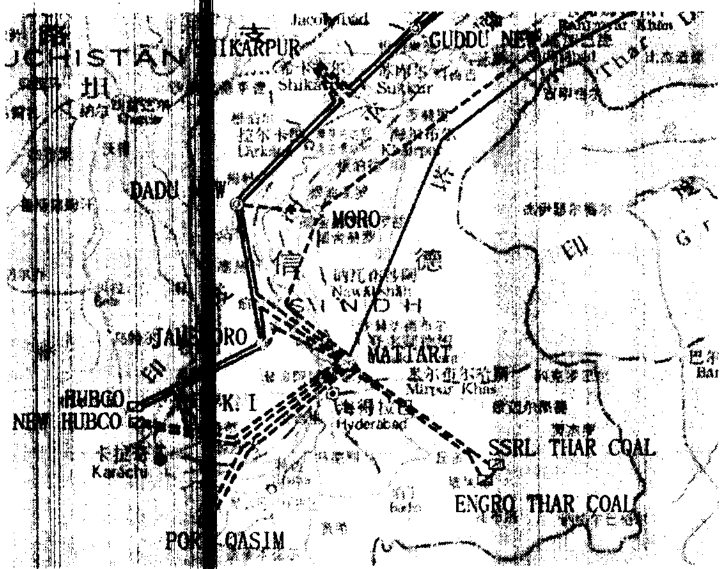

图2-1 送端换流站接入系统示意图

Fig. 2-1 Schematic diagram of access system of sending-end converter station

送端换流站接入系统如图 2-1 所示。默蒂亚里换流站 500kV 规划出线 12 回，本期 10 回，其中 6 回是电源进线，2 回至贾姆沙罗变电站、1 回至莫罗变电站、1 回至新大都变电站。

The access system of sending-end converter station is shown as Fig. 2-1.

The Matiari Converter Station has 12-circuit planned outgoing lines of 500kV, of which 10-circuit lines are in this stage, incl. 6-circuit being incoming lines, 2 to Jamshoro substation, 1 to Moro substation and 1 to Dadu New substation.

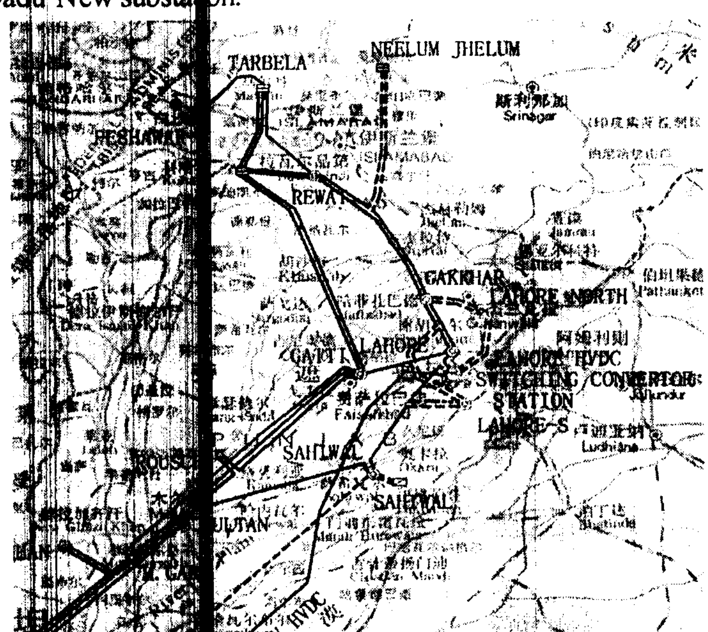

图2-2 受端换流站接入系统示意图

Fig. 2-2 Schematic diagram of access system of receiving-end converter station

受端换流站接入系统如图 2-2 所示。拉合尔换流站 500kV 规划出线 6 回，本期 6 回，其中 2 回至拉合尔变电站、2 回至拉合尔南变电站、2 回至拉合尔北变电站。

The access system of receiving-end converter station is shown as Fig. 2-2.

Lahore Converter Station has 6-circuit planned outgoing lines of 500kV, and all of them are in this stage, incl. 2 to Lahore substation, 2 to Lahore South substation and 2 to Lahore North substation.

1.6 制造公差、测量误差及控制误差 Manufacturing tolerance, measuring error and control error

在直流系统无功消耗设计中，需要考虑换流变压器阻抗的制造公差、直流电压测量装置、直流电流测量装置、交流电压测量装置以及控制系统计算误差等的影响，确保直流系统在各种运行方式下的安全可靠运行。 需要考虑的设备公差和测量偏差见下所示。

The influence of manufacturing tolerance of impedance of conversion transformer, measuring errors of DC voltage measuring equipment, DC current measuring equipment and AC voltage measuring equipment and calculation error of control system shall be considered to guarantee the safe and reliable operation of DC system under various operation modes while the design of reactive power consumption of DC system is executed.

The equipment tolerances and measured deviation that shall be considered are shown as below.

表 2-4 设备公差和测量偏差
Table 2-4 Equipment tolerances and measured deviation

参数 Parameter	描述 Description	误差 Error
d_x	δd_x 换流变相对感性压降的最大制造公差(δd_x) Maximum manufacturing tolerances of relative inductive voltage drop of conversion transformer (δd_x)	±5% d_{xN}
U_d	测量误差 δU_{dmeas} Measuring error δU_{dmeas}	±1% U_{dRN}
I_d	测量误差 δI_{dmeas} Measuring error δI_{dmeas}	±0.3% I_{dN}
U_{dio}	电容分压式电压互感器的测量误差 δ_{Udio} Measuring error of voltage transformer of capacitance divider δ_{Udio}	±1.0% U_{dioN}
γ	测量误差 δ_γ Measuring error δ_γ	±1.0°
α	测量误差 δ_α Measuring error δ_α	±0.5°

2 换流站无功补偿装置研究的基本原则 Principles of Research on Reactive Compensator of Converter Station

1） 无功分层分区就地平衡，不考虑远距离输送。
The reactive hierarchy and partition are balanced locally without considering the far-distance transmission.

2） 换流站的无功补偿总容量原则上按照直流系统全压输送额定功率时的无功消耗计算。

In principle, the total reactive compensation volume of the converter station is calculated on the basis of reactive power consumption when the rated power is transmitted via the full-voltage DC system.

3） 直流过负荷所需额外增加的无功补偿容量由换流站备用补偿分组容量来平衡。因此在换流站最大无功消耗的基础上增加一组备用容量，作为换流站无功补偿容量。

The additional reactive compensation capacity, required by the DC overload, shall be balanced by the backup compensation group capacity of the converter station. A set of reserve capacity is added as the reactive power compensation when the converter station has the maximum reactive consumption.

4） 直流换流站的无功平衡考虑包括换流站的无功损耗及各级电压出线无功损耗的一半。

In principle, the reactive power of the converter station is only equal to half of the sum of the reactive loss and consumption in converter station and reactive loss and consumption of the outgoing voltage line of each level.

5） 交流系统电压控制：根据规程规定，枢纽变电所二次侧母线的运行电压控制水平为网络额定电压的0.93～1.06倍，事故后不应低于网络额定电压的0.87倍。

Voltage control of AC system: according to the provision of regulation, the operation voltage control level of the secondary side bus of the hub substation shall be as 0.93-1.06 times as the rated voltage of network and shall not be less than 0.87 times as the rated voltage of network after the accident.

网络中任一点运行电压，在任何情况下严禁超过网络最高运行电压，正常情况下不应低于网络额定电压0.93-1.00倍，处于网络受端的变电所取低值。

In any case, the operating voltage at any point of the network shall not exceed the highest operation voltage of the network and shall not be less than 0.93-1.00 times of the rated voltage of network. The lower value shall be taken for the substation at the receiving end of the network.

在本次计算中500kV母线电压控制在475～540kV之间。

In this calculation, the 500kV bus voltage is controlled between 475 to 540kV.

另外，系统调压手段主要依靠调整发电机励磁，并辅之以可投切低压电抗器、电容器。

In addition, the voltage regulation means of system are mainly depended on the adjustment of the generator excitation. The low voltage reactor and capacitor can be switched, as the auxiliary means.

6） 发电机最大无功出力控制运行功率以不低于额定力率为限，最小无功出力对汽轮发电机，控制其功率因数不高于0.95，水轮发电机则以不进相为限。发电机机端电压水平控制在

额定电压的1.05～0.95倍。

The operation power factor for the maximum reactive power output control of generator shall not be less than the rated power factor, the power factor of the minimum reactive power output to the steam turbine shall be controlled below 0.95 and the water wheel generator shall be controlled in such a way that the phase is not advanced. The voltage level at the machine end of generator shall be controlled at 1.05-0.95 times of the rated voltage.

7） 换流站所装设的无功补偿装置一般与交流滤波器合并考虑。在直流小方式运行时，为满足滤波要求，需投入一定数量的滤波器，使换流站容性无功过剩，因此，要求交流系统或换流站有吸收一定容性无功的能力。

The reactive compensator installed on the converter station shall be considered to be combined with the AC filter, generally. When the DC small operation means is adopted, a certain number of filters shall be invested to realize the reactive excessive capacity of converter station and meet the filtering requirement. As a result, it is required that the AC system or the converter station is featured by the capacity of absorbing a certain amount of reactive capacity.

8） 本工程考虑换流站近区交流配套工程由巴基斯坦设计并建设，存在较多不确定性，因此，直流工程所消耗无功均考虑在站内补偿。

It is considering setting up the AC supporting works in the nearby location of converter station in this Project and such works are designed and constructed by the Pakistan party. As a quantity of uncertain factors exists, the reactive consumption of DC works is included in the station compensation range.

9） 换流站无功补偿装置分组一般在有效短路比最小的运行方式下考虑。由于无功小组投切引起的电压波动主要与当地机组的开机状态有关，因此，送端换流站同时考虑直流输送功率10%，即配套机组开机最小的情况；受端换流站同时考虑接入线路N-1的情况。

The reactive power grouping of the converter station is generally considered under the minimum ESCR operation mode. As the voltage fluctuation resulted from reactive subgroup switching is mainly related to the starting-up state of local units, the calculation of switching fluctuation of reactive subgroup of Mtiari converter station is executed with 10% transfer power of the HVDC which indicates minimum generation capacity on the sending end.

The calculation of switching fluctuation of reactive subgroup of Lahore converter station is executed with minimum ESCR and Line N-1.

3 换流站容性无功消耗 Capacitive reactive power consumption of converter station

3.1 额定无功消耗 Rated reactive power consumption

在常规功率传输方向和全直流电压双极运行方式下，当高压直流系统输送额定功率(4000MW，在默蒂亚里/整流器交流母线侧)时，考虑默蒂亚里换流站换流变短路阻抗取18%，拉合尔换流站换流变短路阻抗取18%，换流站额定无功消耗如表3-1。

Under the conventional power transmission direction and full DC voltage bipolar operation mode, the short circuit impedance of conversion transformer of Matiari Converter Station is 18% considered and that of Lahore Converter Station is 18% considered when the rated transmission power of high-voltage DC system is 4000MW at the side of AC bus of rectifier/Matiari, and the rated reactive power consumption of converter station is shown as Table 3-1.

表 3-1 换流站额定无功消耗

Table 3-1 Rated reactive power consumption of converter station

项目 Item	单位 Unit	默蒂亚里换流站 Matiari Converter Station	拉合尔换流站 Lahore Converter Station
		500kV	500kV
U_d	kV	660	642.9
U_{di0}	kV	378.5	369.3
U_v	kV	280.3	273.5
I_d	A	3030	3030
α（γ）	°	15	18
μ	°	23.2	22.1
d_x	p.u.	9	9
Q_{dc}	Mvar	2151.8	2183
直流电阻 DC resistance	Ω	5.646	

3.2 最大无功消耗 Maximum reactive power consumption

在无功消耗量计算中考虑可能的设备制造公差及系统测量误差等因素，使换流站无功消耗达到最大值，换流站最大无功消耗如表3-2。

Possible equipment manufacturing tolerances and measuring error of the system are considered during the calculation of reactive power consumption to make the reactive power consumption of converter station reach the maximum value and the maximum reactive power consumption of converter station is shown as Table 3-2.

表 3-2 换流站最大无功消耗

Table 3-2 Maximum reactive power consumption of converter station

项目 Item	单位 Unit	默蒂亚里换流站 Matiari Converter Station	拉合尔换流站 Lahore Converter Station
		500kV	500kV

U_d	kV	645.15	628
U_{di0}	kV	379.33	366.12
U_v	kV	280.9	271.1
I_d	A	3100	3100
α（γ）	°	18	18
μ	°	22.69	22.9
d_x	p.u.	9.45	9.45
Q_{dc}	Mvar	2387	2310.8
直流电阻 DC resistance	Ω	5.056	

默蒂亚里换流站最大无功消耗 Qdc 为 2387Mvar，拉合尔换流站最大无功消耗为 2311Mvar。
Maximum reactive power consumption Qdc of Matiari Converter Station is 2387Mvar and that of Lahore Converter Station is 2311Mvar.

3.3 10%小功率运行方式无功消耗 Reactive consumption of 10% low power operation mode

在常规功率传输方向和双极 10%小功率运行方式下，高压直流系统输送功率(400MW，在默蒂亚里换流站极线平抗出口侧)时，考虑默蒂亚里换流站换流变短路阻抗取 18%，触发角为 15°；拉合尔换流站换流变短路阻抗取 18%，熄弧角为 17°。换流站最小无功消耗如表 3-3。
Under the conventional power transmission direction and 10% low power bipolar operation mode, the short circuit impedance of conversion transformer of Matiari Converter Station is 18% considered and the trigger angle is 15° considered; that of Lahore Converter Station is 18% considered and the extinction angle is 17° when the transmission power of high-voltage DC system is 400MW at the side of outlet of smoothing reactor of pole of Matiari Converter Station.
The minimum reactive power consumption of Converter Station is shown as Table 3-3.

表 3-3 换流站最小无功消耗

Table 3-3 Minimum reactive power consumption of converter station

项目 Item	单位 Unit	默蒂亚里换流站 Matiari Converter Station	拉合尔换流站 Lahore Converter Station
		500kV	**500kV**
U_d	kV	674.85	673
U_{di0}	kV	353.32	354.69
U_v	kV	261.6	262.6
I_d	A	296	296
α（γ）	°	15	17
μ	°	3.7	3.3
d_x	p.u.	9	9
Q_{dc}	Mvar	122	135
直流电阻 DC resistance	Ω	6.18	

根据计算结果可以看出，直流 10%小负荷运行方式下，在正常触发角的条件下，默蒂亚里换流站无功消耗约为 122Mvar，拉合尔换流站无功消耗为 135Mvar。

It is shown that the reactive power consumption of Matiari Converter Station is about 122Mvar and that of Lahore Converter Station is 135Mvar under the condition of normal trigger angle under the operation mode of 10% small load according to the calculation result.

3.4 降压运行方式无功消耗 Reactive consumption of low voltage operation mode

在降压至 70%的运行方式下，高压直流系统输送功率(2800MW，在默蒂亚里换流站极线平抗出口侧)时，考虑默蒂亚里换流站换流变短路阻抗取 18%，换流变分接头在 23 档（最大档）；拉合尔换流站换流变短路阻抗取 18%，换流变分接头在最大档。 换流站无功消耗如表 3-4。

Under reduced voltage operation mode, the short circuit impedance of conversion transformer of Matiari Converter Station is considered 18% with the conversion transformer tapping at the 23ed(the maximum); that of Lahore Converter Station is 18% with the conversion transformer tapping at the maximum. The calculation result is shown in table 3-4.

表 3-4 换流站降压无功消耗

Table 3-4 The reactive power compensation of converter station under reduced operation voltage(70%)

项目 Item	单位 Unit	默蒂亚里换流站 Matiari Converter Station 500kV	拉合尔换流站 Lahore Converter Station 500kV
U_d	kV	462	444.9
U_{di0}	kV	299.86	292.59
U_v	kV	222	216.66
$U_{R(l)}$	kV	510	510
I_d	A	3030	3030
α (γ)	°	27.2	29.7
μ	°	21.3	20.4
d_x	p.u.	9	9
Q_{dc}	Mvar	2262	2297
直流电阻 DC resistance	Ω	5.646	

根据计算结果可以看出，降压运行方式下，默蒂亚里换流站、拉合尔换流站换相变分接头达到 23 档（最大档）的条件下，默蒂亚里换流站无功消耗约为 2262Mvar，拉合尔换流站无功消耗为 2297Mvar。

According to the calculation result, under reducd voltage operation mode and the conversion transformers of Matiari and Lahore converter stations taping to the maximum, the reactive power comsuption of Matiari converter station is 2143 Mvar; of Lahore converter station is 2186 Mvar.

符号说明（Symbols definition）

U_d	kV	Direct voltage
U_{di0}	kV	Ideal no-load direct voltage per 6-pulse converter

U_v	kV	Phase-to-phase voltage on the valve side of the converter transformer, r.m.s. value
$U_{R(I)}$	kV	Phase-to-phase voltage on the line side of the converter transformer, r.m.s. value
I_d	kA	Direct current
α	degrees	Firing angle
γ	degrees	Extinction angle
μ	degrees	Overlap angle
d_x		Relative inductive voltage drop
Q_{dc}	MVAr	Reactive power

4 换流站母线短路电流及短路比计算 Calculation of short circuit current and short circuit ratio of bus of converter station

4.1 默蒂亚里换流站母线短路电流及短路比计算 Calculation of short circuit current and short circuit ratio of bus of Matiari Converter Station

根据送端换流站接入系统设计，送端换流站母线短路比计算水平年为 2018 年，直流配套电源规模按 4620MW 考虑，计算包括正常、检修开机以及线路停运等特殊的运行方式。 计算结果如下：

According to the access system design of sending-end converter station, the calculation level year of short circuit ratio of bus of sending-end converter station is 2018, 4620MW is taken as the auxiliary DC power supply scale and the calculations include operation modes such as normal, maintenance, and line power outage and other special operation modes.

The calculation result is as below:

表 4-1 2018 年默蒂亚里换流站母线短路电流及短路比

Table 4-1 Short circuit current and short circuit ratio of bus of Matiari Converter Station in 2018

运行方式 Operation mode	三相短路电流(kA)/ 短路容量（MVA） Three-phase short circuit current (kA)/ Short circuit capacity (MVA)	短路比 SCR	有效短路比 ESCR
正常 Normal	25.13/21763	5.44	4.83
塔尔电厂关机 1 台 Thar Power Plant-One Unit Shut Down	23.95/20739	5.18	4.58
胡布克电厂关机 1 台 Hubco Power Plant-One Unit Shut Down	23.68/20505	5.13	4.52
卡西姆电厂关机 1 台 Qasim Power Plant-One Unit Shut Down	23.55/20395	5.10	4.49
默蒂亚里换流站～贾姆沙罗线路 N-1 Matiari Converter Station-Jamshoro N-1	23.31/20230	5.06	4.45
默蒂亚里换流站～摩洛线路 N-1 Matiari Converter Station-Moro N-1	23.74/20559	5.14	4.53
默蒂亚里换流站～新大都线路 N-1 Matiari Converter Station- Dadu New N-1	24.07/20845	5.21	4.60
塔尔电厂～默蒂亚里换流站线路 N-1 Thar Power Plant-Matiari Converter Station N-1	23.81/20620	5.16	4.55
卡西姆电厂～默蒂亚里换流站线路 N-1 Port Qasim Coal Power Plant-Matiari Converter Station N-1	24.32/21065	5.27	4.66
胡布克电厂～默蒂亚里换流站线路 N-1 Hubco power plant-Matiari Converter Station N-1	24.29/21033	5.26	4.65

贾姆沙罗～新大都线路未π入默蒂亚里换流站 Jamshoro- Dadu New not π connected to Matiari Converter Station	23.26/20195	5.05	4.44

由上述计算结果可知，在系统小方式下，考虑线路N-1运行方式，默蒂亚里换流站500kV母线侧短路比最低为5.06。若贾姆沙罗～新大都线路未π入默蒂亚里换流站，则短路比降到5.05，有效短路比降到4.44。

According to the above calculation result, it is known that the minimum short circuit ratio of the side of 500kV bus of Matiari Converter Station is 5.06 under small operation means with N-1 operation mode considered.

If Jamshoro- Dadu New is not π connected to Matiari Converter Station, the short circuit ratio is reduced to 5.05. The ESCR reduces to 4.44.

考虑直流投运初期，交流系统及电厂建设进度无法与直流工程匹配，直流无法满送，送端换流站母线短路电流计算结果如下所示：

As it is the early operation stage of DC project, the progress of AC system and power plant construction cannot match with the DC project and DC cannot transmit fully, and the calculation result of short circuit of bus of sending-end converter station is shown as below:

表 4-2 2018 年默蒂亚里换流站母线短路电流（直流功率 10%）

Table 4-2 Short circuit current of bus of Matiari Converter Station in 2018（HVDC 10% Transfer Power）

运行方式 Operation mode	三相短路电流(kA)/短路容量（MVA） Three-phase short circuit current (kA)/ Short circuit capacity (MVA)
送端4回接入交流系统 Access AC system of sending-end 4-circuit 塔尔电厂开机3台，电源进线2回 3 machines start-up in Thar Power Plant, 2-circuit incoming line of power supply	17.81/15420
送端3回接入交流系统 Access AC system of sending-end 3-circuit 塔尔电厂开机3台，电源进线2回 3 machines start-up in Thar Power Plant, 2-circuit incoming line of power supply	15.97/13830
送端2回接入交流系统 Access AC system of sending-end 2-circuit 塔尔电厂开机3台，电源进线2回 3 machines start-up in Thar Power Plant, 2-circuit incoming line of power supply	15.73/13622
送端2回接入交流系统 Access AC system of sending-end 2-circuit 塔尔电厂开机1台，电源进线2回 1 machine start-up in Thar Power Plant, 2-circuit incoming line of power supply	13.12/11360

4.2 拉合尔换流站母线短路电流及短路比计算 Calculation of short circuit current and short circuit ratio of bus of Lahore Converter Station

根据受端换流站接入系统设计，受端换流站母线短路比计算水平年为 2018 年，计算包括正常方式、线路 N-1 等运行方式。

According to the access system design of receiving-end converter station, the calculation level year of short circuit ratio of bus of receiving-end converter station is 2018, and the calculations include operation modes such as normal, and line N-1.

表 4-3 2018 年拉合尔换流站母线短路电流及短路比

Table 4-3 Short circuit current and short circuit ratio of bus of Lahore Converter Station in 2018

运行方式 Operation mode	三相短路电流(kA)/ 短路容量（MVA） Three-phase short circuit current (kA)/ Short circuit capacity (MVA)	短路比 SCR	有效短路比 ESCR
正常 Normal	29.35/25403	6.35	5.77
拉合尔换流站～拉合尔线路 N-1 Lahore Converter Station-Lahore line N-1	28.39/24621	6.15	5.57
拉合尔换流站～拉合尔南线路 N-1 Lahore Converter Station-Lahore south line N-1	28.63/24794	6.20	5.62
拉合尔换流站～拉合尔北线路 N-1 Lahore Converter Station-Lahore north line N-1	29.07/25137	6.29	5.71

由上述计算结果可知，在系统小方式下，考虑线路 N-1 运行方式，拉合尔换流站 500kV 母线侧短路比最低为 6.15，有效短路比为 5.57。

According to the above calculation result, it is known that the minimum short circuit ratio(SCR) of the side of 500kV bus of Lahore Converter Station is 6.15 under small operation means with N-1 operation mode considered. The ESCR is 5.67.

考虑直流投运初期，直流无法满送，交流系统建设进度无法与直流工程匹配，受端换流站母线短路比计算结果如下所示：

As it is the early operation stage of DC project, the progress of AC system construction cannot match with the DC project and DC cannot transmit fully, and the calculation result of short circuit ratio of bus of receiving-end converter station is shown as below:

表 4-4 2018 年拉合尔换流站母线短路电流及短路比

Table 4-4 Short circuit current and short circuit ratio of bus of Lahore Converter Station in 2018

运行方式 Operation mode	三相短路电流(kA)/ 短路容量（MVA） Three-phase short circuit current (kA)/ Short circuit capacity (MVA)	短路比 SCR	有效短路比 ESCR
受端 4 回接入交流系统(无拉合尔北) Access AC system of receiving-end 4-circuit (no	13.9/12870	3.22	2.64

Lahore north)			
受端 4 回接入交流系统(无拉合尔北) Access AC system of receiving-end 4-circuit (no Lahore north) 拉合尔换流站～拉合尔线路 N-1 Lahore Converter Station-Lahore line N-1	13.5/12130	3.03	2.45
受端 4 回接入交流系统(无拉合尔北) Access AC system of receiving-end 4-circuit (no Lahore north) 拉合尔换流站～拉合尔南线路 N-1 Lahore Converter Station-Lahore south line N-1	13.7/12617	3.15	2.57

由上述计算结果可知，在系统小方式下，考虑线路 N-1 运行方式，拉合尔换流站 500kV 母线侧短路比最低为 3.03，有效短路比为 2.45。

According to the above calculation result, it is known that the minimum short circuit ratio(SCR) of the side of 500kV bus of Lahore Converter Station is 3.03 under small operation means with N-1 operation mode considered. The ESCR is 2.45.

5 默蒂亚里换流站无功小组分组容量确定 Determination of grouping capacity of reactive subgroup of Matiari Converter Station

5.1 系统提供能力 System capability

根据默蒂亚里换流站接入系统设计报告，按照交流系统不向送端换流站提供无功考虑。

Based on the grid integration report of Matiari converter station, the AC system is considered not to provide reactive power to the sending end converter station.

5.2 无功分组容量确定 Determination of reactive grouping capacity

换流站无功补偿装置需分组投切运行，以适应直流各种运行方式。换流站无功分组有两种方式：一种是将每个小组直接接在换流站交流母线上，另一组是将几个小组组成一个大组再接在换流站交流母线上，现有的直流工程一般都采用后一种。无功分组容量必须满足系统暂态电压变化率及稳态电压调节的要求。本报告无功分组投切电压波动按以下选择确定。

The reactive power compensation device of converter station shall operate under group switching to adapt to various operation modes of DC.

There are two reactive grouping modes of converter station:

One is to connect every subgroup directly to the AC bus of converter station and the other is to first form several subgroup into a group and then connect it to the AC bus of converter station, and existing DC project generally takes the latter.

Reactive grouping capacity must meet the requirements of change ratio of system transient voltage and steady voltage regulation.

The reactive group switching voltage fluctuation in the report is determined according to the following selection.

1）投切分组的暂态电压变化率一般不大于 1.5%～2%，应根据系统条件在规定范围内确定限值；

1） The change ratio of transient voltage of group switching is generally not more than 1.5%～2% and the limit shall be determined within the specified range according to the system conditions;

2）投切分组的稳态电压变化率一般不大于换流变压器分接头步长的 75%～80%，即稳态交流母线电压变化应不导致换流变压器有载调压分接头动作。

2） Generally, the steady voltage change ratio of switching group is not greater than 75%～80% of the tapping step length of conversion transformer. Namely, the voltage change of steady AC bus shall not cause any action of on-load voltage-regulation tapping on conversion transformer.

5.3 无功小组投切电压波动计算 reactive subgroup switching voltage fluctuation calculation

5.3.1 直流小功率时的电压波动 Voltage fluctuation under DC low power（10%power）

1）基于 2018 年小方式，配套电源开机 3 台 660 机组，直流 10%功率下，投切无功小组，换流母线及换流站近区变电站母线电压波动如下表所示。表中基准值为 500kV。

1）The voltage fluctuation of bus of substation nearby the converter station and conversion bus is shown in the following table based on the small operation means of 2018, start-up of 3 auxiliary power supply machine of 660 units, 10% DC power, and reactive subgroup switching. The reference value in the table is 500kV.

表 5-1 默蒂亚里换流站 500kV 侧的电压波动情况

Table 5-1 Voltage fluctuation at the 500kV side of Matiari Converter Station

运行方式 Operation mode	分组容量 (Mvar) Grouping capacity (Mvar)	暂态电压波动 Transient voltage fluctuation		稳态电压波动 Steady voltage fluctuation	
		投入 Switching in	切出 Switching out	投入 Switching in	切出 Switching out
正常 Normal	150	1.58%	-1.51%	0.78%	-0.76%
	190	2.01%	-1.91%	0.99%	-0.96%
默蒂亚里换流站～贾姆沙罗线路 N-1 Matiari Converter Station-Jamshoro N-1	150	1.63%	-1.57%	0.85%	-0.85%
	170	1.86%	-1.77%	0.97%	-0.95%
	180	1.98%	-1.91%	1.03%	-1.00%
默蒂亚里换流站～摩洛线路 N-1 Matiari Converter Station-Moro N-1	150	1.65%	-1.56%	0.83%	-0.82%
	180	1.99%	-1.89%	1.01%	-0.98%
默蒂亚里换流站～新大都线路 N-1 Matiari Converter Station-Dadu New N-1	150	1.62%	-1.57%	0.82%	-0.77%
	180	1.96%	-1.85%	0.99%	-0.96%
电厂～默蒂亚里换流站线路 N-1 Power plant- Matiari Converter Station line N-1	150	1.76%	-1.67%	0.97%	-0.93%
	180	2.12%	-2.02%	1.16%	-1.12%

2）基于 2018 年小方式，考虑直流投运初期，交流系统及电厂建设进度无法与直流工程匹配，直流 10%功率下，投切无功小组，换流母线及换流站近区变电站母线电压波动如下表所示。表中基准值为 510kV。

2）As it is the early operation stage of DC project and the progress of AC system and power plant construction cannot match with the DC project, the voltage fluctuation of bus of substation nearby the converter station and conversion bus is shown in the following table based on the small operation means of 2018, 10% DC power, and reactive subgroup switching.

The reference value in the table is 5[illegible]kV.

表 5-2 默[illegible]亚里换流站 500kV 侧的电压波动情况

Table 5-2 Voltage fluc[illegible]ation at the 500kV side of Matiari Converter Station

运行方式 Operation mode	分组容量 (Mvar) Grouping capacity (Mvar)	暂态电压波动 Transient voltage fluctuation		稳态电压波动 Steady voltage fluctuation	
		投入 Switching in	切出 Switching out	投入 Switching in	切出 Switching out
贾姆肖罗～新大都站未 π 入默蒂亚里变电站 Jamshoro- Dadu New not π connected to Matiari Converter Station 配套电源开机 3 台 Start-up of 3 auxiliary power supply machines	150	1.65%	-1.57%	0.88%	-0.87%
	180	1.99%	-1.90%	1.05%	-1.03%
贾姆肖罗～新大都站未 π 入默蒂亚里变电站 Jamshoro- Dadu New not π connected to Matiari Converter Station 配套电源开机 1 台 Start-up of 1 auxiliary power supply machine	160	2.06%	-1.93%	1.02%	-1.00%

考虑到直流投运初期，交流系统及[illegible]电厂建设进度都存在不可控性，因此，为保证直流系统调试，应至少保证配套电源 1 台 660[illegible]W 机组开机，则无功小组容量在 160Mvar 以下是合理的，可以满足直流小方式下的运行要求。

As it is the early operation stage of [illegible]DC project and the progress of AC system and power plant construction is uncontrolled, the start[illegible]up of 1 auxiliary power supply machine of 660MW units shall be guaranteed at least, and reactive [illegible]ubgroup capacity of below 160Mvar is reasonable that may meet the operating requirement of D[illegible] small operation means.

5.3.2 直流大功率时的电压[illegible]动 Voltage fluctuation under DC high power

基于 2018 年数据，直流功率 200[illegible]W～4000MW，投切无功。 换流母线及换流站近区变电站母线电压波动如下表所示。

DC power is 2000MW～4000MW a[illegible] switching is reactive based on the data in 2018.

The voltage fluctuation of bus of s[illegible]bstation nearby the converter station and conversion bus is shown in the following table.

表 5-3 默[illegible]亚里换流站 500kV 侧的电压波动情况

Table 5-3 Voltage fluct[illegible]tion at the 500kV side of Matiari Converter Station

运行方式 Operation mode	分组容[illegible] (Mvar) Groupi[illegible] capacit[illegible] (Mva[illegible]	暂态电压波动 Transient voltage fluctuation		稳态电压波动 Steady voltage fluctuation	
		投入 Switching in	切出 Switching out	投入 Switching in	切出 Switching out

夏大方式 Summer maximum-load mode 4000MW 正常接线 Normal wiring mode	350	1.87%	-1.78%	0.96%	-0.92%
	360	1.92%	-1.83%	0.98%	-0.94%
夏小方式 Summer minimum-load mode 3000MW 正常接线 Normal wiring mode	300	1.81%	-1.72%	0.92%	-0.89%
	320	1.93%	-1.83%	0.98%	-0.96%
夏小方式 Summer minimum-load mode 2000MW，5 台机 2000MW, 5 machines 正常接线 Normal wiring mode	300	2.04%	-1.91%	0.94%	-0.93%
	310	2.11%	-1.99%	0.98%	-0.97%
夏小方式 Summer minimum-load mode 2000MW，5 台机 2000MW, 5 machines 默蒂亚里换流站～贾姆沙罗线路 N-1 Matiari Converter Station-Jamshoro N-1	280	1.96%	-1.83%	0.94%	-0.91%
	300	2.09%	-1.96%	1.00%	-0.97%
夏小方式 Summer minimum-load mode 2000MW，5 台机 2000MW, 5 machines 电厂～默蒂亚里换流站线路 N-1 Power plant- Matiari Converter Station line N-1	280	1.98%	-1.86%	0.96%	-0.94%
	300	2.13%	-1.99%	1.03%	-1.02%
夏小方式 Summer minimum-load mode 2000MW，5 台机 2000MW, 5 machines 贾姆肖罗～新大都站未 π 入默蒂亚里变电站 Jamshoro- Dadu New not π connected to Matiari Converter Station	150	1.27%	-1.25%	0.76%	-0.75%
	200	1.65%	-1.67%	1.00%	-1.00%

根据仿真可知，送端接入系统为4回时，无功小组分组容量不大于280Mvar可以满足直流半功率运行时的滤波器投切的暂稳态电压波动要求，如果贾姆肖罗～新大都站未π入默蒂亚里

变电站，则无功小组分组容量不大于 200Mvar 可以满足直流半功率运行时的滤波器投切的暂稳态电压波动要求。

According to the simulation, it is known that the grouping capacity of reactive subgroup is not greater than 280Mvar when the access system of sending-end is 4-circuit that may meet the requirements of transient and steady voltage fluctuations of filter switching during DC half-power operation and the grouping capacity of reactive subgroup is not greater than 200Mvar that may meet the requirements of transient and steady voltage fluctuations of filter switching during DC half-power operation when Jamshoro-Dadu New is not π connected to Matiari Converter Station.

5.4 小结与建议 Summary and suggestions

考虑最严苛方式，默蒂亚里换流站采用 16 组无功小组可满足直流系统各种方式运行要求，并根据成套设计研究结果，无功补偿装置分组方案如下：150×9+180×7=2610Mvar

其中 150Mvar 为交流滤波器，180Mvar 为并联电容器。

Regarding the strictest operation situation, 16 reactive power groups can satisfy various operation conditions of the DC system in Matiari converter station. The designing research results show the reactive power compensation plan as following: 150×9+180×7=2610Mvar

Within which 150Mvar for is the AC filter and 180Mvar is for the shunt capacitor Device.

6 默蒂亚里换流站大组分组研究 Grouping study of groups of Matiari Converter Station

6.1 默蒂亚里换流站分组方案及电压波动计算 Grouping scheme and voltage fluctuation calculation of Matiari Converter Station

结合上一小节的计算结果，小组容量取 150~180Mvar，默蒂亚里换流站共计 16 组无功小组，如果采用 4 大组，最大组的容量为 660Mvar。 如果采用 3 大组，最大组 990Mvar。

150~180Mvar is taken as the subgroup capacity and 16 groups of reactive subgroup are in the Matiari Converter Station according to the calculation result of the previous section, and the capacity of the largest group is 660Mvar in case 4 groups are taken.

The largest group is 990Mvar in case 3 groups are taken.

当无功需求达到 1860Mvar 后，就存在 4 组滤波器均投入的大组。 因此，直流功率达到约 3000MW 后，就需要考核大组投切的电压波动。

When the reactive power requirement reaches 1860Mvar, then a group with input of 4 groups of filters exists.

Therefore, it is necessary to check the voltage fluctuation of group switching when the DC power reaches about 3000MW.

本文研究 2018 年夏小方式，直流功率 3000MW 下，投切大组无功的电压波动如下表所示。 投切无功的电压波动需小于标准 6%的要求。

The summer minimum-load mode in 2018 is studied, and the voltage fluctuation of reactive power of group switching is shown in the following table under DC power of 3000MW.

The voltage fluctuation of reactive power of switching shall be less than the standard 6%.

表 6-1 夏小方式默蒂亚里换流站 500kV 侧的电压波动情况

Table 6-1 Voltage fluctuation at the 500kV side of Matiari Converter Station under summer minimum-load mode

运行方式 Operation mode	大组容量(Mvar) Group capacity (Mvar)	切出后暂态电压波动 Transient voltage fluctuation upon switching out
正常 Normal	1100	-5.78%
	1200	-6.27%
默蒂亚里换流站～贾姆沙罗线路 N-1 Matiari Converter Station-Jamshoro N-1	1100	-5.87%
	1130	-6.02%
默蒂亚里换流站～摩洛线路 N-1 Matiari Converter Station-Moro N-1	1100	-5.79%
	1200	-6.27%
默蒂亚里换流站～新大都线路 N-1 Matiari Converter Station- Dadu New N-1	1100	-5.80%
	1200	-6.28%
电厂～默蒂亚里换流站线路 N-1 Power plant- Matiari Converter Station line N-1	1090	-6.01%
	1100	-6.05%

贾姆沙罗～新大都线路未 π 入默蒂亚里换流站 Jamshoro- Dadu New not π connected to Matiari Converter Station		900	-5.40%
		1000	-6.08%

根据仿真可知，如果送端接入交流系统满足 4 回进线，则大组容量不大于 1090Mvar，换流站母线暂态电压波动满足要求，换流站可分为 3 大组，考虑贾姆沙罗～新大都 500kV 线路 π 入默蒂亚里换流站具有不确定性，则大组容量需小于 900Mvar，换流站分 4 大组才能满足暂态电压波动不超过 6%的要求。

According to the simulation, it is known that the group capacity is not greater than 1090Mvar and transient voltage fluctuation of bus of converter station meets the requirement if the access AC system of sending-end meets 4-circuit incoming line. The converter station can be divided into 3 groups and π connection of Jamshoro- Dadu New 500kV line to Matiari Converter Station is uncertain, so the group capacity shall be less than 900Mvar and that the transient voltage fluctuation cannot exceed 6% can be satisfied only if the converter station is divided into 4 groups.

6.2 小结 Summary

考虑贾姆沙罗～新大都 500kV 线路π入默蒂亚里换流站具有不确定性，因此默蒂亚里换流站采用 4 大组分组方案可以满足暂态电压波动不超过 6%的要求。 因此，默蒂亚里换流站目前采用 4 大组分组方案。

As π connection of Jamshoro- Dadu New 500kV line to Matiari Converter Station is uncertain, that the transient voltage fluctuation cannot exceed 6% can be satisfied only if Matiari Converter Station is divided into 4 groups.

Therefore, the grouping scheme of 4 groups is used in Matiari Converter Station presently.

7 拉合尔换流站换流站无功小组分组容量确定 Determination of grouping capacity of reactive subgroup of Lahore Converter Station

7.1 系统提供能力 System capability

根据拉合尔换流站接入系统设计报告，按照交流系统不向送端换流站提供无功考虑。

Based on the grid integration report of Lahore converter station, the AC system is considered not to provide reactive power to the sending-end converter station.

7.2 无功小组投切电压波动计算 reactive subgroup switching voltage fluctuation calculation

(1)受端新增 3 座燃气电站 3 Gas-fired Power Stations are added at the receiving-end

以下计算均以 2018 年计算水平年，计算直流输送 4000MW 功率时投切无功小组的电压波动。

The following calculations are based on the calculation level year 2018. The voltage fluctuation of reactive subgroup switching is calculated under DC transmission power of 4000MW.

由于无功小组投切引起的电压波动主要与当地机组的开机状态有关，所以选取系统的小方式并考虑线路 N-1 作为严苛的运行方式，对无功小组的投切波动进行计算，结果如下：

As the voltage fluctuation resulted from reactive subgroup switching is mainly related to the starting-up state of local units, the calculation of switching fluctuation of reactive subgroup is executed under the small operation means of the system and Line N-1 taken as the severe operation mode and the result is as below:

表 7-1 拉合尔换流站 500kV 母线电压波动

Table 7-1 500kV Bus voltage fluctuation of Lahore Converter Station

运行方式 Operation mode	分组容量 (Mvar) Grouping capacity (Mvar)	暂态电压波动 Transient voltage fluctuation		稳态电压波动 Steady voltage fluctuation	
		投入 Switching in	切出 Switching out	投入 Switching in	切出 Switching out
正常 Normal	190	1.80%	-1.98%	0.84%	-0.81%
	200	1.88%	-2.09%	0.88%	-0.85%
	220	2.03%	-2.30%	0.97%	-0.93%
拉合尔换流站～拉合尔线路 N-1 Lahore Converter Station-Lahore line N-1	190	1.82%	-2.01%	0.88%	-0.84%
	200	1.90%	-2.12%	0.93%	-0.89%
	210	1.98%	-2.22%	0.98%	-0.93%
拉合尔换流站～拉合尔南线路 N-1 Lahore Converter Station-Lahore south line N-1	190	1.79%	-1.98%	0.86%	-0.83%
	200	1.87%	-2.29%	0.91%	-0.87%
	220	2.02%	-2.48%	1.01%	-0.96%
拉合尔换流站～拉合尔北线路 N-1 Lahore Converter Station-Lahore north line	190	1.81%	-2.01%	0.87%	-0.83%
	200	1.89%	-2.11%	0.91%	-0.88%
	220	2.04%	-2.31%	1.01%	-0.97%

N-1					

计算结果表明： 小组容量小于等于 190Mvar，换流母线电压波动满足暂态波动要求以及稳态波动要求。

The calculation result shows:

The subgroup capacity is not greater than 190Mvar, and the voltage fluctuation of conversion bus meets the requirements of transient fluctuation and steady fluctuation.

(2)受端无 3 座燃气电站(夏小校核) No 3 Gas-fired Power Stations at the receiving-end (summer minimum check)

表 7-2 拉合尔换流站 500kV 母线电压波动

Table 7-2 500kV Bus voltage fluctuation of Lahore Converter Station

运行方式 Operation mode	分组容量 (Mvar) Grouping capacity (Mvar)	暂态电压波动 Transient voltage fluctuation		稳态电压波动 Steady voltage fluctuation	
		投入 Switching in	切出 Switching out	投入 Switching in	切出 Switching out
正常 Normal	170	1.78%	-1.95%	0.86%	-0.84%
	180	1.86%	-2.06%	0.91%	-0.88%
	190	2.01%	-2.25%	1.00%	-0.97%
拉合尔换流站～拉合尔线路 N-1 Lahore Converter Station-Lahore line N-1	170	1.82%	-2.01%	0.93%	-0.90%
	180	1.90%	-2.11%	0.98%	-0.95%
拉合尔换流站～拉合尔南线路 N-1 Lahore Converter Station-Lahore south line N-1	180	1.80%	-1.99%	0.91%	-0.87%
	190	1.88%	-2.08%	0.95%	-0.92%
	200	1.96%	-2.93%	1.00%	-0.97%
拉合尔换流站～拉合尔北线路 N-1 Lahore Converter Station-Lahore north line N-1	180	1.78%	-1.97%	0.88%	-0.85%
	190	1.87%	-2.05%	0.91%	-0.89%
	200	1.94%	-2.90%	0.98%	-0.95%

计算结果表明：如果受端无新增机组，小组容量小于 170Mvar，换流母线电压波动满足暂态波动要求以及稳态波动要求。

The calculation result shows:

If there is no new unit at the receiving-end,the subgroup capacity is smaller than 190Mvar, and the voltage fluctuation of conversion bus meets the requirements of transient fluctuation and steady fluctuation.

基于 2018 年小方式，考虑直流投运初期，拉合尔北变电站建设周期不可控，因此本研究校核无拉合尔北变电站的情况下（有效短路比最小的运行情况），投切无功，换流母线电压波动如下表所示。

As it is the early operation stage of DC project and the construction period of Lahore north substation is uncontrolled based on the small operation means of 2018, the reactive switching is taken and the voltage fluctuation of conversion bus is shown in the following table when there is no Lahore north substation(minimum ESCR operation mode) upon checking in this study.

表 7- 3 拉合尔换流站 500kV 母线电压波动

Table 7-3 500kV Bus voltage fluctuation of Lahore Converter Station

运行方式 Operation mode	分组容量 (Mvar) Grouping capacity (Mvar)	暂态电压波动 Transient voltage fluctuation		稳态电压波动 Steady voltage fluctuation	
		投入 Switching in	切出 Switching out	投入 Switching in	切出 Switching out
无拉合尔北 no Lahore north	150	1.46%	-1.48%	0.92%	-0.94%
	160	1.53%	-1.58%	0.99%	-1.00%
无拉合尔北 no Lahore north 拉合尔换流站～拉合尔线路 N-1 Lahore Converter Station-Lahore line N-1	150	1.49%	-1.52%	0.97%	-0.97%
	170	1.81%	-1.73%	1.05%	-1.07%
无拉合尔北 no Lahore north 拉合尔换流站～拉合尔南线路 N-1 Lahore Converter Station-Lahore south line N-1	150	1.47%	-1.50%	0.99%	-0.99%
	170	1.87%	-1.69%	1.36%	-1.13%

计算结果表明： 如果受端无新增机组，小组容量需小于 150Mvar，换流母线电压波动满足暂态波动要求以及稳态波动要求。

The calculation result shows:

If there is no new unit at the receiving-end, the subgroup capacity shall be smaller than 150Mvar, and the voltage fluctuation of conversion bus meets the requirements of transient fluctuation and steady fluctuation.

7.3 小结 Summary

考虑最严苛方式，拉合尔换流站采用 16 组无功小组可满足直流系统各种方式运行要求，并根据成套设计研究结果。无功补偿装置分组方案如下：160×8+150×8=2480Mvar

其中 160Mvar 为交流滤波器，150Mvar 为并联电容器。

Regarding the strictest operation situation, 16 reactive power groups can satisfy various operation conditions of the DC system in Lahore converter station. The designing research results show the reactive power compensation plan as following:

160×8+150×8=2480Mvar

within which 160Mvar for is the AC filter and 150Mvar is for the shunt capacitor Device

8 拉合尔换流站无功大组容量 Reactive group capacity of Lahore Converter Station

8.1 拉合尔换流站分组方案及电压波动计算 Grouping scheme and voltage fluctuation calculation of Lahore Converter Station

结合上一小节的计算结果，小组容量取 150~160Mvar，默蒂亚里换流站共计 16 组无功小组，如果采用 4 大组，最大组的容量为 620Mvar。 如果采用 3 大组，最大组 930Mvar。

150~160Mvar is taken as the subgroup capacity and 16 groups of reactive subgroup are in the Matiari Converter Station according to the calculation result of the previous section, and the capacity of the largest group is 620Mvar in case 4 groups are taken.

The capacity of the largest group is 930Mvar in case 3 groups are taken.

本报告考察了系统小方式下，切除无功大组后电压波动情况。 并此基础上，考虑换流站出线 N-1 的严苛运行方式。 计算结果如下：

The report studies the voltage fluctuation upon switching out of reactive group under the small operation means of the system.

On this basis, the severe operation mode of outgoing line N-1 is considered for the converter station.

The calculation result is as below:

表 8-1 夏小方式拉合尔换流站 500kV 侧的电压波动情况
Table 8-1 Voltage fluctuation at the 500kV side of Lahore Converter Station under summer minimum-load mode

运行方式 Operation mode	大组容量(Mvar) Group capacity (Mvar)	切出后暂态电压波动 Transient voltage fluctuation upon switching out
正常 Normal	600	-5.13%
	700	-6.11%
拉合尔换流站～拉合尔线路 N-1 Lahore Converter Station-Lahore line N-1	670	-5.93%
	700	-6.25%
拉合尔换流站～拉合尔南线路 N-1 Lahore Converter Station-Lahore south line N-1	600	-5.13%
	700	-6.12%
拉合尔换流站～拉合尔北线路 N-1 Lahore Converter Station-Lahore north line N-1	600	-5.21%
	700	-6.21%

根据仿真可知，无功大组分组容量不大于 670Mvar，可以满足暂态电压波动的要求。
According to the simulation, it is known that the grouping capacity of reactive group is not greater than 670Mvar and can meet the requirement of transient voltage fluctuation.

考虑受端满送方式下是无功分组主要校核方式，而夏小方式下并未满送，因此同时校核夏大方式拉合尔换流站切除无功大组后电压波动情况。

Because the voltage fluctuation of reactive grouping under full transmission at the receiving-end is mainly checked and no full transmission is executed under summer minimum-load mode, the voltage fluctuation of Lahore Converter Station upon switching out reactive group under summer maximum-load mode is checked at the same time.

表 8-2 夏大方式下拉合尔换流站 500kV 侧的电压波动情况

Table 8-2 Voltage fluctuation at the 500kV side of Lahore Converter Station under summer maximum-load mode

运行方式 Operation mode	大组容量(Mvar) Group capacity (Mvar)	切出后暂态电压波动 Transient voltage fluctuation upon switching out
正常 Normal	700	-5.62%
	800	-6.38%
拉合尔换流站～拉合尔线路 N-1 Lahore Converter Station-Lahore line N-1	720	-5.91%
	800	-6.53%
拉合尔换流站～拉合尔南线路 N-1 Lahore Converter Station-Lahore south line N-1	700	-5.64%
	800	-6.41%
拉合尔换流站～拉合尔北线路 N-1 Lahore Converter Station-Lahore north line N-1	700	-5.70%
	800	-6.48%

根据仿真可知，无功大组分组容量不大于 720Mvar，可以满足暂态电压波动的要求。

According to the simulation, it is known that the grouping capacity of reactive group is not greater than 720Mvar and can meet the requirement of transient voltage fluctuation.

考虑受端无新增机组时，夏小方式下，拉合尔换流站切除无功大组后电压波动情况。

The voltage fluctuation upon switching out of reactive group under the summer minimum-load mode is considered when there is no new unit at the receiving-end.

表 8-3 夏小方式下拉合尔换流站 500kV 侧的电压波动情况

Table 8-3 Voltage fluctuation at the 500kV side of Lahore Converter Station under summer minimum-load mode

运行方式 Operation mode	大组容量(Mvar) Group capacity (Mvar)	切出后暂态电压波动 Transient voltage fluctuation upon switching out
正常 Normal	620	-5.81%
	650	-5.98%
拉合尔换流站～拉合尔线路 N-1 Lahore Converter Station-Lahore line N-1	620	-5.99%
	650	-6.18%
拉合尔换流站～拉合尔南线路 N-1 Lahore Converter Station-Lahore south line N-1	620	-5.84%
	650	-6.04%
拉合尔换流站～拉合尔北线路 N-1 Lahore Converter Station-Lahore north line N-1	620	-5.78%
	650	-6.01%

根据仿真可知，无功大组分组容量不大于 620Mvar，可以满足暂态电压波动的要求。

According to the simulation, it is known that the grouping capacity of reactive group is not greater than 620Mvar and can meet the requirement of transient voltage fluctuation.

8.2 小结 Summary

根据计算结果，拉合尔换流站采用4大组分组方案可以满足暂态电压波动不超过6%的要求。
According to the calculation result, the grouping scheme of 4 groups taken by Lahore Converter Station can meet the requirement that the transient voltage fluctuation cannot exceed 6%.

9 感性无功补偿装置配置优化 Configuration optimization of inductive reactive power compensation devices

Q_r 一般来说，直流最小运行方式下，需要换流站吸收的总无功功率按下式计算：

Generally, the total reactive power that shall be absorbed by converter station under the minimum DC operation mode is calculated according to the following formula:

$$Q_r = Q_{f\min} - \frac{Q_{ac} + Q_{dc}}{U^2}$$

式中，

Where,

Q_r 为在正常电压下换流站并联电抗器吸收的总无功；

Q_r is the total reactive power absorbed by shunt reactor of converter station under normal voltage;

Q_{ac} 为在计算无功吸收设备时，允许从换流站流进交流系统的最大无功;

Q_{ac} is the maximum reactive power flowed from converter station to AC system permitted during the calculation of reactive absorption device;

Q_{dc} 为在计算无功吸收设备时，计算的直流系统无功需求；

Q_{dc} is the calculated reactive power requirement of DC system during the calculation of reactive absorption device;

$Q_{f\min}$ 为在正常电压下，由最少交流滤波器组所产生的无功；

$Q_{f\min}$ is the reactive power generated by the minimum AC filter group under normal voltage;

U 为设计时考虑的交流母线标么值电压，取值为 1.0。

U is the per-unit voltage of AC bus during design and it is 1.0.

9.1 默蒂亚里换流站感性无功补偿装置配置 Configuration of inductive reactive power compensation devices of Matiari Converter Station

9.1.1 直流系统小方式下感性无功需求 Inductive reactive power requirement under the small operation means of DC system

按照滤波器单组容量 150Mvar、最小运行方式下投入两组滤波器考虑；交流系统对默蒂亚里换流站没有无功吸收能力。 因此，默蒂亚里换流站直流最小运行方式(仅考虑双极 10%运行方式)下无功平衡结果如下所示：

2 groups of filters are input for consideration under the minimum operation mode according to the single group capacity of 150Mvar of filter; AC system is not capable of reactive absorption capacity of Matiari Converter Station.

Therefore, the reactive balance result under the minimum DC operation mode (only 10% bipolar operation mode considered) of Matiari Converter Station is shown as below:

表 9-1 默蒂亚里换流站小方式下的无功平衡

Table 9-1 Reactive balance of Matiari Converter Station under the small operation means

直流功率(MW) DC power (MW)		400	400
投入滤波器容量(Mvar) Filter capacity input (Mvar)		1×150	2×150
换流站无功消耗(Mvar) Reactive consumption of converter station (Mvar)		122	122
无功平衡(Mvar) Reactive balance (Mvar)		28	178

可以看出，在正常触发角的条件下，在直流双极 10%运行方式下，换流站容性无功剩余约178Mvar，容性无功有剩余。

考虑到换流站与系统无功交换死区约为 90Mvar，双极运行时，需要补偿 88Mvar 感性无功。相关补偿方案与 500kV 线路无功平衡统筹考虑。（详见 9.1.2）

It is shown that about 178Mvar of capacity reactive power of converter station is the rest and the capacity reactive power is surplus under the condition of normal trigger angle and 10% bipolar DC operation mode.

88Mvar of inductive reactive power shall be compensated during bipolar operation because it is about 90Mvar between the converter station and exchange dead zone of reactive power of the system. Relevant compensation plans shall be considered together with the overall planning of 500kV line reactive balance. （with 9.1.2）

9.1.2 交流系统无功平衡情况 Reactive balance of AC system

默蒂亚里换流站本期 500kV 出线 10 回，其中 6 回为电源进线，线路长度在 180~245km 左右。另外 4 回接入系统，2 回至贾姆沙罗变电站，线路长度分别为 40km、43km，1 回至摩洛变电站，线路长度 165km，1 回至新大都变电站，线路长度 172km；500kV 默蒂亚里换流站感性无功平衡见表 9-2 所示。

Matiari Converter Station has 10-circuit 500kV outgoing lines, of which 6-circuit is the incoming line and the line is about 180~245km long.

As for the other 4-circuit access system, 2 to Jamshoro substation, with respective line length of 40km and 43km, 1 to Moro substation with line length of 165km and 1 to Dadu New substation with line length of 172km; Inductive reactive power balance of 500kV Matiari Converter Station is shown in Table 9-2.

表 9-2 默蒂亚里换流站感性无功平衡

Table 9-2 Inductive reactive power balance of Matiari Converter Station

项目 Item	长度 Length	充电功率 Charging power	充电功率 Charging Power	首端高抗 Head end High reactance	末端高抗 Tail end High reactance	高抗补偿度 High reactance Compensation degree
	(km)	(Mvar/100 km)	(Mvar)	(Mvar)	(Mvar)	
塔尔电厂～默蒂亚里换流站 I 回 Thar Power Plant-Matiari Converter Station circuit I	[illegible]45	128	313.6	150	120	86.10%
塔尔电厂～默蒂亚里换流站 II 回 Thar Power Plant-Matiari Converter Station circuit II	[illegible]45	128	313.6	120	150	86.10%
胡布克电厂～默蒂亚里换流站 I 回 Hubco Power Plant-Matiari Converter Station circuit I	[illegible]20	128	281.6	120	120	85.23%
胡布克电厂～默蒂亚里换流站 II 回 Hubco Power Plant-Matiari Converter Station circuit II	[illegible]20	128	281.6	120	120	85.23%
卡西姆电厂～默蒂亚里换流站 I 回 Qasim Power Plant-Matiari Converter Station circuit I	[illegible]80	128	230.4	90	120	91.15%
卡西姆电厂～默蒂亚里换流站 II 回 Qasim Power Plant-Matiari Converter Station circuit II	[illegible]80	128	230.4	120	90	91.15%
贾姆沙罗～默蒂亚里换流站 I 回 Jamshoro-Matiari Converter Station circuit I	[illegible]3	100	43	134.31	0	
摩洛～默蒂亚里换流站 Moro-Matiari Converter Station	[illegible]65	100	165	134.31	0	
贾姆沙罗～默蒂亚里换流站 II 回 Jamshoro-Matiari Converter Station circuit II	[illegible]40	100	40	66	0	
新大都～默蒂亚里换流站 Dadu New-Matiari Converter Station	[illegible]72	100	172	66	90	90.70%
换流站需补偿线路充电功率 Charging power to be compensated for line by the converter station			962			
500kV 电源送出线路容性无功未补偿容量 500KV power outgoing line			0			

Uncompensated capacity of capacitive reactive power		
站内高抗容量 Instation high reactance capacity		810
换流站小功率下的无功缺额 Reactive power shortage of converter station under low power		88
站内低抗容量 Instation low reactance capacity		0
感性无功缺额(+缺-盈) Inductive reactive power shortage (+shortage,-surplus)		240

按照以往工程经验，换流站配套电源汇集线路充电功率应在电厂侧补偿，但因本次线路过长，为能平均补偿线路充电功率，考虑在线路两侧补偿。

According to previous engineering experience, charging power of collective line of auxiliary power source for the converter station shall be compensated at power plant side. But due to overlength of this line, to make the charging power of compensated line averaged, compensation shall be considered at both sides of the line.

由表 9-2 可知，在默蒂亚里换流站补偿线路高抗 810Mvar 的前提下，默蒂亚里换流站感性无功缺额为 240Mvar。

From Table 9-2, we find that under the premise of 810Mvar high reactance of compensation line for Matiari Converter Station, inductive reactive power shortage of Matiari Converter Station is 240Mvar.

综合默蒂亚里换流站 500kV 出线感性无功补偿需求和直流小方式下换流站感性无功补偿需求，建议在默蒂亚里换流站配置 4×60Mvar 低抗。

With synthesizing inductive reactive power compensation demand of 500kV outgoing lines and the converter station in DC mode, we recommend that 4×60Mvar low reactance shall be configured in Matiari Converter Station.

9.2 拉合尔换流站感性无功补偿装置配置 Configuration of inductive reactive power compensation devices of Lahore Converter Station

9.2.1 直流系统小方式下感性无功需求 Inductive reactive power requirement under the small operation means of DC system

按照滤波器单组容量 160Mvar、最小运行方式下投入两组滤波器考虑；交流系统对默蒂亚里换流站没有无功吸收能力。因此，默蒂亚里换流站直流最小运行方式(仅考虑双极 10%运行方式)下无功平衡结果如下所示：

2 groups of filters are input for consideration under the minimum operation mode according to the single group capacity of 160Mvar of filter; AC system is not capable of reactive absorption capacity of Matiari Converter Station.

Therefore, the reactive balance result under the minimum DC operation mode (only 10% bipolar operation mode considered) of Matiari Converter Station is shown as below:

表 9-3 拉合尔换流站小方式下的无功平衡

Table 9-3 Reactive balance of Lahore Converter Station under the small operation means

直流功率(MW) DC power (MW)		400	400
投入滤波器容量(Mvar) Filter capacity input (Mvar)		1×160	2×160
换流站无功消耗(Mvar) Reactive consumption of converter station (Mvar)		135	135
无功平衡(Mvar) Reactive balance (Mvar)		25	185

可以看出，在正常触发角的条件下，在直流双极 10%运行方式下，换流站容性无功剩余约 185Mvar，容性无功有剩余。

考虑到换流站与系统无功交换死区约为 90Mvar，双极运行时，需要补偿 95Mvar 感性无功。相关补偿方案与 500kV 线路无功平衡统筹考虑。（详见 9.2.2）

It is shown that about 185Mvar of capacity reactive power of converter station is the rest and the capacity reactive power is surplus under the condition of normal trigger angle and 10% bipolar DC operation mode.

95Mvar of inductive reactive power shall be compensated during bipolar operation because it is about 90Mvar between the converter station and exchange dead zone of reactive power of the system.Relevant compensation plans shall be considered together with the overall planning of 500kV line reactive balance. （with 9.2.2）

9.2.2 交流系统无功平衡情况 Reactive balance of AC system

拉合尔换流站本期 500kV 出线 6 回，π 接拉合尔～撒西瓦尔 500kV 线路，π 接线路长度 2×2km，π 接拉合尔～拉合尔南 500kV 线路，π 接线路长度 2×12.5km，2 回至拉合尔北 500kV 变电站，线路长度 2×60km。

Lahore Converter Station has 6-circuit 500kV outgoing lines, π connection of Lahore-Sahiwal 500kV line with length of 2×2km, π connection of Lahore- South Lahore 500kV line with length of 2×12.5km, 2 lines to Lahore north 500kV substation with length of 2×60km.

500kV 拉合尔换流站感性无功平衡见表 9-4 所示。

Inductive reactive power balance of 500kV Lahore Converter Station is shown in Table 9-4.

表 9-4 拉合尔换流站小方式下的无功平衡

Table 9-4 Reactive balance of Lahore Converter Station under the small operation means

项目 Item	长度 Length	充电功率 Charging power	充电 Charging 功率 Power	首端 Head end 高抗 High reactance	末端 Tail end 高抗 High reactance	高抗 High reactance 补偿度 Compensation degree
	(km)	(Mvar/100 km)	(Mvar)	(Mvar)	(Mvar)	

拉合尔～拉合尔换流站 I 回 Lahore-Lahore Converter Station circuit I	36	100	36			0
拉合尔～拉合尔换流站 II 回 Lahore-Lahore Converter Station circuit II	53	100	53			0
拉合尔南～拉合尔换流站 I 回 Lahore south-Lahore Converter Station circuit I	21	100	21			0
拉合尔南～拉合尔换流站 II 回 Lahore south-Lahore Converter Station circuit II	20	100	20			0
拉合尔北～拉合尔换流站 I 回 Lahore north-Lahore Converter Station circuit I	60	100	60			0
拉合尔北～拉合尔换流站 II 回 Lahore north-Lahore Converter Station circuit II	60	100	60			0
换流站需补偿线路充电功率 Charging power to be compensated for line by the converter station		130				
500kV 电源送出线路 500KV power outgoing line 容性无功未补偿容量 Uncompensated capacity of capacitive reactive power		0				
站内高抗容量 Instation high reactance capacity		0				
换流站小功率下的无功缺额 Reactive power shortage of converter station under low power		95				
站内低抗容量 Instation low reactance capacity		0				
感性无功缺额(+缺-盈) Inductive reactive power shortage (+shortage,-surplus)		225				

由表 9-4 可知，拉合尔换流站感性无功缺额为 225Mvar。

From Table 9-4, inductive reactive power shortage of Lahore Converter Station is 225Mvar.

综合拉合尔换流站 500kV 出线感性无功补偿需求和直流小方式下换流站感性无功补偿需求，建议在拉合尔换流站配置 4×60Mvar 低抗。

With synthesizing inductive reactive power compensation demand of 500kV outgoing lines and the converter station in DC mode, we recommend that 4×60Mvar low reactance shall be configured in Lahore Converter Station.

10 研究结论 Study conclusions

(1) 默蒂亚里换流站交流系统无法提供容性无功支持。

(1) The AC system of Matiari Converter Station is not capable of providing reactive support.

(2) 默蒂亚里换流站最大无功消耗 2387Mvar；拉合尔换流站最大无功消耗为 2311Mvar。

(2) The maximum reactive power consumption of Matiari Converter Station is 2387Mvar; The maximum reactive power consumption of Lahore Converter Station is 2311Mvar.

(3) 默蒂亚里换流站推荐配置 16 组无功小组，分组方案为： 150×9+180×7=2610Mvar；拉合尔换流站推荐配置 16 组无功小组，分组方案为： 160×8+150×8=2480Mvar。

(3) 16 groups of reactive subgroups are recommended in Matiari Converter Station, and the grouping scheme is:

150×9+180×7=2610Mvar;

16 groups of reactive subgroups are recommended in Lahore Converter Station, and the grouping scheme is:

160×8+150×8=2480Mvar.

(4) 默蒂亚里换流站采用 4 大组分组方案；拉合尔换流站采用 4 大组分组方案。

(4) The grouping scheme of 4 groups is used in Matiari Converter Station; The grouping scheme of 4 groups is used in Lahore Converter Station.

(5) 默蒂亚里换流站需配置 4×60Mvar 低压电抗器，拉合尔换流站站用变低压侧共布置 4×60Mvar 低压电抗器。

(5) 4×60Mvar low voltage reactors shall be configured in the Matiari Converter Station, and 4×60Mvar low voltage reactors are installed at the low voltage side of converter station transformer in Lahore converter station.

(6) 根据以上计算结果，工程采用送受端 4 大组 16 小组方案满足正常及严苛条件下系统电压波动范围要求，因此不需采用 SVC 等动态无功补偿装置。

(6) Based on the above results, the project adopted by the 4 groups sending 16 subgroups plan to meet under normal and harsh conditions of the system voltage fluctuation range requirements in Matiari Converter Station and Lahore Converter Station, eliminating the need for the use of SVC and other dynamic reactive power compensation device.