# APPLICATION FOR 50 MW WIND POWER PLANT GENERATION LICENSE

*[Triplicate]*

IPWPPL

## IRAN-PAK WIND POWER PVT LTD

**IRAN-PAK Wind Power (Pvt) Ltd**
Suite # 214, 2nd Floor, Progressive Plaza
Beaumont Road, Karachi - Pakistan
Tel: +9221-3565.7456 +9221-3565.7457
Fax: +9221-3565.7458
E-mail: planetgroup@cyber.net.pk
REGD: [Suite No 414, 4th Floor Progressive Plaza Beaumont Road Karachi Pakistan]

7th June 2016

Ref No. IPWPPL/NEPRA/66/16

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

**Subject: Application for Generation License**

I, Khurram Sayeed, Chief Executive Officer, being the duly authorized representative of Iran Pak Wind Power (Pvt) Ltd by virtue of Board Resolution dated 15th February 2016, hereby apply to the National Electric Power Regulatory Authority for the grant of a Generation License to Iran Pak Wind Power (Pvt) Ltd pursuant to section 15 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 Bank Draft No. 01487125 Dated 4th June 2016 drawn on Bank Al Habib Ltd M.A. Jinnah Rd Branch Karachi in the sum of Rs. 286,016/= (Pakistan Rupees Two Hundred Eighty Six Thousand Sixteen Only) being the non-refundable license application fee calculated in accordance with Schedule II of the National Electric Power Regulatory Authority Licensing (Application and Modification Procedure) Regulations, 1999, is also attached herewith.

The application is filed in triplicate with all annexure with each set of the application.

Sincerely,

Khurram Sayeed
CEO

Encl: 1. Bank Draft No. 01487125 Dated 4th June 2016
2. Board Resolution
3. Affidavit
4. Annexures

# IRAN-PAK Wind Power (Pvt) Ltd

Suite # 214, 2nd Floor, Progressive Plaza
Beaumont Road, Karachi - Pakistan
Tel: +9221-3565.7456 +9221-3565.7457
Fax: +9221-3565.7458
E-mail: planetgroup@cyber.net.pk
REGD: [Suit No 414, 4th Floor Progressive Plaza Beaumont Road Karachi Pakistan]


Date : 15th Feb 2016

**RESOLUTIONS OF THE BOARD OF DIRECTORS OF IRAN PAK WIND POWER PVT LTD BY CIRCULATION**

**No. 07/2016**

RESOLVED THAT

Iran Pak Wind Power Private Limited ("Company") be and is hereby authorized to file an application for Generation License (including any motions, applications, review motions or re-filings of fresh generation license application) for the Company's proposed IRAN PAK WIND POWER PROJECT (49.5 MW) IN JHIMPIR, SINDH, PAKISTAN (the "Application", and the "Project").

Mr. Khurram Sayeed, Chief executive officer of the Company, be and is hereby authorized by and for and on behalf of the Company, to do all actions and take all measures as may be necessary or appropriate in connection with the filing, presentation and pursuit of the Application, including, without limitation:

i. to sign, file, amend or withdraw the Application, affidavits, powers-of-attorney, statements forms, applications, deeds, certificates, interrogatories, correspondence, replies to information directions, interrogatories, discovery directions or any other documents and instruments as may be necessary or appropriate;
ii. make all filings and pay all applicable fees in connection with the Application;
iii. to appoint and remove consultants, attorneys and advisers;
iv. represent the Company in person or through attorneys, advocates or representatives in all negotiations, representations, presentations, hearings, conferences or meetings of any nature whatsoever with any entity (including, but not limited to NEPRA, private parties, companies, partnerships, individuals, governmental or statutory authorities and agencies, ministries, boards and departments, regulatory authorities or any other entity of any nature whatsoever); and
v. generally to do all other things and take all actions as may be required in connection with the Application until the award of the tariff and further also for any revisions or modifications to the tariff awarded by NEPRA at any stage whatsoever as may be considered fit and appropriate by him in his estimation.

The above resolution was duly passed by circulation by the Board of Directors in accordance with the Articles of Association of the Company.

| Directors and person Authorized to sign Name in full (In CAPITAL Letters) | Official position | Specimen Signature |
|---|---|---|
| MEHDI POURHASHEM | Director | |
| HOOSHANG GHAJARJAZI | Director | |
| EHSAN NADJAFI SEMNANI | Director | |
| SALMAN TUFAIL | Director | Salman Tufail |
| KHURRAM SAYEED | Director | |
| TARIQ SAYEED | Director | |

We further certify that the specimen signatures recorded above are correct.

**11. CV of the Technical and Professional Staff..............................................................Annexure AA**

**12. Evidence regarding availability of adequate financial...............................................Annexure AB and technical resources**

a. Cash balances held in reserve along with the bank certificates;
   i. Letter of Local Bank Attached (in favor of Main Sponsor)

b. Expressions of interest to provide credit or financing................................................Annexure AC along with sources and details thereof;
   i. Letter of Foreign Bank [ Export Department Bank of Iran] Attached AlongwithCertified Translation
   ii. EOI [Term Sheet of Local Bank] Attached

c. Latest financial statements of the applicant.......................................................Annexure AD
   i. Sunir Co, Iran
   ii. Tufail Group

d. Employment records of engineering and technical staff of the applicant proposed to be employed (CV's Attached as Annexure AA)

e. Profile of EPC-Contractors, VESTAS, along with.................................................Annexure AE expressions of interest and verifiable references
   i. VESTAS experience in Wind Sector (As EPC Contractors)
   ii. Case Study Macarthur Wind Farm

f. Verifiable references in respect of the experience.................................................Annexure A of the applicant
   i. Sponsors (Sunir Co.) Experience in Power Sector

13. Technical and Financial proposal for Operation, Maintenance, Planning & Development of the 50 MW IPWPPL Wind Power Generation Facility:

i. Summary of the Technical Details of Proposed Facility..........................................Annexure A

**ii. Executive Summary of Electrical Grid Interconnection Study................................Annexure A Alongwith Appendices**

**iii. Feasibility Study..................................................................................Annexure A**

iii. (a) General Specifications of Vestas 3.3 WTG..................................................Annexure A.

iii. (b) Topography Map of Iran Pak Wind Power Pvt Ltd.............................................Annexure A

**iv. Suitability of Site For IEE.................................................................Annexure A**

a. Executive Summary
b. Layout of Site
c. Layout of Grid Station
d. Letter Of SEPA
e. Pakistan Environmental Protection Agency (Review Of IEE And EIA) Regulations, 2000

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   d. Letter Of SEPA
   e. Pakistan Environmental Protection Agency (Review Of IEE And EIA) Regulations, 2000

# ***Document Structure***

| | |
|---|---|
| 1. Prospectus | Annexure A |
| 2. Project Information | Annexure B |
| 3. Certificate of Incorporation (Duly Certified from SECP) | Annexure T |
| 4. Memorandum & Articles of Association (Duly Certified from SECP) | Annexure U |
| 5. Latest Annual Return (Duly Certified from SECP) | Annexure V |
| 6. Profile of Experience of the Senior Management and Technical Staff in the Electrical Industry (Sponsors Profile) | Annexure Y |
| 7. CV of the Technical and Professional Staff | Annexure AA |
| 8. Evidence regarding availability of adequate financial and technical resources | Annexure AB |
| 9. Executive Summary of Electrical Grid Interconnection Study Alongwith Appendices | Annexure AH |
| 10. Feasibility Study | Annexure AI |
| 11. Suitability of Site For IEE | Annexure AL |

# CHECKLIST

| Sr.no | Information/ Documents Required | Original | Two Copies | |
|---|---|---|---|---|
| 1 | **Application for licence.—** (1) An application for a licence shall be made in the form specified in Schedule I to these regulations. | √ | √ | |
| | | | | |
| 2 | Demand Draft of Rs. 286, 016 | √ | √ | |
| | | | | |
| 3 | certified copies of: | | | |
| (i) | certificate of incorporation; | √ | √ | |
| (ii) | memorandum and articles of association; | √ | √ | |
| (iii) | in case of an applicant who has submitted the annual return required to be submitted to the registrar of companies pursuant to section 156 of the Ordinance, the last filed annual return; | Last Filed of 2014 Attached and Explanation for 2015 Given in Application | | |
| | | | | |
| 4 | a reasonably detailed profile of the experience of the applicant, its management staff and its members in the electricity industry; | √ | √ | |
| | | | | |
| 5 | the curriculum vitae of the applicant's senior management, technical and professional staff; | √ | √ | |
| | | | | |
| 6 | evidence, satisfactory to the Authority, of the availability of adequate financial and technical resources to the applicant for the purposes of the generation, transmission or distribution business, as the case may be, and such evidence may consist of: | √ | √ | |
| | | | | |
| (i) | cash balances held in reserve along with the bank certificates; | √ | √ | |
| | | | | |
| (ii) | expressions of interest to provide credit or financing along with sources and details thereof; | √ | √ | |
| | | | | |
| 7 | employment records of engineering and technical staff of the applicant proposed to be employed; (CV Attached) | √ | √ | |
| | | | | |
| 8 | profile of EPC contractors, along with expressions of interest of such EPC contractors | √ | √ | |
| | | | | |
| 9 | verifiable references in respect of the experience of the applicant and its proposed EPC contractors; | √ | √ | |
| | | | | |
| 10 | in case of a first application for a licence by a going concern, technical and financial proposals in reasonable detail for the operation, maintenance, planning and development of the generation, transmission or distribution facility or system in respect of which the licence is sought; | √ FS | √ | |
| | | | | |
| 11 | in case of: | | | |
| | generation licence applications, the type, technology, model, technical detailsand design of the facilities proposed to be acquired, constructed, developed or installed; | √ | √ | |
| | | | | |
| 12 | in case of a licence for a new facility or system, a feasibility report in respect of the project, specifying in detail: | √ | √ | |
| | | | | |
| 13 | the type, technology, model, technical details and design of the facilit | √ | √ | |
| | proposed to be constructed, developed or installed; | √ | √ | |
| | the expected life of the facility or the system; | √ | √ | |
| | | | | |
| | | | | |
| | | | | |
| 14 | iii) the location of the facility or the system, or the territory with outer boundaries within which the facilities or the system is proposed to be installed and operated by the licensee, along with maps and plans; and (Topo Map) | √ Topo | √ | |
| | | | | |
| 15 | the type and details of the services proposed to be provided; and | √ | √ | |
| | | | | |
| 16 | a prospectus. | √ | √ | |

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| (iii) | in case of an applicant who has submitted the annual return required to be submitted to the registrar of companies pursuant to section 156 of the Ordinance, the last filed annual return; | Last Filed of 2014 Attached and Explanation for 2015 Given in Application | | |
| | | | | |
| 4 | a reasonably detailed profile of the experience of the applicant, its management staff and its members in the electricity industry; | √ | √ | |
| | | | | |
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| | | | | |
| 8 | profile of EPC contractors, along with expressions of interest of such EPC contractors | √ | √ | |
| | | | | |
| 9 | verifiable references in respect of the experience of the applicant and its proposed EPC contractors; | √ | √ | |
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| 10 | in case of a first application for a licence by a going concern, technical and financial proposals in reasonable detail for the operation, maintenance, planning and development of the generation, transmission or distribution facility or system in respect of which the licence is sought; | √ FS | √ | |
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| | | | | |
| 15 | the type and details of the services proposed to be provided; and | √ | √ | |
| | | | | |
| 16 | a prospectus. | √ | √ | |

# ANNEXURE A

# Prospectus

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**PROSPECTUS**

I. The document is a Generation License Application for of the 50 MW Wind Power Project by the SPV M/s Iran Pak Wind Power Pvt Ltd (the "Applicant").

1. The Applicant obtained first Letter of Intent (LOI) from AEDB in August, 2006 to setup the Project. The land for the Project has been allocated and provided by Government of Sindh through an "Agreement to Lease". A fresh LOI to the company was issued by Sindh Energy Board in March 2016.

2. Iran-Pak wind power site is located about 20 km from Jhimpir in Thatta District of Sindh province in Pakistan, 100 km North-East of Karachi. The land in which the proposed wind farm is located is 1,250 acres situated at Deh Kohistan 7/3 Tapo Jungshahi Taluka Thatta at the wind corridor in Jhimpir, Thatta District with the coordinates as detailed below. The company has gathered thirty one month Raw site Wind Data and accordingly it has one of the best wind resource in the corridor.

**M/s Iran-Pak Wind Power (Pvt) Limited 50 MW**

| | Area | Easting | Northing | Elevation |
|---|---|---|---|---|
| Ref Point 1 | | 2127120.731<br>67-53-29.44 | 809885.469<br>24-55-30.90 | 51.411 |
| Ref Point 2 | | 2127068.029<br>67-53-27.66 | 809821.852<br>24-55-28.75 | 51.633 |
| | | 2127238.088<br>67-53-33.47 | 809973.558<br>24-55-33.94 | 50.939 |
| | 1250-C0 | 2127300.130<br>67-53-36.16 | 809685.828<br>24-55-24.68 | 50.140 |
| | | 2127683.953<br>67-53-54.68 | 806781.575<br>24-53-50.88 | 56.582 |
| | | 2126409.205<br>67-53-10.38 | 806105.348<br>24-53-26.96 | 43.478 |
| | | 2125486.846<br>67-52-33.26 | 808650.311<br>24-54-48.27 | 47.883 |
| | | **Total area 1249.99 acres** | | |

3. **The complete feasibility study** was submitted to Sindh Energy **Department In** Nov 2015 and again in March 2016 and the Sindh Energy Department have given their recommendation Letter for issuance of generation license via Letter No. DAE/Wind/50/2015 dated 7th June, 2016 (Attached as Annexure S ). The project involves Foreign Direct Investment (FDI) and given the experience and track record of applicant; both foreign and local banks have shown interest in funding the project.

4. The Electrical and Grid Interconnection Studies were submitted to the National Transmission & Dispatch Company Limited ("NTDC") in Nov 2015 and it has not been processed ; detailed explanation of the case is given in Annexure C ; which is transparent and self-explanatory for authority's consideration.

4(a). The Project shall have an installed capacity of 49.5 MW with 15 wind turbine generators (WTG)of 3.3 MW each. There shall be a substation of 132KV, which shall dispatch electricity to Hyderabad Electric Supply Company Limited grid at a station In Jhimpir, which is to the northeast of the Project site; OR at a station in Nooriabad, which is 22 km away to the northeast of the Project site.

5. Due to the proximity with the railway line (major transport network) an EIA was carried out and later via the letter No. EPA/Tech/DD/2015/04/03 dated 3rd April 2015 of SEPA (Sindh Environmental Protection Agency) (Attached as Annexure S) the project company was allowed to carry out IEE which is in process.

6. The Project is also applying for the Upfront Tariff simultaneously with this application. Upon issuance of the Generation License and Upfront tariff, the applicant would execute the Energy Purchase Agreement with the power purchaser and reach financial close by August 2016. The expected commercial operation date of the Project is Oct 2017.

This document Is submitted In pursuant to Section -5 of Article -3 of NEPRA Licensing (Application & Modification Procedure) Regulation, 1999; and list of documents required are attached as Annexure as mentioned in content/document structure.

## II. Brief of prospectus including salient features of the Application of IPWPPL is as under:-

### 1. Introduction of Applicant :

Iran Pak Wind Power Pvt Ltd incorporated on 15th December 2009 vide Corporate Universal Identification No. 0071078 under section 32 of the Companies Ordinance , 1984 (XLVII OF 1984). The Business Office of the company is Suite # 214, 2nd Floor, Progressive Plaza Beaumont Road, Karachi — Pakistan. According to its Memorandum of Association, the objects of the company, inetralia, include business of power generation.

### 2. Plant Details

| | |
|---|---|
| Type of Power Plant | Type of Power Plant Wind Power Generation Plant |
| Location: | Location Jhimpir, District Thatta, Sindh |
| Gross Capacity | 49.5 MW |
| No of Units | 15 x 33 MW |
| Wind Turbine Make | Vestas |
| Wind Turbine Generator | V126 — 3.3 MW |
| Hub Height | 137 m |
| Expected Commissioning date | October , 2017 |

### 3. Project Cost (Estimated)

| | | |
|---|---|---|
| Total Project Cost | : US $ 112.8 | Million |
| Debt (75%) | : US $ 84.6 | Million |
| Equity (25%) | : US $ 28.2 | Million |

# ANNEXURE B

# Project Information

X

## I. Project Background

This application for Generation License relates to Iran Pak Wind Power Pvt Ltd.

In 2006 one of the largest Water & Power company's of Iran M/s Sunir Co showed interest in setting up a 50 MW Wind Farm in Pakistan on JV basis. First MOU in this regard between Sunir Co and Pakistani Consortium was signed in Feb 2006 and together they approached AEDB for the issuance of LOI for 50 MW Wind Farm; which was issued in 2006.

In the meantime; a follow up MOM was signed during the visit of Iranian Energy Minister Engr. Parviz Fattah and as a result a special purpose vehicle M/s Iran Pak Wind Power Pvt Ltd was established in December 2009 for carrying out the project.

As per Article 2 of the referred LOI letter; the AEDB was to facilitate and lease out land for the project to the sponsors upon its availability from Government of Sindh and added them in the queue for land allocation.

However; with the passage of time the AEDB could not provide the land to the sponsors till 2010. Since the Article 3 of the subject letter stated that the sponsors have the option to proceed for the acquisition of its own land, therefore accordingly; in 2010 the sponsors approached the Government Sindh for allocation of land for its 50 MW project and gave them a detail presentation on Wind Corridor in Jhimpir and identified the land with good wind resource.

Consequently ; a MOU was signed with Sindh Board of Investment back in April 2010 after which survey was carried out and availability of land was confirmed in the location in which it was desired.

In February 2011; the Sindh Government allotted the requisite land to the sponsors; but the right of way and possession was not given to sponsors until Oct 2013.

There were many reasons for this delay; including but not limited to :

1. During the period Feb 2011 and Aug 2011; three different corrigendums were issued for various corrections in the allotment letter.

2. A Rs 2/ sq yd rent was being charged in the original allotment letter; which was against the spirit of the announced policy and its removal also caused delays.

3. During July 2011 and Sept 2012 ; on more than three occasions the Sindh local bodies system was changed between Commissionerate and LG; which caused considerable delay in completing the paperwork.

4. In may 2012; the Sindh Government also changed the land allotment policy to footprint policy ; which again was against the spirit of announced incentive; therefore this also caused considerable delay.

During this time the sponsors are also credited with initiating some landmark changes to the policy of land allotment for Wind Power Projects and which later propelled the wind market into the mainstream; fruits of which are being born by investors today and these changes were mainly :

a. Change of time period for completion of wind power projects from 2 to 5 years.
b. Removal of Rs. 2 per sq. yd rent on land.
c. Change in benchmarks of timeline from date of allotment to date of possession.
d. Pointed out the deficiencies in "Foot Print" Policy such as Oil/ Gas execution in the middle of project land , hunting permission etc which resulted in the reversal of the policy benefitting the whole industry.

Finally in Oct 2013 the sponsors were granted right of way and possession of land to carry out the data collection work.

Since then the Applicant conducted various studies to assess the feasibility of the Project. These studies included the wind resource assessment, geo technical investigation, digital topographic map, initial environmental examination and grid interconnection study. Based on the studies conducted by the Project technical consultant (M/s Ghods Niroo Engineering Company), the complete feasibility study was submitted by the Applicant to Sindh Energy Department for its review.

## II. Project Site

The proposed site for the implementation of the Project was selected after detailed analysis of USAID Pakistan Wind Power Resource Map by considering (I) location in the wind corridor, (ii) wind conditions at the site, (iii) topographic conditions, (iv) site accessibility, and (v) location of the grid with reference to the site for interconnection. The site is located within the wind corridor identified by SED/USAID and the land has been obtained from Sindh Government.

The site is located in Jhimpir; district Thatta, Sindh, and has one of the best wind resources. The Wind Farm is located about 20 km from Jhimpir in Thatta District of Sindh province in Pakistan, 100 km North-East of Karachi with easy road access from both Nooriabad Industrial Estate (via Jhimpir ) and from Makli side Thatta.

*Page Six*

**SCHEDULE**

**DETAILS OF LAND**

Measurement and site plan of land with strips as per following coordinates is attached duly attested by Mukhtiarkar Estate, and Mukhtiarkar Revenue Thatta.

**M/s Iran-Pak Wind Power (Pvt) Limited 50 MW**

| | Area | Easting | Northing | Elevation |
|---|---|---|---|---|
| Ref Point 1 | | 2127120.731<br>67-53-29.44 | 809685.469<br>24-55-30.90 | 51.411 |
| Ref Point 2 | | 2127068.029<br>67-53-27.66 | 809821.852<br>24-55-28.75 | 51.633 |
| | | 2127238.088<br>67-53-33.47 | 809973.558<br>24-55-33.94 | 50.939 |
| | 1250-00 | 2127300.130<br>67-53-36.16 | 809685.828<br>24-55-24.68 | 50.140 |
| | | 2127683.953<br>67-53-54.68 | 806781.575<br>24-53-50.88 | 56.582 |
| | | 2126409.205<br>67-53-10.38 | 806105.348<br>24-53-26.96 | 43.478 |
| | | 2125486.846<br>67-52-33.26 | 808650.311<br>24-54-48.22 | 47.883 |
| | | | Total area 1249.99 acres | |

**ON THE NORTH:** Railway Line,

**ON THE EAST:** Road from Thatta to Baradabad.

**ON THE SOUTH** Government state Land

**ON THE WEST** State Land.

Iran-Pak Wind Power (Pvt) Ltd
Naeem
Chief Executive

Thatta

The Project site is exposed to very strong south westerly winds; wind data analysis of the area suggests that 40% wind blows from the south west direction. The terrain of the area is flat with some change in altitude. The proposed site lies under roughness class 1.5 as there is low vegetation. The site is easily accessible through metallic roads. The ground is hard and rocky; the subsurface soil also includes clay and silt. There are few hilly areas in the middle of the project land which is 2.5 x 2.5 km rectangular shape.

The proposed wind farm lies on a flat Inland area with hard and rocky ground conditions. The site would be categorized as inland wind development as opposed coastal wind project development The general terrain at the site can be described as simple and flat terrain. Internal access roads would be constructed to connect the wind turbines with each other as well as external access road would be upgraded and grid station would be constructed during the civil works of the wind farm.

The proposed site area lies in an arid zone with very little annual precipitation. The result is that there is hardly any natural vegetation in the area. Some hardy tree species are visible scattered far and wide in the area. The area is rocky with some rock outcrops. There are one or two hilly outcrops and hillocks left over in the middle of the project land. The site boundary is rectangular in shape approximately 2.5 x 2.5 km.The terrain at the site and surrounding area is generally flat with elevations varying between 50 m in the north of the site, 40 m in the centre and upto 75 meter in the south of site.

The proposed wind farm site is located about 100km to the northeast of the Karachi Port. Karachi is located by the Arabian Sea and the weather of Karachi is tropical monsoon climate. Rainfall is scarce with about 200mm for whole year and most of this is concentrated in July and August. The temperature in winter varies from November to February between 10-20 Celsius and it is hot with high temperature in summer from April to August ; highest temperature reaching upto 44 +°C.

## I. Wind Farm Layout

The wind farm site rectangular in shape, the topography is relatively flat and the elevation above sea level is approximately 40—75 m. There is little vegetation at the wind farm site. Wind Turbines will have 137m hub height. See figure below for the sketch map for the WTG towers location setting parameters.


# I. Topographical and Geological Conditions at Project Site

## IV(a) Topographical conditions

The Project site is on a plain area at an elevation of 40-75m, which is generally flat, but a bit higher to the south and lower on the middle and north. The landform at wind farm site is mainly of pediment and the vegetation there is less developed.

### IV (b) Geological conditions

The planned wind farm site is covered mainly by marine alluvium of Holocene and underlain mainly by Tertiary limestone. The bedrock at the site is generally outcropped .As the Wind Turbine Generator ("WTG") is a high-rise structure, it has a high gravity center and should sustain high loads, large horizontal wind force and overturning. WTGs are designed to withstand these forces.

### IV(c) Hydrology

According to the regional hydrological data available, the Project site is in a dry area, where the water table is deep underground and the surface water and water in the shallow surface layers is weak to slightly corrosive to the concrete and is corrosive to the rebars in the concrete which has been immerged in water for a long-time or alternatively in wet and dry conditions. Corrosion prevention measures will be adopted in the design and implementation of the wind farm.

### IV(d) Site Accessibility

The Project is located on Makli, Bahadurabad Road with Jhimpir city to the east of the project. The machinery for the project will be routed from Port Karachi which is on the eastern edge of the Karachi city and the site will be accessed from the Super Highway connecting Karachi to Hyderabad.

There were two options to transport Heavy Machinery

#### IV(d) a National Highway – Makli – Site :

Detailed study was carried out from National Highway upto Makli and then connecting project site via access route going upto Bahadurabad Railway Station.

This route was not acceptable for movement of heavy machinery especially large blades and heavy turbine through Makli and beyond to site.

#### IV(c ) b Super Higway – Nooriabad Site :

Detailed study was carried from Super Highway to Nooriabad and Connecting project through bypass road from Jhimpir to the project site. This option was suitable for heavy generator sets as well as large turbine blades.

## IV. Grid Connectivity

The IPWPPL gird connection study was carried out by M/s Power Planners International (Pvt.) Ltd., who is the leading consultant in this sector.
We feel that great injustice and discrimination was done against our project in not processing our grid study as of yet and the case is explained in detail at Annexure C.

### VIII (a) Grid Interconnection Point:

The proposed Grid Interconnection point will be the Jhimpir –New 220/132 kV grid station to be connected to Hyderabad (T. M. Khan Rod 220 kV) through double circuit of 220 kV and a double circuit of 132 kV line to be connected with T. M. Khan grid station of 132 kV. The double circuit of 132 will emanate from the Wind Farm substation which will have a dimension of 100 by 80 meter. The substation layout is annexed to this document as Annexure S.

Alternatively; if the 220 kV and 132 kV lines from Jhimpir-New grid station cannot take overload of 50 MW power plant then the second option is to take a new 220 kV double circuit line from Jhimpir-New grid to Matiari. The existing grid at Matiari is 500 kV and in this regard it will be required to add 220 kV voltage level by adding 500/220 kV transformers and a bus bar of 220 kV in the same grid station.

## V. Annual Energy Production

Annual Energy Production of the project is 174.762 GWh. The table below shows key details relating to power generation from the project.

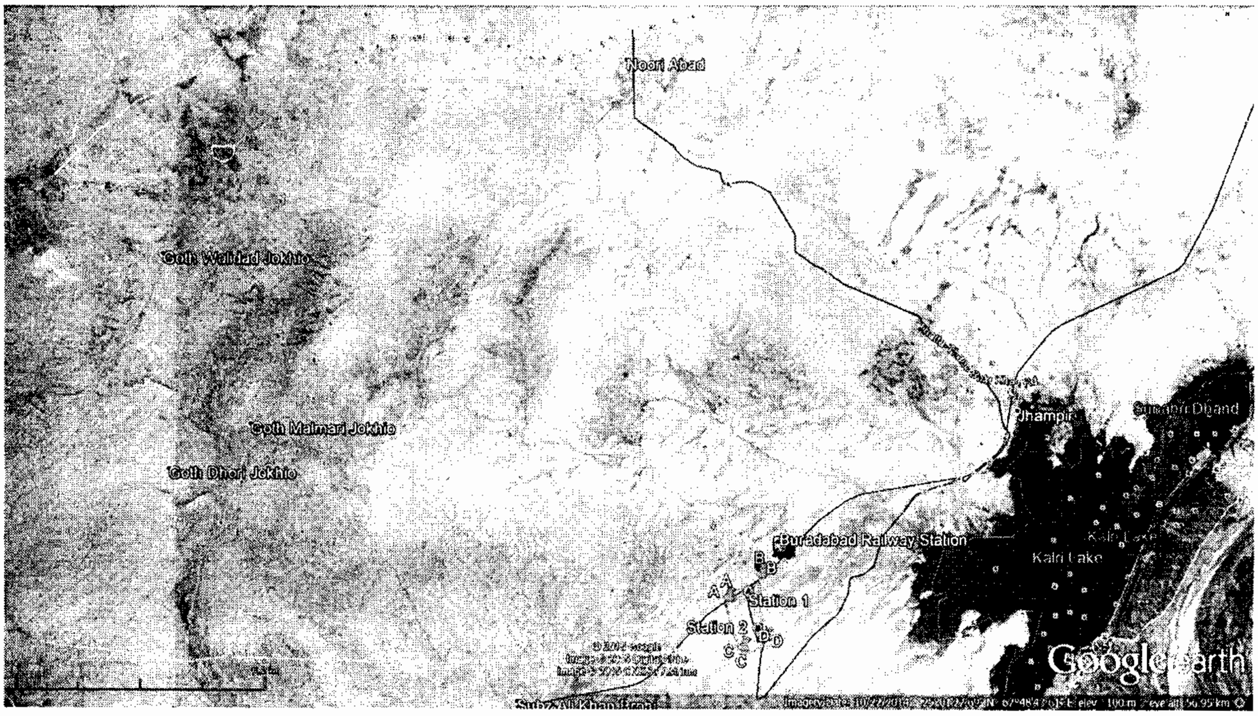
| | |
|---|---|
| Total Installed Gross ISO Capacity of the Generation Facility | 49.5 MW |
| Annual Energy Generation | 174.762 Gwh |
| Capacity Factor | 39.9 % |

## VI. WTG Technology

The Wind Turbine Generator used is VESTAS V126 – 3.3 MW. The details of VESTAS V126 are given below.

## X(a) Vestas - The WTG manufacturer

Vestas is the only global energy company dedicated exclusively to wind energy - improving business case certainty and reducing the cost of energy for its customers.




## I. Telecommunication at project site

Near the site, the wire based telecommunication system is installed. The Met Mast are already connected to back office via Zong network which is offering services including GPRS.

For the SCADA system of the wind farm, a wire based telecommunication infrastructure has to be installed. Land line network will be arranged from the nearby village Jhimpir once civil work starts at the site.

## II. Availability of Semi-Skilled and Skilled Labor

Since more than 10 projects are operational or in construction phase therefore there is plenty of wind power project specific Skilled labor , Semi - skilled labor and Un- Skilled Labors available in the area and it will be source of employment for the local people.

## III. Site Security

The project site has already been provided enough security to protect its wind masts from occasional trespassing and a proper security infrastructure will be provided at site at the time the project starts EPC works.

Vestas works in close partnership with customers to offer the most effective solutions towards energy independence. Their core business is the development, manufacturing, sale and maintenance of wind power plants – with competencies that cover every aspect of the value chain from site studies to service and maintenance. With installed wind turbines in 75 countries around the world and installing more than 55,000 turbines on six continents, which generate more than 100 million MWh of energy per year; clearly makes it the leader in WTG Technology.

Vestas has more than 35 years' experience in wind energy. During that time, Vestas has delivered more than 70 GW (70,000 MW's) of installed capacity in 75 countries. That is more than 15 per cent of total wind turbine capacity installed globally – and over 15 GW more than its closest competitor. Vestas currently monitors over 28,000 wind turbines across the globe. All tangible proof that Vestas is the right partner to help realise the full potential of your wind site.

The 3 MW platform was introduced in 2010 with the launch ofthe V112-3.0 MW®. Over 8 GW of the 3 MW platform has been installed all over the world onshore and offshore making it the obvious choice for customers looking for highly flexible and trustworthy turbines. Since then the 3 MW platform was upgraded and new variants were introduced utilising untapped potential of the platform. All variants carry the same nacelle design and the hub design has been re-used to the largest extend possible. In addition, our engineers have increased the nominal power across the entire platform improving your energy production significantly.

With this expansion, the 3 MW platform covers all IEC wind classes with a variety of rotor sizes and a higher rated output power of 3.45 MW.

Vestas EOI to supply turbines to Iran Pak Wind Power Project has been attached as Annexure R and Track Record of Vestas has been attached at Annexure S.

## X(b) <u>Organizational Structure</u>

Vestas' organization is structured on seven key pillars representing all key disciplines of the company and all employees. These seven key pillars are headed by the eight members of the Executive Committee, which ensures the well-functioning of the company as well as Vestas' overall performance.

As a structurally lean organization, Vestas has offices in 24 countries and five strong regional sales business units in Northern Europe, Central Europe, Americas, Mediterranean, and Asia Pacific & China.

## X(c ) Details of (3.3 MW) Wind Turbine Generator

| | | |
|---|---|---|
| Rotor | Diameter | 126 m |
| | Swept area | 12469 $m^2$ |
| | Speed range | 5.3-16.5 |
| | Number of Blades | 3 |
| | Brakes | Aerodynamic – Full Feathering |
| Operating data | Cut in wind speed | 3 m/s |
| | Rated wind speed | 12 m/s |
| | Cut out wind speed | 22.5 m/s |
| | Survival wind speed | 52.5 m/s |
| Generator | Type | Asynchronous with cage rotor |
| | Rated Voltage | 750 v |
| | Rated Power | 3650 kw |

## VII. Vestas – The EPC Contractor

Vestas not only has more than 35 years' experience in wind energy delivering more than 70 GW (70,000 MW's) of installed capacity in 75 countries but they have also undertaken many projects worldwide as EPC contractors. They are currently monitoring over 28,000 wind turbines across the globe.

Vestas has considerable experience in all the key disciplines – engineering, transportation, construction and operations and maintenance. Its projects have covered every kind of site, from high altitude to extreme weather conditions.

Vestas will be responsible for the operations and maintenance of the plant for at least 10 years, 2 years in the warranty period and 8 years of contractual period.

The detailed profile of Vestas as EPC contractors has been attached at Annexure AI.

## XII. Capital Budget

The estimated total Project cost (the **Total Project Cost),** expressed in US $, has been calculated after thorough analysis, evaluation and understanding of the dynamics that affect the development and operation of a wind farm. The Total Project Cost comes to approximately US$ 112.8 Million (United States Dollars One Hundred Twelve Million Eight Hundred Thousand only).

The capital structure of the Project is proposed as follows:

| | **USD IN THOUSANDS** |
|---|---|
| **Project Debt** | 84.6 Million |
| **Project Equity** | 28.2 Million |
| **Total** | 112.8 Million |

F

# ANNEXURE C

# Case Of
# Grid Interconnection
# Study

## Case of Grid Interconnection Study

1. One of the conditions for opting of Upfront tariff is that only those companies having a certificate from Power Purchaser regarding availability of power evacuation arrangement/ capacity for absorption of power supplied into the national grid can be eligible to avail tariff.

2. The Iran Pak Wind Power Pvt Ltd (IPWPPL) approached NTDC for NOC to use their data for completing grid interconnection study back in Feb 2014 but once they found that the consultant was foreign company; they said that this study should be carried out by local consultant. By the time we hired a local consultant and approached NTDC again for NOC; they apprised that the Grid Utilization at the Sindh Wind corridor has been exhausted at 1,756 MW's (956 MW's at Jhinpir, 300MW's at Gharo, 500MW's at Jamshoro) and that they are unable to grant NOC to IPWPPL for carrying out the grid study. Furthermore; they advised us to contact relevant authority for replacement of our project with any slow moving/non fulfilling project out of the 1,756 MW's and/or wait for the USAID funded GOPA upgradation / energy mix study which was supposed to be completed by Feb 2015.

3. Having waited almost one and a half year ; IPWPPL finally put forth its case at the time of the Nepra Hearing against the Determination of the Upfront Wind Tariff in August 2015; in which IPWPPL proposed that there needs to be a change in Policy for giving out NOC's to projects.

   a. It was suggested that condition of having certificate from the power purchaser should be removed for companies to be eligible to avail upfront tariff as the NOC is given so that the sponsor can complete its bankable feasibility study and it does not guarantee that the project will materialize. Therefore; calculating the grid utilization through the number of NOC's issued is not correct and we recommended that the NTDC should only consider those projects with whom they have signed EPA as the projects that will utilize the grid and to whom NTDC is obligated to providing grid. At the time only 756 MW had signed EPA's out of 1756 MW capacity. ( The submission were duly recorded in the Transcript of the Nepra Hearing dated August 18th 2015 (Pg No. 37- 38 copy attached as Annexure D) and also in the Nepra Determination Ruling dated June 24th , 2015 (Pg No 19 – 24 Copy Attached as Annexure E)

4. Therefore as a result of hearing the NTDC eventually issued a conditional NOC to IPWPPL to carry out Grid Interconnection Study in June 2015 via Letter No. GMPP/CEMP/TRP-380/2557-58 dated 18th June 2015. (Attached as Annexure G)

5. The IPWPPL Grid Study was completed and submitted to CPPA in Nov 2015.( Copy Attached as Annexure H).

6. Sometime in Feb/ March 2016; a 500 MW NBT project Grid was freed due to cancellation of the project.

7. Following merit; those companies which were issued NOC by NTDC and completed and submitted Grid Study (two in total including IPWPPL) were in line on merit to receive Grid from this space.

8. However; apparently without informing sponsors ; the authorities (Ministry of Water and Power/ AEDB/ Government of Sindh) created a criteria of marking based on project performance submitted to them and tabulated a list of projects.

9. Afterwards ; through Letter No. B/3/1/GWT/Tech/07 dated 8th April 2016 a list of 10 companies (issued by AEDB) were out of turn and unjustly allotted Grid from the 500 MW NBT slot (only 1 out of 10 had NOC and Grid Study completed. (Copy of Letter alongwith List Attached as Annexure I)

10. Without going into the merit of the allotment; there were many ambiguities in the list with regards to the criteria of selection:

    a. There was no consideration / points for companies having NTDC NOC for Grid Study and /or completed/submitted study ; in essence leaving the most important milestone of " Grid Study" itself for which this whole exercise was being done.

    b. Only 1 out of 10 projects selected had NOC and Grid Study completed at the time.

    c. Many of them were allotted Land only in Feb 2016.

    d. Some did not even have Wind Masts installed.

    e. Few were even without LOI's at the time of selection.

11. When IPWPPL approached CPPA regarding this matter and for processing its Grid Interconnection Study; they replied via their Letter No. CPPAGL-GM/CE-II/MT-IV/IPWPPL/1698-1701 dated 11th April 2016 (Copy of Letter attached as Annexure J ) stating that IPWPPL Grid Study cannot be processed because IPWPPL LOI surpasses the date of 08.04.2015 which was the date of ban on wind power set forth by Cabinet

Committee on Energy. (Decision of Cabinet Committee on Energy Attached as Annexure K)

12. IPWPPL replied to CPPA via Letter No. IPWPPL/CPPA/22/16 dated 26th April 2016 (Copy Attached as Annexure L) that the CCOE decision is not applicable on IPWPPL because:

    a. The CCOE's decision is not applicable to LOI's issued by Sindh Government. (As the Clarification dated 19th May 2015 issued by Ministry of Water and Power only mentioned AEDB Attached as Annexure M)

    b. As per the Press release issued by Zafar Yab Khan Deputy Secretary / Spokesman Ministry of Water and Power dated 14th May 2015 it was declared by the Federal Minister of Water And Power that there is no ban on new wind and solar projects.(Press Release Attached as Annexure N)

    c. As per the Letter No. DO No. PS/P.SECY/CMS/15-593 dated 25th April 2015 of Chief Minister Sindh addressed to Prime Minister of Pakistan; the Chief Minister categorically stated that the Cabinet Committee on Energy is not constitutionally empowered to decide these matters.

13. While no reply was received from CPPA in response to our Letter; however a Board Resolution No. XIII (IX) 15 dated 19th April 2016 was issued by CPPA allowing NOC/Power Evacuation to the list of 10 companies including 9 of those whose LOI's also surpass the date of 08.04.2015 (Copy of Board Resolution Attached as Annexure O )

14. IPWPPL wrote a Letter No. IPWPPL/CPPA/38/16 dated 6th May 2016 to CEO, CPPA (G) Ltd pointing out discrimination against IPWPPL in not processing its Grid Study while processing 9 project studies whose LOI's were also issued after the date of 08.04.2015 (Copy of Letter Attached as Annexure P)

15. The IPWPPL wrote a Letter No. IPWPPL/GOS/61/1618th May 2016 addressed to Secretary Energy, Government of Sindh against injustice and requested for Allocation of Grid on Merit basis and in its reply Energy Department, Govt of Sindh wrote a Letter No. DAE/wind/50/2015 dated 18th May, 2016 to GMPP, NTDC for Approval of Grid Interconnection Study of IPWPPL (Copy of Letter Attached as Annexure Q)

**Conclusion :**

It is evident from the above history that IPWPPL was one of the two company's having NOC from NTDC and submitted its Grid Study to CPPA well before other 9 projects whose studies are currently being approved on fast tarck basis and are being issued Grid Certificate so that they can opt for Upfront Tariff while IPWPPL was being left out.

This discrimination has not only resulted in delaying the project of IPWPPL but may also lead to non – issuance of Grid Evacuation Certificate which is totally unjustified and tantamount to killing the project.

Therefore; it is humbly requested that the Authority takes the above into consideration viz a viz Grid Study when deciding on the Generation License application of IPWPPL.

# ANNEXURE T

# Certificate
# Of
# Incorporation

SECURITIES AND EXCHANGE COMMISSION OF PAKISTAN

SECP

COMPANY REGISTRATION OFFICE
(KARACHI)

00717

# CERTIFICATE OF INCORPORATION

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

Corporate Universal Identification No. **0071078**

I hereby certify that **IRAN-PAK WIND POWER (PVT.) 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 **Karachi** this **Fifteenth** day of **December,** Two Thousand and **Nine**.

Company Registration Office ★ Karachi ★ Securities & Exchange Commission of Pakistan SECP

Fee Rs. **39,500/=**

**(Muhammad Naeem Khan)**
Joint Registrar of Companies

Certified to be True Copy
Deputy Registrar of Companies

# ANNEXURE U

# Memorandum

# &

# Articles

# Of Association

## THE COMPANIES ORDINANCE, 1984

### (COMPANY LIMITED BY SHARES)

## MEMORANDUM OF ASSOCIATION

## OF

## IRAN-PAK WIND POWER (PRIVATE) LIMITED

I. The name of the Company is **IRAN-PAK WIND POWER (PRIVATE) LIMITED**.

II. The registered office of the Company will be situated in the Province of Sindh, Pakistan.

III. The sole and only object of the company is to establish an industrial undertaking to produce and generate electricity, energy and power through alternate / renewable resources and in order to achieve this primary objective, to do the following activities:-

1. To establish power generation station, wind turbines, solar cells, geysers/ cookers, solar stilling engines, cables wires, lines, accumulators, boilers, lamps and works to generate, accumulate, distribute and sale electricity, energy and power through alternate and or renewable resources including but not limited to:

   i) Wind Turbines
   ii) Solar Systems
   iii) Biogas/Biodiesel
   iv) Fuel cells
   v) Micro Hydel
   vi) Wave/Tidal

2. To run, maintain, control and operate power plant, Wind turbines or mechanical drive applications.

Company Registration Office Karachi Securities & Exchange Commission

3. To Design, finance, insure, build, own, operate and maintain a power generating plant for generation and supply of electric power.

4. To import, purchase or otherwise acquire any land, building, plant, accessories and spare parts thereof for the purpose of company's business.

5. To obtain foreign affiliation, expertise etc. and to use foreign name for any power plant established or to be established by the company.

6. To sell its products/electricity within Pakistan to Government, Semi government and private sectors.

7. To purchase, machinery, raw material, chemicals and lubricants from the local and/or foreign market.

8. To do all such acts, deeds and things as would be required conducive and incidental to the attainment of this object.

9. To purchase, acquire on lease, build, charge or otherwise acquire any leasehold estate or other rights of property, installations, buildings, plants, apparatus, machinery, tools, office furniture, motor vehicles, utensils and other appliances which may seem to the company necessary or suitable or convenient for the conditions as the company shall deem expedient.

10. To carry on any other business of the similar nature which may in the opinion of the company be conveniently carried on in Pakistan or any other place in the world.

11. To borrow or raise money whether on local or international financial markets by the issue of debentures, debenture stock, participation term certificates, bonds, mortgages, or any other securities or charges based upon all or any of the property and rights of the company, or without any such security, and upon such terms as to priority or otherwise as the company shall think fit in the course of business.

12. To borrow or raise or arrange local and/or foreign currency loan from Scheduled Banks, Industrial Banks and Financial Institutions for the purchase of machinery, construction of factory building, working capital and for its other requirements by creating mortgages, charges, hypothecations and other encumbrances on the property, assets and undertaking of the company and in such manner and on such terms and conditions as the directors of the company may determine or approve.

X

13. To guarantee the performance of its contracts, obligation of the company in relation to the payment of any loan debenture, stock, bonds, securities by or in its favour and to guarantee the payment or return on investment or of dividends on its share.

14. To pay promotional and development expenses, incurred by sponsors up to the date of incorporation of the company which shall be reimbursed to the sponsors respectively by the company.

15. To apply for and obtain all consents or permissions from relevant authorities necessary for foreign sponsors to repatriate out of Pakistan all re-imbursements, and all equity capital invested and any appreciation of capital invested and any dividends payable in respect of its shareholdings in the company.

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

17. To obtain all requisite licenses, authorizations permissions, consents, powers and authorities necessary to carry out any of the objects herein contained.

18. To support and subscribe to any charitable or public objects including donations to charitable and benevolent foundations and any institution, society, or club or for any purpose which may be for the benefit of the company or its employees, or may be connected with or for the benefit and welfare of any town or place where the company carried on business, to give pensions, gratuities or charitable aid to any persons who may have been directors of or may have served the company, or the wives, children, or other relatives or dependents of such persons, to make payments towards insurance, and to form and contribute to provident, gratuity and or superannuation funds for the benefit of any such persons, or of their wives, children, or other relatives or dependents.

19. To enter into working arrangements of all kinds with other companies, corporations, firms or persons but not to act as managing agents.

20. To carry on the said business, anywhere in Pakistan or in the world.

21. To carry on indenting, warehousing, trading, importing etc. and all types of computer and information Technology Equipments.

22. To open all types of bank accounts and to draw, make, accept, discount, execute or negotiate and issue cheques, promissory

notes, bills, bills of lading, bills of exchange, warrants, debentures, and other negotiable or transferable instruments or securities concerning this company.

23. To dispose of any shares and securities of the Companies which may be acquired by this Company and in such manner as may, from time to time, be determined.

24. To establish at any place in and outside Pakistan such branches, agencies for managing any affairs of the Company as may be decided by the Directors (except managing agency).

25. To amalgamate, consolidate or merge either in whole or in part, with or into any other companies, associations, firms or persons carrying on any trade or business of a similar nature to that which this company is authorized to carry on but in any event not to act as managing agents.

26. To invest the surplus moneys of the company not immediately required in such manner as may from time to time be determined.

27. To carry on the business as management consultants of all types and to prepare studies and to carry out assignments on turn key basis except financial advisory services.

28. To carry on the business as advertising agents, travel agents, general sales agents, consultants, surveyors, dry cleaners, engineers, transporters, estate agents, jewelers, tailors, auctioneers, etc.

29. To carry on the business as management consultants of all types and to prepare feasibility studies and to carry out assignments on turn key basis.

30. To provide consultancy services for industrialization, privatization, capitalization etc. for any project.

31. To carry on the business of hospitals, mining, laboratories, boutiques, computer centers, film production, fast food centers, ice cream parlors, restaurants, newspapers and magazines, pharmaceuticals, printing, shipping, airlines, etc.

32. To give surety or security and to mortgage or encumber land, building, machinery, goods or other property of the company in favour of bank or any financial institution or agency for and on behalf of associated company, holding company, subsidiary or sister concern on such terms and conditions as may consider proper.

33. It is hereby undertaken and declared that the company shall not engage in banking business, business of an investment company, Non-banking Finance Corporation, leasing company and insurance company, business of managing agency or any unlawful business and nothing in object clauses shall be construed to entitle company to engage in such business, directly or indirectly. The company shall not launch multilevel marketing, pyramid and ponzi schemes. The company will not engage in Real Estate / Developer business.

34. 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 any particular business.

35. It is undertaking that the company shall not by advertising, pamphlets, other mean of other negotiation, offer for sale or take advance money for the further sale of plots, houses, flats etc. to the general public or individual and shall not indulge in any sort of housing finance company business as mentioned in NBFC Rules, 2003.

36. AND it is hereby declared that the word "Company" (save when used in reference to this company) in this clause shall be deemed to include any partnership or other body of persons whether incorporated or not and wherever domiciled and that the objects set forth in any sub-clause of this clause shall not except when the context expressly so required, be in any way limited or restricted by reference to or inference from the terms of any other sub-clause, or by the name of the company. None of sub-clauses or the objects therein specified or the powers thereby conferred shall be deemed subsidiary or auxiliary. And the company shall have full power to exercise from time to time all or any of the powers conferred by any part of the sub-clause of this clause in any part or parts of the world.

IV. The liability of the members is limited.

V. The capital of the Company is Rs. 10,000,000/- (Rupees Ten Million only) divided into 1,000,000 ordinary shares of Rs. 10/- (Ten) each with power to increase or reduce the share capital and consolidate and divide shares into higher and lower denomination.

Serial No.
Name of the Com...
Brief Descri...
Then date on ...

Companies ... Karachi.

We the several persons whose names, addresses, and descriptions are subscribed 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 in the Capital of the Company set opposite our respective names.

| Name and surname (present & former) in full (in Block Letters) & CNIC NO. | Father's/Husband's Name in full | Nationality with any former Nationality | Occupation | Residential Address in full | Number of shares taken by each subscriber | Signature |
|---|---|---|---|---|---|---|
| **M/S. SUNIR CO.**<br>**Nominee:**<br>Mohammad Kabiriisfahani<br>Passport No. B16069192 | Gholam Abbas | Irani | Business in Power Generation | 1, Mozhdehi Alley Somayeh St. Tehran, Iran. | 415,000<br>(Four hundred & fifteen thousand) | Sd/- |
| Mr. Salman Tufail<br>CNIC No. 42201-8384982-7 | Zubair Tufail | Pakistani | Business in Power Generation | H-36, Block-6, P.E.C.H.S., Karachi. | 207,500<br>(Two hundred seven thousand & five hundred) | Sd/- |
| Mr. Khurram Sayeed<br>CNIC No. 42201-4088735-5 | Tariq Sayeed | Pakistani | Business in Power Generation | House No. 88/3, Flynn Street, Garden East, Karachi. | 41,500<br>(Forty one thousand & five hundred) | Sd/- |
| Mr. Tariq Sayeed<br>CNIC No. 42201-1698741-5 | Sayeed A. Shaikh | Pakistani | Business in Power Generation | House No. 88/3, Flynn Street, Garden East, Karachi. | 41,500<br>(Forty one thousand & five hundred) | Sd/- |
| **M/S. COMPACT NETWORK (PVT) LIMITED**<br>**Nominee:**<br>Mr. Joozer<br>CNIC No. 42301-8026250-7 | Jiwa Khan | Pakistani | Business in Information Technology | Flat No. A-503, Saima Spring Field Apartments, Plot No. 18, Frere Town, Karachi | 124,500<br>(One hundred twenty four thousand & five hundred) | Sd/- |
| | | | | Total Number of Shares: | 830,000<br>(Eight hundred and thirty thousand) | |

Dated the 11th day of November 2009.

Witness the above signature:

**NATIONAL INSTITUTIONAL FACILITATION TECHNOLOGIES (PVT) LIMITED**
**5TH FLOOR, AWT PLAZA, I. I. CHUNDRIGAR ROAD, KARACHI**

41716

**THE COMPANIES ORDINANCE, 1984**

**(COMPANY LIMITED BY SHARES)**

**ARTICLES OF ASSOCIATION**

**OF**

# IRAN-PAK WIND POWER (PRIVATE) LIMITED

**PRELIMINARY**

1. In these regulations:-

   (i) "Section" means section of the Ordinance;

   (ii) The "Ordinance" means the Companies Ordinance, 1984;

   (iii) The "Seal" in relation to the company means the Common Seal of the company; and

   (iv) The "Office" means the Registered Office for the time being of the company.

2. Unless the context otherwise required, words or expressions contained in these regulations shall have the same meanings as in the Ordinance and words importing the singular shall include the plural and vice versa and words importing the masculine gender shall include females and the words importing persons shall include bodies corporate.

3. Subject to as hereinafter provided the regulations contained in Table 'A' of the First Schedule to the Ordinance will apply to the company so far as those are applicable to private companies except where these are modified hereunder.

**PRIVATE LIMITED COMPANY**

4. The Company is a private limited company within the meaning of Section 2(1) Clause 28 of the Companies Ordinance 1984 and accordingly:-

   i. no invitation shall be issued to the public to subscribe for any shares, debenture or debenture-stock of the Company;

   ii. the number of members of the company (exclusive of members in the employment of the Company) shall be limited to fifty, provided that for the purposes of this provision when two or more persons jointly hold one or more shares in the Company they shall be treated as single member; and

   iii. the right to transfer shares in the Company is restricted in the manner and the manner to the extent hereinafter appearing.

**REGISTERED OFFICE**

5. The registered office of the company shall be situated at such place in the province of Sindh as the directors may determine from time to time.

**BUSINESS**

6. The business of the company may include all or any of the objects enumerated in the Memorandum of Association and can be commenced immediately after the incorporation of the company, notwithstanding that a part of the capital has been subscribed.

**CAPITAL**

7. The authorized Capital of the Company is Rs. 10,000,000/- (Rupees Ten million only) divided into 1,000,000 ordinary shares of Rs. 10/- (Ten) each with power to the company, to increase or reduce, consolidate, sub-divide or otherwise reorganize the share capital of the company in accordance with the provisions of the Companies Ordinance, 1984 and subject to any permission required under the law.

**SHARES**

8. The shares shall be under the control of the directors who may allot or otherwise dispose off the same or any of them to such persons, firms or corporations on such terms and conditions and such time as may be though fit.

## TRANSFER OF SHARES

9. No transfer of any share shall be made or registered without the sanction of the directors who shall so decline in the case of any transfer the registration of which will involve the contravention of the provision of the Ordinance. Unless the vendee of the shares agree otherwise, the sale price of the shares shall be determined on the basis of the break-up value of the shares of the company calculated on the basis of the then market value of the assets and liabilities of the company. Intending seller of the shareholding of the company shall first offer to the shareholders of the company thus refusal right shall be in writing vested with the shareholders of the company.

10. The instrument of transfer must be accompanied by the certificate of the shares.

11. In the case of the death of any or more of the persons named in the register as the joint holders of any shares, the survivor shall be the only persons recognized by the company as having any title to or interest in such shares, but nothing herein contained shall be taken to release the estate of the deceased joint holder from any liability on shares held by him jointly by any other person.

## GENERAL MEETINGS

12. The meetings of the company shall be held within the period required by the Ordinance.

13. The First Annual General Meeting shall be held in accordance with the provisions of section 158, within eighteen moths from the date of incorporation of the company and thereafter once at least in every calendar year within a period of four months following the close of the financial year and not more than fifteen months after the holding of its last preceding annual general meeting, as may be determined by the directors.

14. All general meetings of the company other than the annual general meeting mentioned in section 158 shall be called extra ordinary general meetings.

15. The directors may, whenever they think fit, call an extraordinary general meeting, and extraordinary general meetings shall also be called on such requisition, or in default, may be called by such requisitionists, as is provided by section 159. If at any time, there are not within Pakistan, sufficient directors capable of acting to form a quorum, any director of the company may call an extraordinary general meeting in the same manner as nearly as possible as that in which meetings may be called by the directors.

16. The chairman of the board of directors, if any, shall preside as chairman at every general meeting of the company but if there is no such chairman, or if at any meeting, he is not present within fifteen minutes after the time appointed for the meeting or is unwilling to act as chairman, any one of the directors, present may be elected to be the chairman. If none of the directors is present, or willing to act as chairman, the members present shall choose one of their number to be the chairman.

17. Votes may be given at meeting either personally or by proxy. A vote in accordance with the terms of an instrument of one proxy shall be valid notwithstanding the previous death or insanity of the principal officer or revocation of the proxy or of the authority under which the proxy was executed, or the transfer of the share in respect of which is given, provided that no information in writing of the death, insanity, revocation or transfer as aforesaid shall have received at the registered office of the company before the meeting.

18. Twenty one day's notice (exclusive of the day on which the notice is served or deemed to be served, but inclusive of the day for which notice is given) specifying the place, the day and hour of meeting and in case of special business, the general nature of that business, shall be given in the manner provided in the Ordinance or the regulations of the company, to all members entitled to receive such notices from the company; but the accidental omission to give notice to, or the non-receipts of notice by any member shall not invalidate the proceedings at any general meeting.

19. All business shall be deemed special that is transacted at any extraordinary general meeting, and also all that is transacted at an annual general meeting with the exception of declaring a dividend, the consideration of the accounts, balance sheet and the reports of the directors and auditors, the election of directors, the appointment of, and the fixing of the remuneration of the auditors.

20. The chairman may, with the consent of any meeting for which a quorum is present (and shall if so directed by the meeting) adjourn the meeting from time to time but no business shall be transacted at any adjourned meeting other than business left unfinished at the meeting for which the adjournment took place. When a meeting is adjourned for ten days or more, notice of the adjourned meeting shall be given as in the case of an 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 any adjourned meeting.

21. At any general meeting a resolution to the vote of the meeting shall be decided on a show of hands unless a poll is (before or on the declaration of the result of the show of hand) demanded. Unless a poll is so demanded, a declaration by the chairman that a resolution has, on a show of hands, been carried, or carried unanimously, or by a particular majority, or lost, and an entry to that effect in the book of

the proceedings of the company shall be conclusive evidence of the fact, without proof of the number or proportion of the votes recorded in favour of, or against, that resolution.

22. A poll demanded shall be in accordance with the provisions of section 167.

23. If a poll is duly demanded, it shall be taken in accordance with the manner laid down in section 168 and the result of the poll shall be deemed to be the resolution of the meeting at which the poll was demanded.

24. A poll demanded on the election of chairman or on a question of adjournment shall be taken at once.

**VOTE OF MEMBERS**

25. Subject to any rights or restrictions for the time being attached to any class or classes of shares, on a show of hands every member present in persons shall have one vote excepts for election of directors in which case the provisions of section 178 shall apply. On a poll every member shall have voting right as laid down in section 160.

26. In 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 the other joint holders and for this purpose seniority shall be determined by the order in which the names stand in the register of members.

**DIRECTORS**

27. Unless otherwise determined by the company in general meeting, the number of directors shall not be less than two. The first directors of the company shall be the following persons:

***1. Mr. Mohammad Kabiriisfahani***
***(Nominee of "M/S. SUNIR CO.")***
***2. Mr. Salman Tufail***
***3. Mr. Khurram Sayeed***
***4. Mr. Tariq Sayeed***
***5. Mr. Joozer***
***{Nominee of M/s. Compact Network (Pvt) Ltd.}***

28. A director, including the chief executive, shall hold office for a period of not more than three years unless he resigns earlier, becomes disqualified for being a director or otherwise ceases to hold office.

29. The directors shall be elected in the general meeting by the members of the company, for a term of three years in the following manner:-

ii) A member may give all his/her votes to a single candidate or divide them between more than one of the candidates in such a manner as he/she may choose; and

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

30. The qualification of a director shall be the holding in his own right at least one share of Rs. 10 each in the capital of the company and it shall be his duty to comply with this provision within two months after his appointment as director.

31. The company may by an extraordinary resolution remove any or all directors before the expiration of their period of office and may by an ordinary resolution appoint another person(s) on his or their stead. Provided that a resolution for removing a director shall not be deemed to have been passed if the number of votes is equal to or exceeds the number of votes that would have been necessary for the election of director or directors at the immediately preceding annual election of directors in the manner prescribed under these Articles.

32. Each director of the company shall be paid out of the fund of the company a fee which shall be decided by the board of directors from time to time, for such meeting of the board of directors attended by him besides such traveling or other expenses as may be sanctioned for the board meeting in case of directors who attend the board meeting from a place outside the city or town in which the meeting is held.

33. If any director being willing, is called upon to perform extra services or to make any special exertions for any of the purpose of the company or giving any special attendance to the business of the company, the company may remunerate the directors so being either by a fixed sum or otherwise, as may be determined by the directors.

34. The directors may appoint chief executive on such terms and conditions as they think fit and delegate all or any of their powers to him.

## PROCEEDINGS OF DIRECTORS

35. The quorum necessary for the transaction of the business of the director may be fixed by the directors and unless so fixed shall be two.

36. A resolution passed without holding a meeting of the directors by circular and assented by all of them shall have the same force as passed by a meeting of the directors duly convened and held.

## BORROWING POWERS

37. The directors may from time to time raise or borrow any of money for and on behalf of the company from the members or other persons, companies, banks, financial institutions or they may themselves advance money to the company on such terms and conditions as they may think fit.

38. The directors may from time to time secure the payment of such money in such manner and upon such terms and conditions in all respect as they may think fit and in particular by the issue of the debentures or bonds of the company charged upon some or all the assets of the company.

39. Any debentures, bonds or the securities may be issued at a discount, premium or otherwise and with the special privileges.

## AUDITORS

40. Auditors shall be appointed at each annual general meting of the company and shall hold office until the next annual general meeting. Their appointment, remuneration, rights and duties shall be regulated, in accordance with section 252 to 255 of the Ordinance or any statutory modification thereof for the time being in force.

## DIVIDENDS

41. No dividend shall be payable except out of the profits of the year or any other undistributed profits and no dividend shall carry any interest as against the company. The directors may from time to time pay such interim dividends as in their opinion the position of the company justifies.

42. Dividend shall not be paid out of unrealized gain on investment property credited to profit and loss account.

43. The company on the recommendations of the board of directors may declare a dividend, in general meeting, not exceeding the amount recommended to be paid to the members according to their rights and interest in the profits and may fix the time of payment.

44. The directors may before recommending dividend, set aside out of the profit of the company, such sums as they think proper as a reserve which shall at the discretion of the directors be applicable to meet the

emergencies or for equalizing dividend or for any other purpose to which the profits of the company may properly be applied and pending such application may at their discretion either be employed in the business or be disbursed as the directors thinks fit.

45. Unless otherwise directed, any dividend may be paid by cheque or warrant, send through post to the registered address of the member entitled. Any one of the several persons who are registered as joint holder of any share may give effectual receipts for all dividend and payments in respect thereof.

## THE SEAL

46. The company shall have a common seal and the directors shall provide for the safe custody thereof. The seal shall not be applied to any instrument except by the authority of a resolution of the directors in the presence of at least one director or such other person as the directors may appoint for the purpose and shall sign every instrument to which the seal is affixed. Such signatures shall be conclusive evidence of the fact that seal has been property affixed in their presence.

## ACCOUNTS

47. The directors shall cause to be kept proper books of account as required under section 230.

48. The books of account shall be kept at the registered office of the company or at such other place as the directors shall think fit and shall be open to inspection by the directors during business hours.

49. The directors shall from time to time determine whether and to what extent and at what time and places and under what conditions or regulations the accounts and books of papers of the company or any of them shall be open to inspection of members not being directors and no member (not being a director) shall have any right of inspecting any account and book or papers of the company excepts as conferred by law or authorized by the directors or by the company in general meeting.

50. The directors shall as required by sections 233 and 236 cause to be prepared and to be laid before the company in general meeting such profit and loss accounts balance sheets duly audited and reports as are referred to in those sections.

51. A balance sheet, profit and loss account and other reports referred to in regulation 51 shall be made out in every year and laid before the company in the annual general meeting made up to a date not more than four months before such meeting. The balance sheet and profit and loss account shall be accompanied by a report of the auditors of the company and the report of directors.

52. The directors shall in all respect comply with the provisions of sections 230 to 236.

## NOTICES

53. A notice may be given by the company to any member either personally or by sending it by post, telex or telefax to the registered address.

54. 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.

55. A notice may be given by the company to the joint holders of a share by giving the notice to the joint holders of a share by giving the notice to the joint-holder named first in the register.

## WINDING UP

56. If the company is wound up, the liquidator may, with the sanction of a special resolution of the company, and any other sanction required by the Ordinance, divide amongst the members, in specie or kind, the whole or any part of the assets of the company, whether they consist of property of the same kind or not.

57. For the purpose aforesaid, the liquidator may set such value as he deems fair upon any property to be divided as aforesaid and may determine how such division shall be carried out as between the members or different classes of members.

58. The liquidator may, with like sanction, vest the whole or any part of such assets in trustees upon such trusts for the benefit of the contributors as the liquidator, with the like sanction thinks fit, but so that no member shall be compelled to accept any shares or other securities whereon there is any liability.

## INDEMNITY

59. Every officer or agent for the time being of the company may be indemnified out of assets of the company against any liability incurred by him in defending any proceedings, whether civil or criminal, arising out of his dealings in relation to the affairs of the company, excepts those brought by the company against him, in which he is acquitted, or in connection with any application under section 488 in which relive is granted him by the court.

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

| Name and surname (present & former) in full (in Block Letters) & CNIC NO. | Father's/Husband's Name in full | Nationality with any former Nationality | Occupation | Residential Address in full | Number of shares taken by each subscriber | Signature |
|---|---|---|---|---|---|---|
| **M/S. SUNIR CO.** **Nominee:** Mohammad Kabiriisfahani Passport No. B16069192 | Gholam Abbas | Irani | Business in Power Generation | 1, Mozhdeh Alley Somayeh St. Tehran, Iran. | 415,000 (Four hundred & fifteen thousand) | Sd/- |
| Mr. Salman Tufail CNIC No. 42201-8384982-7 | Zubair Tufail | Pakistani | Business in Power Generation | H-36, Block-6, P.E.C.H.S., Karachi. | 207,500 (Two hundred seven thousand & five hundred) | Sd/- |
| Mr. Khurram Sayeed CNIC No. 42201-4088735-5 | Tariq Sayeed | Pakistani | Business in Power Generation | House No. 88/3, Flynn Street, Garden East, Karachi. | 41,500 (Forty one thousand & five hundred) | Sd/- |
| Mr. Tariq Sayeed CNIC No. 42201-1698741-5 | Sayeed A. Shaikh | Pakistani | Business in Power Generation | House No. 88/3, Flynn Street, Garden East, Karachi. | 41,500 (Forty one thousand & five hundred) | Sd/- |
| **M/S. COMPACT NETWORK (PVT) LIMITED** **Nominee:** Mr. Joozer CNIC No. 42301-8026250-7 | Jiwa Khan | Pakistani | Business in Information Technology | Flat No. A-503, Saima Spring Field Apartments, Plot No. 18, Frere Town, Karachi | 124,500 (One hundred twenty four thousand & five hundred) | Sd/- |
| | | | | Total Number of Shares: | 830,000 (Eight hundred and thirty thousand) | |

Dated the 11th day of November 2009.

Witness the above signature:

**NATIONAL INSTITUTIONAL FACILITATION TECHNOLOGIES (PVT) LIMITED**
**5TH FLOOR, AWT PLAZA, I. I. CHUNDRIGAR ROAD, KARACHI**

Certified to be True Copy

24/1/16

Deputy Registrar of Companies

Report No. PPI-173.1-Draft-Iran-Pak Wind/15

PPI

# ELECTRICAL GRID STUDIES

*For*

# 50 MW Wind Power Plant by Iran-Pak Wind Power Pvt. Limited

**Draft Report**
**(October 2015)**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## Executive Summary

- The study objective, approach and methodology have been described and the plant's data received from the client Iran-Pak Wind Power Pvt. Ltd has been validated.
- The project by the name of Iran-Pak Wind Power Pvt. Ltd. (referred to as Iran-Pak WPP in the remainder of this report) is expected to start commercial operation by the end of year 2017. Therefore, the month of June 2018 have been selected to carry out the study as it will help determine the maximum impact of the project.
- The latest generation, transmission plan and load forecast provided by NTDC has been used vide data permission letter no. GMPP/CEMP/TRP-380/2557-58 dated 18-06-2015.
- A sixth sub cluster has been proposed at Jhimpir-New 220/132 kV collector substation to evacuate another 200 MW power from four Wind Power Plants namely, Iran-Pak WPP, Hatrford, Western Energy and DHA-City generating 50 MW each. Therefore, the interconnection of Iran-Pak WPP has been proposed by connecting through a double circuit of 132 kV looping in-out with a sub cluster connecting Wind Power Plants mentioned above with the Jhimpir-New 220/132 kV collector substation.
- The scheme of interconnection of Iran-Pak WPP presupposes the following reinforcement already in place in Jhimpir and Gharo clusters.
    - 220/132 kV Jhimpir-New substation (now under construction)
    - 70 km long double circuit from Jhimpir-New 220 kV Substation to the existing T.M. Khan Road 220 kV Substation (now under construction)
    - A 132 kV double circuit of 82 km using Greeley conductor would be constructed to connect Jhimpir-New 220/132 kV Substation with T.M. Khan in HESCO network (now under construction).
    - 75 km long 220 kV double circuit from Gharo-New 220 kV Substation to Jhimpir-New 220 kV Substation (now under construction).

- 220/132 kV Gharo-New substation at suitable location in Gharo cluster(now under construction)
- The additional power injected into Jhimpir-New 220/132 kV grid station would require another outlet of 220 kV D/C because the ongoing 220 kV D/C from New-Jhimpir to TM Khan Rd. would already be reaching to its full capacity to evacuate already commissioned Wind Power Plants in Jhimpir cluster. The additional outlet is proposed as follows:
  - Addition of 22 kV level at the ongoing 500kV Matiari Collector Substation
  - 100 km long 220 kV D/C from Jhimpir 220/132 kV to Matiari 500/220 kV grid station using Greeley conductor.
- Five sub-collectors groups will be connected to Jhimpir 220/132 kV collector substation through 132 kV double circuits using Greeley Conductor
- FFC and Zorlu looped in-out with Jhimpir-Nooriabad 132 kV circuit.
- Four WPPs in the collector system of Gharo 220/132 kV substation
- FWEL-I and FWEL-II through a 64 km long 132 kV D/C on Greeley conductor connected to Thatta
- Rehabilitation of the exiting 132 kV lines in the vicinity of WPP clusters, i.e. Jhimpir-Kotri, Jhimpir-Thatta, Thatta-Sujawal and Nooriabad-Jamshoro Old.

➢ The existing grid system of HESCO and NTDC in the vicinity of Iran-Pak WPP has been studied in detail by performing load flow, short circuit and dynamic analysis for the conditions prior to commissioning of Iran-Pak WPP and no bottlenecks or constraints have been found in the grid system.

➢ Wind Farm of Iran-Pak has been modeled considering Type-3 WTGs. They are Doubly Fed Induction Generators which are designated as Type-3 WTG. The terminal voltage is 0.65 kV. The medium voltage level of wind farm has been selected as 33 kV for unit step-up transformers, for collector circuits and step-up from MV to HV (132 kV) at Farm substation to connect to the 220/132 kV New Jhimpir 220/13 kV grid station of NTDC.

- A conceptual design of scheme of 132/33 kV substation of Iran-Pak Wind Farm has been laid down as follows

  i. For 33 kV;

     a. Two single bus-sections of 33 kV with a bussectionalizer
     b. Three breaker bays to connect three collector circuits from three collector groups of WTGs
     c. Two breaker bays to connect two 132/33 kVtransformers
     d. Two breaker bays to connect two switched shunt capacitor banks of 2 x (4x2.5) MVAR, one in each bus section
     e. Two breaker bays to connect two station auxiliary transformers 33/0.4 kV, 315 kVA

  ii. For 132 kV;

     a. Single bus with Sectionalizer if Farm substation isGIS
     b. Double bus bars with a Bus Coupler if Farm substation isAIS
     c. Two breaker bays to connect two 132/33 kVtransformers
     d. The protection scheme would be designed in compliance of NTDC requirements sent by Chief Engineer Protection, vide letter No.3416-19/CE/SP/MN/50MW CWE WPP Jhimpir dated23/07/2010
     e. The telecommunication scheme would be designed in compliance of NTDC requirements sent by Chief Engineer Telecommunication, vide letter No. CE (Tel)/NTDC/232/4372 dated27/08/2010.

  iii. Other Equipment:

     a. Two 132/33 kV, 31.5/40/50 MVA ONAN/ONAF1/ONAF2 OLTC transformers, 132±11×1%/22kV, to fulfill N-1 criteria of Grid Code

b. Two station auxiliary transformers of 33/0.4 kV, 315 kVA

c. Two switched shunt capacitor banks each of the size of 10 MVAR (4 x 2.5 MVAR) to provide 20 MVAR at 33 kV with contactors and PLC (Programmable Logic Controller).

d. Energy meters would be installed on HV side (132 kV) of the 132/33kV transformers.

- Load flow analysis has been carried out for June 2018 considering the COD targeted by Iran-Pak WPP, for the dispersal of load from Iran-Pak WPP into HESCO Grid at 132 kV level using the latest load forecast, generation and transmission expansion plans of NTDC and HESCO. The above mentioned interconnection scheme has been evolved by performing the load flow studies testing the steady state performance for normal as well as N-1 contingency conditions fulfilling the Grid Code criteria of Wind Power Plants. The reactive power requirement at point of common coupling to meet PF of ± 0.95, voltage and line loading criteria are fulfilled by these studies. The grid facilities of HESCO are found adequate to absorb output power of Iran-Pak WPP. The load flow results for these scenarios also establish that the proposed scheme of interconnection of Iran-Pak WPP shows no bottlenecks or capacity constraints in the adjoining 500 kV, 220 kV and 132 kV network in terms of absorbing all the output of Iran-Pak WPP under normal as well as the contingency conditions.
- Maximum and minimum short circuit levels for three-phase faults and single-phase faults have been evaluated. The maximum short circuit level has been evaluated for the year 2017-18 and the minimum short circuit level has been evaluated for 2017-2018 to evaluate the most stringent conditions, the fault levels of Iran-Pak 132 kV are 11.82 kA and 6.52 kA for 3-phase and single phase faults respectively for 2017-18. This is much less than the switchgear rating of 40 kA recommended for Iran-Pak Farm Substation as per NTDC requirements for 132 kV. The fault levels for Iran-Pak 33 kV are 11.80 kA and 10.14 kA for 3-phase and single-phase faults respectively for year 2017-18. Therefore the short circuit

rating for 33 kV switchgear is recommended as 25 kA. It has been found that the proposed scheme provides maximum SC strength for the evacuation of Iran-Pak WPP power to the grid.

The switchgear ratings for Iran-Pak WPP substation are as follows:

**132 kV:**

Short circuit rating = 40 kA (3 sec.)

Continuous rating = 2500 A

**33 kV:**

Short circuit rating = 25 kA (3 sec.)

Continuous rating = 2500 A

- Transient Stability analysis has been carried out for Iran-Pak WPP based on their selection of Type-3 WTGs, with connectivity of proposed scheme. Different disturbances have been simulated to apply stresses from the system faults on the wind farm and vice versa and it was found that Iran-Pak WTG unit's dynamic characteristics and the grid connectivity is strong enough to maintain stability under all disturbances. In turn, any disturbance from Iran-Pak WPP side did not cause any stress on the main grid or the power plants in HESCO area viz. Kotri, Lakhra or Jamshoro such that the whole system remained stable under all events.
- The LVRT requirements have been tested to fulfill 100 ms (5 cycles) under normal clearing time and 180 ms (9 cycles) for contingency condition of delayed fault clearing due to stuck- breaker (breaker failure) reason. The simulations have proved that the proposed machine fulfills the LVRT criteria as required in the Grid Code for Wind IPPs.
- The issues of power quality like flicker, unbalance and harmonic resonance have been studied in detail. The results have indicated that the levels of flicker and unbalance are within the permissible limits of IEC and other International Standards.
- There are no technical constraints whatsoever in the way of bringing in the 50 MW of Iran-Pak Wind Power Plant at the proposed site and scheduled time of

commissioning, in any respect of steady state (load flow) or short circuit or dynamic performance (stability) or power quality issues related to this plant.

## Report Contents

# 1. Introduction

## 1.1 Background

There exists a huge wind corridor in coastal Sindh, starting from Gharo-Ketti Bandar up to Jhimpir and upward, that has been identified by AEDB with an actual potential of about 50,000 MW. There are many entrepreneurs coming forward to tap this huge natural resource of power; fourteen of them in the Jhimpir cluster who have been allocated lands by AEDB to develop wind farms and set to achieve COD. Iran-Pak Wind Power Pvt. Ltd. is one such pioneering entrepreneur who has come forward with a Wind Power Plant within this cluster at Jhimpir.

The proposed wind farm shall have the installed capacity of about 50 MW of electricity. The project is being developed in the private sector and the electricity generated from this project would be supplied to power grid of HESCO / NTDC. The services of Power Planners International have been engaged to perform the impact studies of penetration of this wind power in the national grid to evolve the most feasible interconnection scheme for this plant.

## 1.2 Objectives

The overall objectives of this study are:

1. Impact of Iran-Pak Wind Power Plant on the System
2. Impact of the System on Iran-Pak Wind Power Plant

These impacts are to be studied for different operating conditions of Plant as well as the System. The operating condition of the plant may vary from its 100 % output to 0 % i.e. no output at all. The system conditions would be peak load, off-peak load under two generation dispatch scenarios with high hydro power availability and low hydro (or high thermal) power generation.

The impacts are required to be studied for steady state as well as the dynamic and disturbed conditions of the system. The specific objectives are:

1. To develop a feasible scheme of interconnections of Iran-Pak Wind Power Plant (WPP) with HESCO/NTDC network at 132 kV for which right of way (ROW) and space at the terminal substations would be required to be made available.
2. To check the load-ability of lines and transformers to be within their rated limits satisfying the clauses OC 4.8, OC 4.9, and OC 4.10 of NEPRA Grid Code regarding the criteria of operation of frequency, voltage and stability under normal and contingency conditions for peak and off-peak load conditions of grid as well as the plant.
3. To check the voltage profile of the bus bars of the neighboring interconnected network under different operating conditions
4. To check the reactive power limitations of the wind turbines and the neighboring generators of the system; and evaluate the size of switched shunt capacitor banks at Medium Voltage level of substation of collector system of Iran-Pak Wind Farm to regulate the voltage under steady state and contingency conditions to fulfill the Grid Code criteria of ± 0.95 Power Factor at the point of common coupling (interface point) interconnecting Wind Farm and the Grid i.e. 132 kV gantries of outgoing circuits.
5. To check if the contribution of fault current from this new plant increases the fault levels at the adjoining substations at 220 kV and 132 kV voltage levels to be within the rating of equipment of these substations, and also determine the short circuit ratings of the proposed equipment of the Medium Voltage substation of collector system of Iran-Pak Wind Farm and the NTDC/HESCO substations of 132 kV connecting with the Iran-Pak Wind Farm.
6. To check the minimum short circuit strength of the system to handle large variation of generation of wind turbine

7. To check if the interconnection with the grid withstands transient stability criteria of post fault recovery with good damping satisfying the NEPRA Grid Code.
8. Transient stability to see the dynamic performance of Iran-Pak WPP in response to Grid disturbances and vice versa the dynamic impact of disturbances in Iran-Pak WPP on the Grid.
9. To check the ability of the wind turbine generators of Iran-Pak WPP to remain connected following major disturbances and grid disruptions i.e. the Low Voltage Ride Through (LVRT) capability to satisfy the Grid Code requirement of LVRT for 180 ms
10. Analysis of power quality issues such as flicker, voltage-unbalance, harmonics and resonance of the system.

## 1.3 Planning Criteria

The planning criteria required to be fulfilled by the proposed interconnection as enunciated in NEPRA Grid Code including Addendum No.1 for WPPs are as follows:

| | |
|---|---|
| **Voltage** | ± 5 %, Normal Operating Condition |
| | ± 10 %, Contingency Conditions |
| **Frequency** | 50 Hz, Continuous, ± 1% variation steady state |
| | 49.4 - 50.5 Hz, Under Contingency |

**Short Circuit:**

132 kV Substation Equipment Rating 40kA

**Dynamic/Transient and Low Voltage Ride through (LVRT):**

The WTGs should remain connected during voltage dip upto 30 % level, under fault conditions by ride through capability for the following sequence of disturbance

1. Total normal fault clearing time from the instant of initiation of fault current to the complete interruption of current, including the relay time and breaker interruption time to isolate the faulted element, is equal to 100 ms (5 cycles) for the systems of 132 kV and above.

2. In case of failure of primary protection (stuck breaker case), the total fault clearing time from the instant of initiation of fault current to the complete interruption of current to isolate the faulted element, including the primary protection plus the backup protection to operate and isolate the fault, is equal to 2ms (9 cycles) for 132 kV and higher voltage levels.

3. LVRT of 100 ms for normal fault clearing and 180 ms for the case of failure of primary protection (stuck breaker case).

**Reactive Power and Power factor:**

Reactive Power Control to maintain the power factor within the range of 0.95 lagging to 0.95 leading, over full range of plant operation, according to Dispatch Instructions/manual voltage adjustment requirements.

**Power Quality Requirements:**

As per IEC61400-21standards

## 1.4 Operating Criteria

The operating requirements to be fulfilled by the proposed Iran-Pak WPP as enunciated in NEPRA Grid Code for WPPs (Addendum No.1) are as follows:

**Black Start and Islanded Operation:**

Exempted

**Active Power and Frequency Control:**

Exempted from precise frequency control responsibility

**Synchronization / De-Synchronization:**

(i) The Wind Power Plant will manage for

- (a) Smooth Synchronization
- (b) Smooth De-Synchronization

(ii) The above operations, achieved through appropriate equipment, will be without jerk(s), felt on the grid system

**Power Generation Capability Forecasting Requirement:**

(i) Power Generation Capability Forecasting, of average power on hourly basis, will be managed by the Wind Power Plant as required from conventional power plants, except provisions of clause (ii) & (iii) below.

(ii) The forecasting, as required in (i), will be estimated by Wind Power Plant through

(a) Expected availability of plant during the period offorecast.

(b) Predicted value of wind speed at site based upon analysis of historic wind data available.

(iii) The forecasting, as required in (i), will be on the basis of total Wind Power Plant and break-up for each WTG will not be required.

(iv) The forecasted values will not be a binding upon the wind power plant as actual wind speeds may differ significantly from predicted values over short durations.

## 1.5 Input Data

The input data of HSECO / NTDC has been used in this study as per letter No. GMPP/CEMP/TRP-380/2557-58 dated 18-06-2015. In addition, NTDC via its letter No. MD/NTDCL/PS/4403-13, has intimated that the 132 kV collector substation at Jhimpir would be completed by June 2015 and the 220 kV Collector Substations at Jhimpir and Gharo would be completed by the end of 2016-2017. The load forecast and the generation expansion plan of NTDC provided vide this letter has been used as shown in Appendix 2.

The input data regarding Iran-Pak Wind Farm has been provided by the client who has indicated to use 3.3 MW Vestas Type-3 WTG. The main parameters of the WTGs have been attached in Appendix-2.

# 2. Description of Problem & Study Approach

## 2.1 Description of the Problem

In Pakistan, there is big wind power generation potential in the Southern parts of Sindh province, which is untapped as yet. However now with the establishment of Alternative Energy Development Board, this sector of power generation has taken an unprecedented stride and many entrepreneurs have come forward to build small and big Wind farms in this area.

The peculiar nature of wind power turbine is such that its output fluctuates in terms of MW and MVAR, being dependent on the wind speed and its direction. So long as the capacity of wind farm is less significant compared to the size of the power grid it is connected, these fluctuations are absorbable without compromising the power quality. But as the penetration of wind power in the power grid increases, the capability of the power grid may not be as strong as may be required to absorb constant variations of MW, MVAR and hence rapid deviation in voltage and frequency from the system's normal operating set point.

The existing power plants nearest to the vast wind farm areas of Jhimpir in the existing power grid are Kotri and Jamshoro having installed capacity of 120 MW and 600 MW respectively. Next to them are Hub with 1200 MW, Lakhra with 70 MW. Apparently this amount of generation in Southern grid seems strong enough to absorb the penetration of wind power of 50MW. But there are other variables that necessitate detailed studies like strengths of nodes of connectivity, loading capacity of the transmission lines to evacuate power from Wind Farm area and dynamic response of wind turbine generators and neighboring conventional synchronous generators.

The dynamic response of power plants in the neighborhood may not be uniform; as some of them are gas turbines and some are steam turbines i.e. Kotri has gas turbines whereas Jamshoro, Lakhra and Hub have steam turbines. Normally gas turbines are faster than the steam turbines to respond to changes in the system. The dynamic studies will determine how they respond to dynamic behavior of Iran-Pak WPP.

The above-mentioned thermal power plants do not run at their full capacity all along the whole year. During high water months when cheaper hydel power is abundantly available in the Northern grid of NTDC, many generating units of these plants are shut down for the sake of economic dispatch. Therefore in high hydel season, which is low thermal season by default, the southern power grid would get weaker in terms of system strength, especially during off-peak hours. The dynamics of this season is different than that of high thermal season.

There are different models of different sizes and make available in the market viz. GE, Vestas, Nordex, Gamesa, Siemens, Goldwind and Vensys etc. The dynamics of each model may be different with respect to grid's dynamics. Iran-Pak Wind Energy is considering using Type-3 WTGs which are Doubly Fed Induction Generators.

There are other wind farms going to get developed soon in the neighborhood of Iran-Pak wind farm. With the increase of penetration of more wind power in the same power grid, the impact studies would become even more involving from the point of view of dynamic stability.

## 2.2 Approach to the problem

We will apply the following approaches to the problem:

- The COD of Iran-Pak WPP as provided by the Client Iran-Pak and AEDB we have decided to perform our analysis for the scenario of 2017-18 to judge the maximum impact of the plant after the COD of the plant when the 220 kV Substation of Jhimpir is commissioned in 2016-2017.
- The base case for the year 2017-18 comprising all 500kV, 220kV and 132 kV, and 66kV system would be prepared envisaging the load forecast, the generation additions and transmission expansions for each year particularly in the Southern parts of the country. The case would include the Wind Power Plants which are developing on fast track basis and are expected to be commissioned by 2017-18 as per the latest schedule of AEDB.

- Interconnection scheme without any physical constraints, like right of way or availability of space in the terminal substations, would be identified.
- Perform technical system studies for peak load conditions of high wind seasons' power dispatches, to confirm technical feasibility of the interconnections.
- The proposed interconnection scheme will be subjected to steady state analysis (load flow), short circuit and transient stability to test the robustness of the scheme under normal and contingency conditions by checking steady state and transient/dynamic behavior under all events.
- Determine the relevant equipment for the proposed technically feasible scheme of interconnection
- Perform sensitivity studies considering adjacent wind farms to check their impact on HESCO/NTDC Grid. This sensitivity check can be performed for the ultimate planned number of Wind Power Plants in the neighborhood of Iran-Pak Wind PP.

# 3. Analysis of Network Prior to Iran-Pak WPP Interconnection

## 3.1 Description of the Network

The electrical grid, which is relevant for interconnection of Iran-Pak Wind PP, is the 132 kV network that stretches through South of Hyderabad and Jamshoro up to coastal areas of Southern Sind. This network, as it stands today is shown in Sketch-1 in Appendix-4. It comprises the following NTDC grid stations;

- Existing 500/220/132 kV grid station at Jamshoro connected through double circuits of 500 kV with Dadu in the North and Hub/New-Karachi in the South.
- Existing 220/132 kV Hala Road connected to Jamshoro 500/220/132 kV grid through a double circuit of 220 kV
- Existing T. M. Khan Road 220/132 kV grid station connected to Jamshoro 500/220/132 kV grid station by a double circuit of 220 kV

The 132 kV network under HESCO has been shown only for the circuits that emanate from Hyderabad, Jamshoro and Kotri to connect to the substations of 132 kV lying South of Hyderabad. There are four existing branches of network of 132 kV that stretch southward and pass close to Iran-Pak WPP near Jhimpir, as follows:

- Jamshoro-Old - Nooriabad – Kalukuhar 132 kV single circuit
- Kotri-Jhimpir-Thatta-P.Patho-M.P.Sakro-Garho 132 kV single circuit
- Hyderabad-T.M.Khan-B.S.Karim-Sujawal-Thatta 132 kV single circuit
- The Jhimpir-Nooriabad 132 kV single circuit on double-circuit-towers (SDT) provides parallel reliability with the other two branches up to Thatta and Nooriabad.

Two of the branches connecting Thatta provide parallel reliability to each other up to Thatta. However the single circuit South of Thatta going to Garho via P.Patho and M.P.Sakro does not support the supply to these substations under an outage condition. The Jhimpir-Nooriabad 132 kV S/C would be the nearest electrical grid passing by the site of Iran-Pak WPP, that lies in between Jhimpir and Nooriabad. This line has been built using double-circuit towers (SDT) and the work of stringing of second circuit is in progress these days and is nearing completion.

The network as it is planned with wind power plants scheduled prior to commissioning of Iran-Pak WPP in late 2017 is shown in Sketch-2 in Apendix-4 , For further addition of WPPs, NTDC, via its letter No. MD/NTDCL/PS/4403-13, has intimated that the 132 kV collector substation at Jhimpir would be completed by June 2015 and the 220 kV Collector Substations at Jhimpir and Gharo would be completed by the end of 2016-2017. Based on this letter, the following interconnection facilities will be in place by the end of 2016-2017:

- 220/132 kV Jhimpir-New substation (now under construction)
- 70 km long double circuit from Jhimpir-New 220 kV Substation to the existing T.M. Khan Road 220 kV Substation (now under construction)
- A 132 kV double circuit of 82 km using Greeley conductor would be constructed to connect Jhimpir-New 220/132 kV Substation with T.M. Khan in HESCO network (now under construction).
- 75 km long 220 kV double circuit from Gharo-New 220 kV Substation to Jhimpir-New 220 kV Substation (now under construction).
- 220/132 kV Gharo-New substation at suitable location in Gharo cluster(now under construction)
- The additional power injected into Jhimpir-New 220/132 kV grid station would require another outlet of 220 kV D/C because the ongoing 220 kV D/C from New-Jhimpir to TM Khan Rd. would already be reaching to its full capacity to evacuate already commissioned Wind Power Plants in Jhimpir cluster. The additional outlet is proposed as follows:
- Addition of 22 kV level at the ongoing 500kV Matiari Collector Substation
- 100 km long 220 kV D/C from Jhimpir 220/132 kV to Matiari 500/220 kV grid station using Greeley conductor.
- Five sub-collectors groups will be connected to Jhimpir 220/132 kV collector substation through 132 kV double circuits using Greeley Conductor
- FFC and Zorlu looped in-out with Jhimpir-Nooriabad 132 kV circuit.
- Four WPPs in the collector system of Gharo 220/132 kV substation

- FWEL-I and FWEL-II through a 64 km long 132 kV D/C on Greeley conductor connected to Thatta
- Rehabilitation of the exiting 132 kV lines in the vicinity of WPP clusters, i.e. Jhimpir-Kotri, Jhimpir-Thatta, Thatta-Sujawal and Nooriabad-Jamshoro Old.

Of the two sub clusters developed in Jhimpir area, one sub-cluster will comprise FFC and Zorlu looped in-out on one circuit of the Jhimpir-Nooriabad 132 kV double circuit whereas the other sub-cluster would comprise the Jhimpir-New 220/132 kV Collector Substation and would connect five sub-collectors groups through 132 kV double circuits prior to the connection of Iran-Pak Wind Power Plant. Another sub-collector group will be added to evacuate 200 MW from four Wind Power Plants namely, Iran-Pak Wind, Hartford, Western Energy and DHA-City generating 50 MW each.

We have carried out the studies of the case "without" Iran-Pak WPP but including all the other WPPs which have COD by 2017-18 according to the latest schedule by AEDB to ascertain if there are any constraints in the system prior to Iran-Pak WPP's commissioning.

### 3.1.1 Load Forecast

The load forecast of NTDC attached in Appendix-2 has been used and in addition 650 MW export to KESC has been assumed.

### 3.1.2 Transmission Expansion

Because of sizable additions of generation scheduled in South, the following transmission expansion has been planned to reinforce 500 kV and 220 kV network in South;

**500 kV**

- Guddu-Multan 2nd circuit 500 kV In-Out at D. G. Khan 2013-14
- Guddu-Multan 3rd circuit 500 kV In-Out at R. Y. Khan 2013-14
- Guddu-R.Y. Khan 500 kV circuit In-Out at Guddu-New PP 2013-14
- Guddu-New Power Plant to M. Garh 500 kV S/C 2013-14
- Guddu-Dadu 1st circuit 500 kV In-Out at Shikarpur New 2014-15

| | |
|---|---|
| • Guddu-Dadu 2nd circuit 500 kV In-Out at Shikarpur New | 2014-15 |
| • Jamshoro-Moro 500 kV S/C | 2016-17 |
| • Moro-R.Y. Khan 500 kV S/C | 2016-17 |
| • Dadu-Moro 500 kV S/C | 2016-17 |
| • Jamshoro-Moro 500 kV circucit In-Out at Matiari | 2017-18 |
| • Engro-Matiari 500 kV D/C | 2017-18 |

**220 kV**

| | |
|---|---|
| • Rohri New – Shikarpur 220 kV D/C | 2012-13 |
| • Dadu-Khuzdar 220 kV D/C | 2013-14 |
| • Uch-1-Shikarpur S/C in-out at Uch-2 Power Plant 220 kV | 2013-14 |
| • Uch-Guddu S/C In-Out at D. M. Jamali | 2013-14 |
| • Uch-2 Power Plant – Sibbi 220 kV D/C | 2014-15 |
| • Uch-1-Guddu S/C in-out at Shikarpur New 220 kV | 2014-15 |
| • Hala Road – T. M. Khan Road 220 kV S/C | 2015-16 |
| • Jhimpir-T. M. Khan Rd. 220 kV D/C | 2015-16 |
| • Gharo-Jhimpir 220 kV D/C | 2015-16 |
| • Jhimpir-New-Matiari 220 kV D/C (Proposed) | 2017-18 |

## 3.2 Load Flow Analysis

Load flow analysis has been carried out for the NTDC / HESCO network including the connections provided to new wind power plants FFC, Zorlu, TGF, Master, Sapphire, Yunus, Sachal, Hawa ,Wind-Eagle-1 and 2, UEPL, SUNEC, Tapal, Gul Ahmed, JHM WIND , METRO, TCN-A, TCN-B, TCN-C, Hartford, Western Energy and DHA-City in the Jhimpir cluster FWEL-I, FWEL-II, HYDROCHINA Dawood (HDPPL) and Tenaga, in the Gharo cluster but without including Iran-Pak WPP to see if the network was adequate for dispersal of wind power without it. The case has been studied for the system conditions of June 2018. The month has been selected as NTDC, via its letter No. MD/NTDCL/PS/4403-13, has intimated that the 220 kV Collector Substations at

Jhimpir and Gharo would be completed by the end of 2016-2017. We kept the dispatch of the nearby power plant such as Thatta, Nooriabad and Kotri-Site at its maximum therefore we can see the maximum distributed generation on 132 kV network prior to commissioning of Iran-Pak WPP. With this dispatch, the power flow conditions on 132 kV network around Jhimpir, Thatta and Nooriabad area would be almost same irrespective of High or Low Water dispatch conditions on the primary network of NTDC. The results are shown plotted in Exhibit 3.0 in Appendix-3 which indicates that no circuit is loaded more than its rated power carrying capacity and the voltage profile at all the bus bars of 132 kV, 220 kV and 500 kV is within the permissible range. All power plants are running at lagging power factor within their rated range.

The N-1 contingency check has also been applied for the three Southward branches each, and the results are attached in Appendix-3 as below:

| | |
|---|---|
| Exhibit 3.1 | Werstern energy to Hartford 132 kV Single Circuit Out |
| Exhibit 3.2 | Hartford to Jhimpir-New 132 kV Single Circuit Out |
| Exhibit 3.3 | Western Energy to Iran-Pak Wind 132 kV Single Circuit |
| Out Exhibit 3.4 | DHA-City to Jhimpir-New 132 kV Single Circuit Out |
| Exhibit 3.5 | Saphire to Jhimpir-New 132 kV Single Circuit Out |
| Exhibit 3.6 | UEPL to Jhimpir-New 132 kV Single Circuit Out |
| Exhibit 3.7 | WE-2 to Jhimpir-New 132 kV Single Circuit Out |
| Exhibit 3.8 | TCN-C to Jhimpir-New 132 kV Single Circuit Out |
| Exhibit 3.9 | Gul Ahmed to Jhimpir-New 132 kV Single Circuit Out |
| Exhibit 3.10 | Zorlu to Jhimpir 132 kV Single Circuit Out |
| Exhibit 3.11 | Jhimpir to Nooriabad 132 kV Single Circuit Out |
| Exhibit 3.12 | Jhimpir to Kotri GTPS 132 kV Single Circuit Out |
| Exhibit 3.13 | Jhimpir-New to T.M.Khan 132 kV Single Circuit Out |
| Exhibit 3.14 | Jhimpir-New 220/132 kV Single Transformer Out |
| Exhibit 3.15 | Gharo-New 220/132 kV Single Transformer Out |
| Exhibit 3.16 | Jhimpir-New to TM.KH.RD 220 kV Single Circuit Out |

| | |
|---|---|
| Exhibit 3.17 | Gharo-New to Jhimpir-New 220 kV Single Circuit Out |
| Exhibit 3.18 | TM.KH.RD to Jamshoro 220 kV Single Circuit Out |
| Exhibit 3.19 | Jhimpir-New to Matiari 220 kV Single Circuit Out |
| Exhibit 3.20 | Matiari 500/220 kV Single Transformer Out |
| Exhibit 3.21 | Matiari to Jamshoro 500 kV Single Circuit Out |
| Exhibit 3.22 | Matiari to Moro 500 kV Single Circuit Out |
| Exhibit 3.23 | Moro to R.Y.Khan 500 kV Single Circuit Out |
| Exhibit 3.24 | Moro to Dadu 500 kV Single Circuit Out |

The load flow results of the network in the close vicinity of Iran-Pak WPP shown plotted in Exhibits 3.1 to 3.24 indicate that all the power flows on the lines are within the rated limits of this network.

The load flow results show that the network existing before Iran-Pak WPP in the same vicinity in Jhimpir cluster including the Jhimpir-New 220/132 kV collector substation is enough to absorb their power, and has no limitations in terms of power transfer capacity under normal as well as N-1 contingency, prior to connection of Iran-Pak WPP. We will check the adequacy of network after adding Iran-Pak WPP in Chapter 6.

## 3.3 Short Circuit Analysis

In order to assess the short circuit strength of the network of 132 kV without Iran-Pak WPP for the grid of Southern HESCO especially in the vicinity of the site of this Wind Farm, fault currents have been calculated for balanced three-phase and unbalanced single-phase short circuit conditions. The fault levels also include the contributions from other Wind Farms such as FFC, Zorlu, TGF and others in the Jhimpir Cluster and FWEL-I, FWEL-II, HDPPL and Tenaga in the Gharo cluster, as mentioned earlier, which are expected to be in operation before Iran-Pak WPP as per AEDB's latest generation schedule.

The results of this analysis will not only give us the idea of the fault levels without Iran-Pak WPP but also it will, by comparison, let us know as to how much the contribution of fault current from Iran-Pak WPP may add to the existing fault levels.

From this analysis we also get a feel of the probable nodes to connect the Wind Farm depending on their relative short circuit strength. The calculations have been made for maximum and minimum short circuit levels considering maximum and minimum generation dispatch conditions of the system in high water and low waterseasons.

### 3.3.1 Maximum FaultLevels

A case for the year 2017-18 has been developed in which all the hydel and thermal generating plants have been dispatched to cover the highest possible fault current contributions.

PSS/E software provides an option of calculating the fault currents using the IEC 909 criteria, and we have used this option for all the fault calculations for this study. For maximum fault currents we have applied the following assumptions under IEC 909:

- Set tap ratios to unity
- Set line charging to zero
- Set shunts to zero in positive sequence
- Desired voltage magnitude at bus bars set equal to 1.1 P.U. i.e. 10 % higher than nominal, which is the maximum permissible voltage under contingency condition.

The short circuit levels have been plotted on the bus bars of 132 kV, 220 kV and 500 kV of substations lying in the electrical vicinity of our area of interest i.e. Jhimpir area, and are shown plotted in the Exhibit 3.25 attached in Appendix-3.

Both 3-phase and 1-phase fault currents are indicated in the Exhibit which are given in polar coordinates i.e. the magnitude and the angle of the current. The total fault currents are shown below the bus bar.

The tabular output of the short circuit calculations is also attached in Appendix-3 for the 132 kV, 220 kV and 500 kV bus bars of our interest i.e. the substations connecting in the three branches of 132 kV running South of Hyderabad up to Southern Sind coast line. The tabular output is the detailed output showing the contribution to the fault current from the adjoining sources i.e. the lines and transformers connected to that bus. The phase currents, the sequence currents and the sequence impedances are shown in detail for each faulted busbar.

The total maximum fault currents for 3-phase and 1-phase short circuit at these substations are summarized in Table 3.1. We see that the maximum fault currents do not exceed the short circuit ratings of the equipment at these 132 kV substations which normally are 25 kA or 31.5 kA for older substations and 40 kA for new substations.

**Table 3.1**
**Maximum Short Circuit Levels without Iran-Pak-WPP**

| Substation | 3-Phase fault current, kA | 1-Phase fault current, kA |
|---|---|---|
| Nooriabad 132 kV | 6.97 | 5.88 |
| Kotri GTPS 132 kV | 21.51 | 20.81 |
| Jamshoro Old 132 kV | 23.06 | 20.79 |
| Lakhra 132 kV | 11.03 | 8.99 |
| Jamshoro New 132 kV | 25.00 | 23.46 |
| T.M.KHAN 132 kV | 14.42 | 10.78 |
| Jhimpir-New 132 kV | 19.69 | 9.65 |
| Gharo-New 132 kV | 7.64 | 8.10 |
| Kotri Site 132 kV | 18.22 | 16.65 |
| Hyd-TMKhanRoad 132 kV | 24.45 | 22.36 |
| Jhimpur-New 220 kV | 15.69 | 23.49 |
| Gharo-new 220 kV | 7.53 | 7.98 |
| Matiari 220 kV | 14.61 | 15.67 |
| Jamshoro 220 kV | 32.50 | 33.50 |
| TM.KH.RD 220 kV | 25.35 | 22.95 |
| Jamshoro 500 kV | 17.27 | 14.84 |
| Matiari 500 kV | 15.79 | 11.92 |
| R.Y.Khan 500 kV | 13.21 | 7.06 |
| Moro 500 kV | 12.70 | 6.51 |
| Dadu 500 kV | 15.54 | 10.28 |

### 3.3.2 Minimum Fault Levels

For minimum fault levels minimum generation dispatches are assumed which in practice may correspond to minimum load conditions. We normally have minimum thermal power dispatch during High Water season and it gets further minimum during off-peak hours. Especially in Southern Sind, the thermal generation would be at its minimum during minimum load conditions of high water season. Therefore we have calculated the minimum short circuit levels under High Water off-peak conditions. Also the dispatch of WTGs from other wind farms of FFC, Zorlu, TGF and others in the Jhimpir Cluster and FWEL-I, FWEL-II, Tenaga and HDPPL in the Gharo cluster is also assumed as minimum to have the minimum fault contributions from these Farms. The results are shown in Appendix-3.

For minimum fault currents we have applied the following assumptions under IEC 909:

- Set tap ratios to unity
- Set line charging to zero
- Set shunts to zero in positive sequence
- Desired voltage magnitude at bus bars set equal to 0.9 P.U. i.e. 10 % lower than nominal, which is the minimum permissible voltage under contingency condition.

The plotted results of the minimum fault currents are attached in Exhibit 3.26 the same way as before focusing on the significant 132 kV, 220 kV and 500 kV bus bars of substations in the electrical vicinity of Jhimpir. The tabular output of minimum fault currents shown in Appendix-3 is the detailed output showing the contribution to the fault current from the adjoining sources i.e. the lines and transformers connected to that bus. The phase currents, the sequence currents and the sequence impedances are shown in detail for each faulted bus bar.

The minimum fault currents for 3-phase and 1-phase short circuit at these substations are summarized in Table 3.2.

Table 3.2

Minimum Short Circuit Levels without Iran-Pak-WPP

| Substation | 3-Phase fault current, kA | 1-Phase fault current, kA |
|---|---|---|
| Nooriabad 132 kV | 4.74 | 3.69 |
| Kotri GTPS 132 kV | 13.03 | 12.43 |
| Jamshoro Old 132 kV | 14.40 | 13.56 |
| Lakhra 132 kV | 8.01 | 6.30 |
| Jamshoro New 132 kV | 15.48 | 15.10 |
| T.M.KHAN 132 kV | 10.01 | 7.75 |
| Jhimpir-New 132 kV | 12.39 | 4.82 |
| Gharo-New 132 kV | 5.68 | 6.20 |
| Kotri Site 132 kV | 11.62 | 10.81 |
| Hyd-TM KhanRoad 132 kV | 15.24 | 14.76 |
| Jhimpur-New 220 kV | 9.81 | 14.69 |
| Gharo-new 220 kV | 5.38 | 5.97 |
| Matiari 220 kV | 9.86 | 10.82 |
| Jamshoro 220 kV | 16.45 | 17.10 |
| TM.KH.RD 220 kV | 14.04 | 13.82 |
| Jamshoro 500 kV | 8.96 | 8.49 |
| Matiari 500 kV | 8.44 | 7.36 |
| R.Y.Khan 500 kV | 8.68 | 5.37 |
| Moro 500 kV | 7.95 | 4.86 |
| Dadu 500 kV | 9.15 | 7.14 |

### 3.3.3 Comparison of Fault Levels

Comparing the short circuit strengths, both in terms of maximum and minimum, of the existing substations of 132 kV in the vicinity of Iran-Pak WPP *viz*. Jhimpir-New, Nooriabad, Jhimpir Sujawal and Thatta, we find that Jhimpir-New, Nooriabad and Jhimpir are strong point with relatively higher short circuit levels; whereas the worst is Thatta with very poor short circuit levels. In fact Nooriabad draws strength from its direct connection with Jamshoro-old having direct connection with a very strong source of Jamshoro. Jhimpir draws its strength from its direct connection with Kotri where sits a medium size gas turbine power plant and also have connection with Jamshoro. But Thatta and the grids connected in the branches that emanate from Thatta towards Sujawal etc. are poor due to weak sources feeding these branches.

Jhimpir-New collector substation is showing good circuit strength because of the completion of its 220 kV phase, having six sub-collector groups connecting TGF, Master, Sapphire, Yunus, Sachal, Hawa ,Wind-Eagle-2, UEPL, SUNEC, Tapal, Gul Ahmed, JHM WIND , METRO, TCN-A,TCN-B, TCN-C, Western Energy, Hartford and DHA-City to the Jhimpir-New 220/132 kV Substation at 132 kV level. The other source of fault current is T. M. Khan which is 75 km away connected through a D/C of 132 kV. Together the contribution from these sources makes it a strong node of interconnection for Iran-Pak WPP.

# 4. Development of Interconnection Scheme

## 4.1 Interconnection of Iran-Pak 50 MW WPP

To connect the wind farms to the main grid of NTDC / HESCO, one may think of connecting each Farm with any nearby available 132 kV substation by laying a direct 132 kV circuit from the gantry of each Farm's substation. But it is important to first see if the nearby substation has enough short circuit strength to connect to a Wind farm having characteristics of time-varying output because flicker and harmonics' resonance are a function of short circuit MVA of that node where this variation would be occurring.

In case there is a potential of developing of several Wind Farms in the same area, then a better interface or common coupling point may be a collector substation where each Wind Farm is connected and then this collector substation is connected to suitable node or nodes of the main national grid system. From suitable node or nodes we mean the nodes (bus bars) having relatively higher short circuit levels to mitigate the impact of time-variant generation from WTG.

In case of Iran-Pak WPP, the nearest substation is the collector substation of Jhimpir-New 220/132 kV whose first stage of 132 kV would be completed by June 2015 and the second stage of 220 kV would be completed in 2016-2017.

## 4.2 Proposed Interconnection Scheme

Given that there can be 22 WPPs coming in commercial operation in the Jhimpir region and 4 WPPs coming in commercial operation in the Gharo region around the time that Iran-Pak WPP also comes into commercial operation, the following reinforcements in the system would be pre-requisite before we connect Iran-Pak WPP with the system as shown in Sketch-2:

- 220/132 kV Jhimpir-New substation (now underconstruction)
- 70 km long double circuit from Jhimpir-New 220 kV Substation to the existing T.M. Khan Road 220 kV Substation (now underconstruction)

- A 132 kV double circuit of 82 km using Greeley conductor would be constructed to connect Jhimpir-New 220/132 kV Substation with T.M. Khan in HESCO network (now under construction).
- 75 km long 220 kV double circuit from Gharo-New 220 kV Substation to Jhimpir-New 220 kV Substation (now under construction).
- 220/132 kV Gharo-New substation at suitable location in Gharo cluster(now under construction)
- The additional power injected into Jhimpir-New 220/132 kV grid station would require another outlet of 220 kV D/C because the ongoing 220 kV D/C from New-Jhimpir to TM Khan Rd. would already be reaching to its full capacity to evacuate already commissioned Wind Power Plants in Jhimpir cluster. The additional outlet is proposed as follows:
- Addition of 22 kV level at the ongoing 500kV Matiari Collector Substation
- 100 km long 220 kV D/C from Jhimpir 220/132 kV to Matiari 500/220 kV grid station using Greeley conductor.
- Five sub-collectors groups will be connected to Jhimpir 220/132 kV collector substation through 132 kV double circuits using Greeley Conductor
- FFC and Zorlu looped in-out with Jhimpir-Nooriabad 132 kV circuit.
- Four WPPs in the collector system of Gharo 220/132 kV substation
- FWEL-I and FWEL-II through a 64 km long 132 kV D/C on Greeley conductor connected to Thatta
- Rehabilitation of the exiting 132 kV lines in the vicinity of WPP clusters, i.e. Jhimpir-Kotri, Jhimpir-Thatta, Thatta-Sujawal and Nooriabad-Jamshoro Old

Of the two sub clusters developed in Jhimpir area, one sub-cluster will comprise FFC and Zorlu looped in-out on one circuit of the Jhimpir-Nooriabad 132 kV double circuit whereas the other sub-cluster would comprise the Jhimpir-New 220/132 kV Collector Substation and would connect six sub-collectors groups through 132 kV double circuits.

The connection scheme of Iran-Pak WPP for the scenario of 2017-18 in Sketches 3 is as follows:

- A sixth sub cluster has been proposed at Jhimpir-New 220/132 kV collector substation to evacuate 200 MW power from four Wind Power Plants namely, Iran-Pak Wind Power Plant, Hartford, Western Energy and DHA-City generating 50 MW each. Therefore, the interconnection of Iran-Pak WPP would be by connecting by a double circuit of 132 kV looping in-out with a sub cluster connecting Wind Power Plants of Hartford, Iran-Pak and DHA-City of 50 MW each to Jhimpir-New 220/132 kV collector substation.

# 5. Modeling of Iran-Pak Wind Farm

## 5.1 Electrical Layout of Wind Farm

### 5.1.1 Iran-Pak WPP Energy Selection

Iran-Pak has selected Type-3 WTGs which they are considering to install on their Wind Farm at Jhimpir. It is a Doubly Fed Induction Generator. Each WTG would step up from its terminal LV voltage of 0.65 kV to a medium voltage (MV) that will be 33 kV.

### 5.1.2 Electrical Layout

The WTGs would be connected to MV collector cables of 33 kV laid down in the Farm connecting each line (row) of the WTGs to the Farm substation. The layout is shown in **Sketch – 4** (Appendix-5), briefly described as follows;

| | | |
|---|---|---|
| Line – 1 | WTGs 1-5 | (5 x 3.3 = 16.5 MW) |
| Line – 2 | WTGs 6-10 | (5 x 3.3 = 16.5 MW) |
| Line – 3 | WTGs 11-15 | (5 x 3.3 = 16.5 MW) |

The average length of cable between the two WTGs has to be enough to completely outdo the wake effect from the adjoining WTG based on thumb rule to leave 4xD (rotor diameter) between the WTGs to take care of wake effect. In actual micro-siting the distances between WTGs might be slightly different due to many other factors. We have taken about 400 meters distances between the WTGs.

The Farm Substation has been assumed to be located somewhere in the middle of the Farm.

The three collector circuits of 33 kV would thus be laid as shown in Sketch-4 and explained as follows;

| | |
|---|---|
| Collector Line-1 | from WTG-1 to Farm Substation |
| Collector Line-2 | from WTG-10 to Farm Substation |
| Collector Line-3 | from WTG-15 to Farm Substation |

Since each collector would carry approximately 16.5 MW at normal rating, the 33 kV collector circuits loading capacity should be in the range of 18 MVA each, giving some margin for reactive power at 0.95 Power Factor and some losses in the circuits with certain overload capacity as well.

### 5.1.3 33 kV Collector Circuits

The MV voltage level selected by Iran-Pak for interconnection of collector groups of WTGs in the Farm is 33 kV. Underground cables will be used.

The collector cable ratings would be 33 kV as the rated kV level and 17.37 MVA as the loading capacity of collector cables.

Maximum nominal current of 33 kV cable = (17.37/33xsqrt (3)) x 1000= 303.88A

With 10 % safety margin, maximum nominal current of 33 kV cable = 334 A

Therefore, we select available factory standard cable 185 $mm^2$ Single Core with Stranded Aluminum Conductor with following parameters

Maximum Current Rating = 350 Amps

Resistance = 0.019008 P.U. at 100 MVA Base

Reactance = 0.071887 P.U. at 100 MVA Base

## 5.2 Wind Farm Substation 132/33 kV

A substation would be built in the middle of the Farm to collect all the power from the WTGs, spread out in the Farm, at medium voltage (MV) level of 33 kV and step-up this power to high voltage (HV) level of 132 kV so that the Farm's output may be evacuated to the main grid of HESCO/NTDC. The single line diagrams of the substation, as a conceptual design, are briefly shown in SLD-1 and SLD-2A and SLD-2B in Appendix-5 for 33 kV and 132 kV respectively.

Keeping in view of the current practices in NTDC and DISCOs, the substations for power plants of the order of 50 MW, the 132 kV bus bars are double bus with a coupler i.e. double bus-single-breaker scheme. However for 132/11 kV substations, the MV bus i.e. 11 kV a single bus with or without sectionalizers. Keeping in view the NTDC/DISCOs practice, we propose to provide good reliability to a power plant as follows:

- Single bus scheme with a sectionalizer to enable to have two bus sections at 33 kV.
- Double-bus single-breaker scheme with a Bus Coupler at 132 kV, if the substation is AIS.

- Single-bus with a sectionalizer to enable to have two bus sections at 132 kV, if the substation is GIS.

The schemes are shown in SLD-1 and SLD-2A, SLD-2B respectively and described as follows.

### 5.2.1 Conceptual Design of 33 kV

The single line diagram SLD–1 in Appendix-5 shows the conceptual design of 33 kV (MV) bus bar of the Farm substation. It comprises of

- Two single bus-sections of 33 kV with a bus sectionalizer
- Three breaker bays to connect three collector double circuits of WTG Lines 1-4
- Two breaker bays to connect two transformers of 132/33 kV
- Two breaker bays for connecting two auxiliary transformers of 33/0.4 kV
- Two breaker bays to connect switched shunt capacitor banks

Rating of all the breakers and bus bar equipment would be

Short circuit rupturing capacity = 25 kA

Normal continuous current = 1250 A for line breakers

= 2500A for Bus Sectionalizer and Power TF

### 5.2.2 Conceptual Design of 132 kV

Single-line-diagram SLD–2A and 2B (Appendix–5) shows 132 kV bus bars of the Farm substation, which would comprise as follows:

- Single bus with Sectionalizer if Farm substation is GIS
- Double bus bars with a Bus Coupler if Farm substation is AIS
- Two breaker bays to connect two transformers 132/33 kV
- Two breaker bays to connect two circuits of 132 kV i.e. double circuit on single tower overhead line to connect to the grid system.

Rating of all the breakers and bus bar equipment would be

Short circuit rupturing capacity = 40 kA

Normal continuous current = 1250 A for line and TF breakers

= 2500 A for Bus Sectionalizer

The other equipment of the substation consists of:

- Two 132/33 kV, 31.5/40/50 MVA ONAN/ONAF1/ONAF2 OLTC transformers, 132±11×1%/33kV, to fulfill N-1 criteria of Grid Code
- Two station auxiliary transformers 33/0.4 kV, 315 kVA
- Two switched shunt capacitor banks each of the size of 10 MVAR (4 x 2.5 MVAR) with contactors and PLC (Programmable Logic Controller).
- Energy meters would be installed on HV side (132 kV) of the 132/33kV transformers.

### S.2.3 Protection and Telecommunication Scheme

The protection scheme would be designed in compliance of NTDC requirements intimated by Chief Engineer Protection, vide letter No.3416-19/CE/SP/MN/50MW CWE WPP Jhimpir dated 23/07/2010 (attached in Appendix-5).

The telecommunication scheme would be designed in compliance of NTDC requirements intimated by Chief Engineer Telecommunication, vide letter No. CE (Tel)/NTDC/232/4372 dated 27/08/2010 (attached in Appendix-5).

# 6. Load Flow Analysis

Load flow analysis has been carried out for the proposed scheme of interconnection of Iran-Pak WPP with NTDC / HESCO grid for the base case of 2017-18 as per Sketch-3 in Appendix-4.

## 6.1 Modeling of Wind Farm in Load Flow

Representation of all the individual machines in a large Wind Farm is inappropriate in most grid impact studies [1]. There is a provision in the model structure of PSS/E to allow single equivalent WTG machine model to represent multiple WTGs. However there are limitations. Disturbances within the local collector grid cannot be analyzed, and there is some potentially significant variation in the equivalent impedance for the connection to each machine. A single machine equivalent requires the approximation that the power output of all the machines will be the same at a given instant of time. For grid system impact studies, simulations are typically performed with the initial wind of sufficient speed to produce the rated output on all the machines. Under this condition, the assumption that all the machines are initially at the same (rated) output is not an approximation [2]. Otherwise this assumption presumes that the geographic dispersion is small enough that the wind over the farm is uniform. Though simulations of bulk system dynamics using a single machine equivalent are adequate for most planning studies, we have adopted a rather more detailed level of modeling by using an equivalent machine just for one group of WTGs connected to one collector feeder. Since we have three collector feeders connecting to three groups of WTGs, therefore there are three equivalent WTGs assumed for each collector group in this study report.

The Farm Substation is represented by two bus bars as Iran-Pak-MV 33 kV and Iran-Pak

132 kV, with two inter-bus transformers of 31.5/40/50 MVA each. These transformers have an overload capacity of 50 MVA for a limited time to cover N-1 contingency criteria of Grid Code i.e. in case of outage of one transformer, the other can take up the full output of Farm i.e. 50MVA.

## 6.2 Reactive Power Requirements

Iran-Pak is considering using 3.3 MW Type-3 WTGs, which are doubly fed induction generators, in their WPP. Its power factor is 0.90 lagging (capacitive/generating) and 0.95 leading (inductive/absorbing).The maximum reactive power output that can be available at the 0.65 kV terminal is 1.6 MVAR for each WTG. Part of this reactive power will be consumed by the 0.65/33 kV step-up (GSU) transformer and the rest may be consumed in the MV collector cables of the wind farm. However some reactive power might reach the MV bus bar of Farm substation. That means each WTG is self sufficient to meet VAR absorption requirement of its step-up transformer with some contribution of VARs to the Farm MV network.

The Grid Code Addendum No.1 requires to meet the criteria of ± 0.95 power factor at the point of interconnection with the NTDC/HESCO grid at 132 kV (point of common coupling). Therefore a Farm of 50 MW generating capacity is required to pump 15.6 MVAR to the grid at full output of 50 MW. The VAR generating capability of WTG at 0.95 PF will not be able to fully meet this VAR demand of the system because of VAR loss in step-up transformers, collector cables and the HV/MV i.e. 132/33 kV transformers at the Farm substation. In order to meet the Grid Code criteria, we need to install switched shunt capacitor bank at 33 kV bus of the Farm substation of sufficient size capable of delivering 15.6 MVAR at 132 kV bus after VAR loss across 132/33 kV transformers.

## 6.3 Load Flow Analysis for Peak Load Case of 2017-18

Load flow analysis has been carried out for the NTDC / HESCO network to see the steady state impact of adding the generation of Iran-Pak WPP on the network including the connections provided to other wind power plants already scheduled having been connected. These are FFC, Zorlu, TGF, Master, Sapphire, Yunus, Sachal, Hawa ,Wind-Eagle-2, UEPL, SUNEC, Tapal, Gul Ahmed, JHM WIND , METRO, TCN-A,TCN-B, TCN-C, Western Energy, Hartford and DHA-City in the Jhimpir cluster FWEL-I, FWEL-II, HYDROCHINA Dawood (HDPPL), NBT-ZAB and Tenaga in the Gharo cluster as mentioned earlier. The network configuration is same for Jhimpir and Gharo clusters as indicated in Sketch-3 of Appendix-4 and discussed in Ch. 3.

The integrated case has been studied for the system conditions of 2017-18, the time line associated with the COD of Iran-Pak WPP and of the 220 kV parts of Jhimpir and Gharo Collector Substations. We kept the dispatch of the nearby power plant at 132 kV at a maximum therefore we can see the maximum distributed generation on 132 kV network.

Load flow simulations have been run for normal and contingency conditions. The results are shown plotted in Appendix-6.

### 6.3.1 Normal Case

Exhibit 6.0 shows the normal case under the system conditions of 2017-18. All the wind farms in Jhimpir and Gharo clusters with installed capacity of 50 MW or 49.5 MW has been assumed after deducting Farm losses and given some diversity in the maximum output of all the Wind Power Plants at one time. For Iran-Pak WPP we assume to deliver 49.5 MW at the point of delivery to grid at 132 kV.

All these loadings are within the rated limits of these circuits. The bus voltages on all the substations in Southern HESCO grid are within the normal limits of operation.

We see that all the WTGs are running at a power factor above its rated value of 0.90 not using full reactive power capability leaving enough margin to cover contingencies. The switched shunt capacitor bank of 20 MVAR at 33 kV bus bar is supplying 10.4 MVAR at (29.8 kV) voltage and, after VAR loss across 132/33 kV transformers, supplying about 15 MVAR (nearly 0.95 PF) at 132 kV bus i.e. fulfilling the Grid Code criteria at the point of interconnection. The voltage profile on all the bus bars of 132 kV of HESCO grid are well within the normal operating criteria of ± 5 % off the nominal.

### 6.3.2 Contingency cases and evolving of reliable scheme

The N-1 contingency cases have been run and the results have been shown plotted as under:

| | |
|---|---|
| Exhibit 6.1 | Iran-Pak Wind to Hartford 132 kV Single Circuit |
| Out Exhibit 6.2 | Hartford to Jhimpir-New 132 kV Single Circuit Out |
| Exhibit 6.3 | Western Energy to Iran-Pak Wind 132 kV Single Circuit |
| Out Exhibit 6.4 | DHA-City to Jhimpir-New 132 kV Single Circuit Out |
| Exhibit 6.5 | Saphire to Jhimpir-New 132 kV Single Circuit Out |
| Exhibit 6.6 | UEPL to Jhimpir-New 132 kV Single Circuit Out |
| Exhibit 6.7 | WE-2 to Jhimpir-New 132 kV Single Circuit Out |
| Exhibit 6.8 | TCN-C to Jhimpir-New 132 kV Single Circuit Out |
| Exhibit 6.9 | Gul Ahmed to Jhimpir-New 132 kV Single Circuit Out |
| Exhibit 6.10 | Zorlu to Jhimpir 132 kV Single Circuit Out |
| Exhibit 6.11 | Jhimpir to Nooriabad 132 kV Single Circuit Out |
| Exhibit 6.12 | Jhimpir to Kotri GTPS 132 kV Single Circuit Out |
| Exhibit 6.13 | Jhimpir-New to T.M.Khan 132 kV Single Circuit Out |
| Exhibit 6.14 | Jhimpir-New 220/132 kV Single Transformer Out |
| Exhibit 6.15 | Gharo-New 220/132 kV Single Transformer Out |
| Exhibit 6.16 | Jhimpir-New to TM.KH.RD 220 kV Single Circuit Out |
| Exhibit 6.17 | Gharo-New to Jhimpir-New 220 kV Single Circuit Out |
| Exhibit 6.18 | TM.KH.RD to Jamshoro 220 kV Single Circuit Out |
| Exhibit 6.19 | Jhimpir-New to Matiari 220 kV Single Circuit Out |
| Exhibit 6.20 | Matiari 500/220 kV Single Transformer Out |
| Exhibit 6.21 | Matiari to Jamshoro 500 kV Single Circuit Out |
| Exhibit 6.22 | Matiari to Moro 500 kV Single Circuit Out |
| Exhibit 6.23 | Moro to R.Y.Khan 500 kV Single Circuit Out |
| Exhibit 6.24 | Moro to Dadu 500 kV Single Circuit Out |

The results show that power flows on intact 132 kV circuits remain within their rated limits.

The results also show that under all events of outages the switched shunt capacitor banks at 33 kV bus regulates the voltage under all events. The reactive power being supplied by the 20 MVAR switched shunt capacitor banks connected at 33 kV bus, maintains the supply of VARS to the grid under all contingencies adjusting its output according to the system requirement. Therefore to cover the steady state, normal and outage conditions, we need switched shunt capacitor bank of 20 MVAR at 33 kV bus.

## 6.4 Conclusion of Load Flow Results

The load flow results of the proposed scheme of interconnection of Iran-Pak WPP in 2017-18 shows no bottlenecks or capacity constraints in the adjoining 220 kV and 132 kV network in terms of absorbing all the output of Iran-Pak WPP under normal as well as the contingency conditions.

Iran-Pak Wind Power Plant would be connected by a double circuit of 132 kV looping in-out with a sub cluster connecting Wind Power Plants of Hartford, Iran-Pak and DHA- City of 50 MW each to Jhimpir-New 220/132 kV collectorsubstation.

The Greeley conductor will be used with the capacity of 184 MVA per circuit. In the load flow simulation, however, the MVA capacity is assumed to be 202.4 MVA taking into account the increase in MVA capacity of the conductors at high wind speed during high wind season.

### *References:*

1- WECC Wind Generator Modeling Group; *Generic Type-3 Wind Turbine-Generator Model for Grid Studies; Version 1.1*, September 14, 2006, p. 2.2

2- *Ibid.* p.3.1

# 7. Short Circuit Analysis

## 7.1 Methodology and Assumptions

The methodology of IEC 909 has been applied in all short circuit analyses in this report for which provision is available in the PSS/E software used for these studies. For calculations of maximum fault levels the bus voltage has been assumed as 1.10 PU i.e. 10 % above the nominal as per IEC909. For calculations of minimum fault levels the bus voltage has been assumed as 0.9 PU i.e. 10 below the nominal. That covers the entire ± 10 % range of the ratings of the equipment.

### 7.1.1 Assumptions for maximum and minimum short circuit levels

#### 7.1.1.1 Assumptions-Maximum short circuit levels

For evaluation of maximum short circuit levels we have assumed contribution in the fault currents from all the installed generation capacity of hydel, thermal and nuclear plants in the system in the year 2017-18 to assess the impact ofIran-Pak WPP.

The maximum fault currents have been calculated with the following assumptions under IEC909:

- Set tap ratios to unity
- Set line charging to zero
- Set shunts to zero in positive sequence

Desired voltage magnitude at bus bars set equal to 1.10 P.U. i.e. 10 % higher than nominal, which is the maximum permissible voltage under contingency condition However tabular results of some significant bus bars of 220 kV and 132 kV in the electrical vicinity of Iran-Pak WPP have also been produced and placed in Appendix-7.

#### 7.1.1.2 Assumptions-Minimum Short Circuit Levels

The minimum fault currents are important for the evaluation of power quality issues such as flicker, unbalance, sudden voltage dip and harmonics.

For assess the minimum short circuit levels we have considered off-peak conditions of 2017-18 to simulate the minimum short circuit strength of southern grid. For

Iran-Pak WPP we have assumed dispatch of 25% of its capacity for the minimum short circuit calculations i.e. just one collector group with partial output of 16.5 MW is on bar.

For minimum fault currents we have applied the following assumptions under IEC 909:

- Set tap ratios to unity
- Set line charging to zero
- Set shunts to zero in positive sequence

Desired voltage magnitude at bus bars set equal to 0.9 P.U. i.e. 10 % lower than nominal, which is the minimum permissible voltage under contingency condition.

## 7.2 Fault Currents Calculations

### 7.2.1 Maximum Short Circuit Levels

The short circuit levels have been calculated and plotted on the bus bars of 500 kV, 220 kV and 132 kV of substations lying in the electrical vicinity of our area of interest i.e. Jhimpir, Thatta and Gharo area, and are shown plotted in the Exhibit 7.1 for the year 2017-18 and attached in Appendix-7. Both 3-phase and 1-phase fault currents are indicated in the Exhibit which are given in polar coordinates i.e. the magnitude and the angle of the current. The total fault currents are shown below the bus bar. The tabular output of the short circuit calculations is also attached in Appendix-7 for the 500 kV, 220 kV and 132 kV bus bars of our interest i.e. the substations connecting in the three branches of 132 kV running South of Hyderabad up to Southern Sind coast line. The tabular output is the detailed output showing the contribution to the fault current from the adjoining sources i.e. the lines and transformers connected to that bus. The phase currents, the sequence currents and the sequence impedances are shown in detail for each faulted busbar.

The total maximum fault currents for 3-phase and 1-phase short circuit at these substations are summarized in Table 7.1. We see that the maximum fault currents do not exceed the short circuit ratings of the equipment at these 132 kV substations which normally are 25 kA or 31.5 kA for older substations and 40 kA for new substations.

The fault levels of Iran-Pak 132 kV are 11.82 kA and 6.52 kA for 3-phase and single phase faults respectively for 2017-18. This is much less than the switchgear rating of 40 kA recommended for Iran-Pak Farm Substation as per NTDC requirements for 132 kV.

The fault levels for Iran-Pak 33 kV are 11.80 kA and 10.14 kA for 3-phase and single-phase faults respectively for 2017-18. Therefore the short circuit rating recommended for 33 kV switchgear is recommended as 25 kA.

**Table-7.1**

**Maximum Short Circuit Levels with Iran-Pak WPP**

| Substation | 3-Phase fault current, kA | 1-Phase fault current, kA |
|---|---|---|
| Iran-Pak-MV 33 kV | 11.80 | 10.14 |
| Iran-Pak Wind 132 kV | 11.82 | 6.52 |
| Nooriabad 132 kV | 6.98 | 5.88 |
| Kotri GTPS 132 kV | 21.55 | 20.83 |
| Jamshoro Old 132 kV | 23.10 | 20.81 |
| Lakhra 132 kV | 11.04 | 9.00 |
| Jamshoro New 132 kV | 25.05 | 23.49 |
| T.M.KHAN 132 kV | 14.47 | 10.84 |
| Jhimpir-New 132 kV | 20.05 | 10.12 |
| Gharo-New 132 kV | 7.67 | 8.13 |
| Kotri Site 132 kV | 18.25 | 16.67 |
| Hyd-TM KhanRoad 132 kV | 24.52 | 22.41 |
| Jhimpur-New 220 kV | 15.84 | 23.71 |
| Gharo-new 220 kV | 7.57 | 8.01 |
| Matiari 220 kV | 14.66 | 15.71 |
| Jamshoro 220 kV | 32.60 | 33.58 |
| TM.KH.RD 220 kV | 25.44 | 23.01 |
| Jamshoro 500 kV | 17.30 | 14.86 |
| Matiari 500 kV | 15.81 | 11.93 |
| R.Y.Khan 500 kV | 13.21 | 7.06 |

| | | |
|---|---|---|
| Moro 500 kV | 12.72 | 6.51 |
| Dadu 500 kV | 15.55 | 10.29 |

### 7.2.2 Minimum short circuit levels

The minimum fault levels have been calculated for minimum dispatch of power in the grid system. The plotted results of short circuit analysis are attached as Exhibit 7.2. Both 3-phase and 1-phase fault currents are indicated in the Exhibit which are given in polar coordinates i.e. the magnitude and the angle of the current. The total fault currents are shown below the faulted busbar.

The tabular output of the short circuit calculations is also attached in Appendix-7 for the 132 kV bus bars of our interest i.e. the substations connecting in the three branches of 132 kV running South of Hyderabad up to Southern Sind coast line. The tabular output is the detailed output showing the contribution to the fault current from the adjoining sources i.e. the lines and transformers connected to that bus. The phase currents, the sequence currents and the sequence impedances are shown in detail for each faulted bus bar.

The total minimum fault currents for 3-phase and 1-phase short circuit at these substations are summarized in Table 7.2.

**Table-7.2**

**Minimum Short Circuit Levels with Iran-Pak WPP 2016-2017**

| Substation | 3-Phase fault current, kA | 1-Phase fault current, kA |
|---|---|---|
| Iran-Pak-MV 33 kV | 8.72 | 6.73 |
| Iran-Pak Wind 132 kV | 8.20 | 3.72 |
| Nooriabad 132 kV | 4.76 | 3.69 |
| Kotri GTPS 132 kV | 13.31 | 12.59 |
| Jamshoro Old 132 kV | 14.66 | 13.71 |
| Lakhra 132 kV | 8.07 | 6.33 |
| Jamshoro New 132 kV | 15.76 | 15.28 |
| T.M.KHAN 132 kV | 10.20 | 7.84 |
| Jhimpir-New 132 kV | 12.60 | 4.98 |

| | | |
|---|---|---|
| Gharo-New 132 kV | 5.72 | 6.23 |
| Kotri Site 132 kV | 11.89 | 10.95 |
| Hyd-TM KhanRoad 132 kV | 15.57 | 14.96 |
| Jhimpur-New 220 kV | 9.96 | 14.91 |
| Gharo-new 220 kV | 5.42 | 6.01 |
| Matiari 220 kV | 9.95 | 10.89 |
| Jamshoro 220 kV | 16.72 | 17.29 |
| TM.KH.RD 220 kV | 14.29 | 13.98 |
| Jamshoro 500 kV | 9.06 | 8.56 |
| Matiari 500 kV | 8.53 | 7.41 |
| R.Y.Khan 500 kV | 8.74 | 5.40 |
| Moro 500 kV | 8.02 | 4.88 |
| Dadu 500 kV | 9.24 | 7.18 |

## 7.3 Conclusions of Short Circuit Analysis

In order to see how much the Iran-Pak WPP has contributed to increase the fault levels of the substations in its electrical vicinity, we compare the maximum fault levels in the peak case of 2017-18 with the fault levels of the same bus bars in Table 3.1 (Chapter-3) evaluated without Iran-Pak WPP but inclusive of other Wind Farms such as FFC, ZEPL, TGF, Sapphire, Jhimpir Wind and others in the Jhimpir Cluster and FWEL-I, FWEL-II HDPPL, NBT-ZAB and Tenaga in the Gharo to see the impact on the short circuit levels in the area in the vicinity of Iran-Pak WPP in the extended term after the adding Iran-Pak WPP. We find that the fault levels at Jhimpir and Jhimpir-New have increased. As a whole the fault levels at all the 132 kV bus bars are well below the short circuit rating of the equipment at these substations.

The fault levels of Iran-Pak 132 kV are 11.82 kA and 6.52 kA for 3-phase and single phase faults respectively for 2017-18. This is much less than the switchgear rating of 40 kA recommended for Iran-Pak Farm Substation as per NTDC requirements for 132 kV.

The fault levels for Iran-Pak 33 kV are 11.80 kA and 10.14 kA for 3-phase and single-phase faults respectively in the year 2017-18. Therefore the short circuit rating recommended for 33 kV switchgear is recommended as 25 kA.

Comparing the minimum short circuit levels of the 132 kV substations of HESCO near the Wind Farms, we find that in terms of short circuit strength, the levels at Jhimpir-New and Jhimpir 132 kV get better and the short circuit strength is improved after the interconnection of Iran-Pak WPP in 2017-18. The short circuit strength is very important for Power Quality issues like flicker, harmonics and voltage unbalance. Exhibit 7.2.1 and 7.2.2 show the results of minimum fault levels in MVA to be used in Power Quality analysis carried out in Ch.9

The fault levels indicate that there are no constraints in terms of short circuit ratings of the equipment of the adjoining substations and there is improvement in minimum fault levels. The proposed interconnection scheme holds good on the basis of short circuit analysis as well.

# 8. Transient Stability Analysis

The objective of transient stability study is to see:

1. Dynamic impact of Iran-Pak Wind Power Plant on the System
2. Dynamic impact of the System on Iran-Pak Wind Power Plant

## 8.1 Assumptions & Methodology

### 8.1.1 Type-3 WTG Dynamic Model

Iran-Pak is considering using Doubly Fed Induction Generator which is designated as Type-3 WTG in their Wind Power Plant. We have used the generic Type-3 wind turbine-generator model, which has been developed and has been made available by Siemens–PTI to their users of PSS/E software. Only the main parameters have been incorporated in this model, whereas other details and minute control parameters have been based on assumptions in the controllers of generic model of Siemens-PTI software PSS/E.

## 8.2 Dynamic Impact of System Disturbances

### 8.2.1 Three Phase Faults, Normal Clearing Time of 5 Cycles & Trip of Circuits

The system disturbances have been simulated for this model as follows;

Three- phase fault applied at Iran-Pak 132 kV bus bar, cleared in 5 cycles as normal clearing time i.e. 100 m seconds, followed by trip of 132 kV single circuit between Iran-Pak WPP and Hartford WPP, which was significantly loaded in the pre-fault normal load flow case and its outage may cause severe impact.

**Fig 8.1.1** indicates the bus voltages in pre and post fault conditions at 132 kV substations in the vicinity of Iran-Pak WPP. We find that the voltages recover smoothly and quickly to their pre-disturbance values.

The system frequency indicated in **Fig. 8.1.2** shows very nominal excursions of frequency that damps down very quickly and smoothly

The MW and MVAR output of equivalent WTG get back to normal quickly after the fault clearance as shown in **Fig 8.1.3.**

The dynamic response of generator is shown in **Figs 8.1.4** showing the recovery of speed and mechanical power. We find that the WTG is robust enough to damp down transients in the generator speed and Pmech.

**Fig 8.1.5** shows that the aerodynamic torque that dips down after fault is recovered by pitch angle control which responds quickly and restores the aerodynamic torque to normal with good damping of oscillations after fault clearance.

**Fig. 8.1.6** shows no impact on shaft twist angle and quick damping of transients in aerodynamic power (Paero) on the rotor blade side.

**Fig. 8.1.7** indicates no impact on turbine rotor speed and quick recovery of generator speed.

**Fig. 8.1.8** shows the dynamic response of pitch control and pitch compensation that acts quickly to stabilize the WTG.

The outage of 132 kV single circuit between Iran-Pak WPP and Hartford WPP causes the entire output of Iran-Pak to shift to the intact circuit between Iran-Pak and Western Energy which causes significant loading on the Dha-City WPP to Jhimpir-New 132 kV Single Circuit. **Fig. 8.1.9** shows the transients of MW and MVAR flows DHA-City WPP to Jhimpir-New 132 kV circuit which settles the transients quickly and acquires new steady state levels soon.

The angular stability of other conventional generators of the system can be seen in **Fig. 8.1.10**. The relative rotor angles of Kotri GTPS 132 kV, Lakhra 132 kV, Nooriabad 132 kV, Thatta 132 kV and Jamshoro 220 kV are plotted w.r.t. Hub 500 kV. The results show that they remain in synchronism with the system generators and stay stable. The angular swings are also nominal and damp quickly.

### 8.2.2 Three Phase Faults, Clearing Time of 9 Cycles (Stuck Breaker): LVRT Test

The worst-case fault on system may be the failure of breaker (stuck-breaker) and fault clearing with backup protection in 9 cycles. It may also be termed as testing the ride through capability (LVRT) of Wind Power Plant for clearing time of 9 cycles i.e. 180 ms which is a criterion set out in the Grid Code to be fulfilled.

Three- phase fault applied at Iran-Pak 132 kV bus bar, cleared in 9 cycles as normal clearing time i.e. 180 m seconds, followed by trip of 132 kV single circuit between Iran-Pak WPP and Hartford WPP, which was significantly loaded in the pre-fault normal load flow case and its outage may cause severe impact.

**Fig 8.2.1** indicates the bus voltages in pre and post fault conditions at 132 kV substations in the vicinity of Iran-Pak WPP. We find that the voltages recover smoothly and quickly to their pre-disturbance values.

The system frequency indicated in **Fig. 8.2.2** shows very nominal excursions of frequency that damps down very quickly and smoothly

The MW and MVAR output of equivalent WTG get back to normal quickly after the fault clearance as shown in **Fig 8.2.3.**

The dynamic response of generator is shown in **Figs 8.2.4** showing the recovery of speed and mechanical power. We find that the WTG is robust enough to damp down transients in the generator speed and Pmech.

**Fig 8.2.5** shows that the aerodynamic torque that dips down after fault is recovered by pitch angle control which responds quickly and restores the aerodynamic torque to normal with good damping of oscillations after fault clearance.

**Fig. 8.2.6** shows no impact on shaft twist angle and quick damping of transients in aerodynamic power (Paero) on the rotor blade side.

**Fig. 8.2.7** indicates no impact on turbine rotor speed and quick recovery of generator speed.

**Fig. 8.2.8** shows the dynamic response of pitch control and pitch compensation that acts quickly to stabilize the WTG.

The outage of 132 kV single circuit between Iran-Pak and Hartford WPP causes the entire output of Iran-Pak to shift to the intact circuit between Iran-Pak and Western Energy WPP which causes significant loading on the DHA-City WPP to Jhimpir 132 kV Single Circuit. **Fig. 8.2.9** shows the transients of MW and MVAR flows on DHA-City WPP to Jhimpir 132 kV circuit which settles the transients quickly and acquires new steady state levels soon.

The angular stability of other conventional generators of the system can be seen in **Fig. 8.2.10**. The relative rotor angles of Kotri GTPS 132 kV, Lakhra 132 kV, Nooriabad 132 kV, Thatta 132 kV and Jamshoro 220 kV are plotted w.r.t. Hub 500 kV. The results show that they remain in synchronism with the system generators and stay stable. The angular swings are also nominal and damp quickly.

## 8.3 Dynamic Impact of Wind Farm Disturbances

### 8.3.1 Sudden Loss of a group of WTGs

We have simulated the sudden loss of a group of WTGs, i.e. loss of one equivalent WTG representing a collector group. This happens due to 3-phase fault on the MV bus of Iran-Pak Farm substation and cleared by tripping of a collector double circuit. The fault clearing at 33 kV is assumed as 9 cycles (180 ms). The following variables are monitored

**Fig 8.3.1** indicates the bus voltages in pre and post fault conditions at 132 kV substations in the vicinity of Iran-Pak WPP. We find that the voltages recover smoothly and quickly to their pre-disturbance values.

The system frequency indicated in **Fig. 8.3.2** shows very nominal excursions of frequency that damps down very quickly and smoothly

The MW and MVAR output of equivalent WTG get back to normal quickly after the fault clearance as shown in **Fig 8.3.3**.

The dynamic response of generator is shown in **Figs 8.3.4** showing the recovery of speed and mechanical power. We find that the WTG is robust enough to damp down transients in the generator speed and Pmech.

**Fig 8.3.5** shows that the aerodynamic torque that dips down after fault is recovered by pitch angle control which responds quickly and restores the aerodynamic torque to normal with good damping of oscillations after fault clearance.

**Fig. 8.3.6** shows no impact on shaft twist angle and quick damping of transients in aerodynamic power (Paero) on the rotor blade side.

**Fig. 8.3.7** indicates no impact on turbine rotor speed and quick recovery of generator speed.

**Fig. 8.3.8** shows the dynamic response of pitch control and pitch compensation that acts quickly to stabilize the WTG.

The outage of a collector group causes the power flow through the 132/33 kV Transformers to change. **Fig. 8.3.9** shows the transients of MW and MVAR flows on a 132/33 kV TF at Iran-Pak WPP which settle the transients quickly and acquire new steady state levels soon.

The angular stability of other conventional generators of the system can be seen in **Fig. 8.3.10**. The relative rotor angles of Kotri GTPS 132 kV, Lakhra 132 kV, Nooriabad 132 kV, Thatta 132 kV and Jamshoro 220 kV are plotted w.r.t. Hub 500 kV. The results show that they remain in synchronism with the system generators and stay stable. The angular swings are also nominal and damp quickly.

### 8.3.2 Sudden Loss of one 132/33 kV Transformer in the Farm Substation

The sudden trip of 132/33 kV transformer in the Iran-Pak Farm is caused after the clearing of 3-phase fault on MV bus of Farm substation.

**Fig 8.4.1** indicates the bus voltages in pre and post fault conditions at 132 kV substations in the vicinity of Iran-Pak WPP. We find that the voltages recover smoothly and quickly to their pre-disturbance values.

The system frequency indicated in **Fig. 8.4.2** shows very nominal excursions of frequency that damps down very quickly and smoothly

The MW and MVAR output of equivalent WTG get back to normal quickly after the fault clearance as shown in **Fig 8.4.3**.

The dynamic response of generator is shown in Figs 8.4.4 showing the recovery of speed and mechanical power. We find that the WTG is robust enough to damp down transients in the generator speed and Pmech.

**Fig 8.4.5** shows that the aerodynamic torque that dips down after fault is recovered by pitch angle control which responds quickly and restores the aerodynamic torque to normal with good damping of oscillations after fault clearance.

**Fig. 8.4.6** shows no impact on shaft twist angle and quick damping of transients in aerodynamic power (Paero) on the rotor blade side.

**Fig. 8.4.7** indicates no impact on turbine rotor speed and quick recovery of generator speed.

**Fig. 8.4.8** shows the dynamic response of pitch control and pitch compensation that acts quickly to stabilize the WTG.

The outage of one 132/33 kV Transformer at Iran-Pak WPP Substation causes the entire output of Iran-Pak WPP to shift to the intact Transformer at Iran-Pak WPP Substation. **Fig. 8.4.9** shows the transients of MW and MVAR flows on the 132/33 kV Iran-Pak WPP transformer which settles the transients quickly and acquire new steady state levels soon.

The angular stability of other conventional generators of the system can be seen in **Fig. 8.4.10**. The relative rotor angles of Kotri GTPS 132 kV, Lakhra 132 kV, Nooriabad 132 kV, Thatta 132 kV and Jamshoro 220 kV are plotted w.r.t. Hub 500 kV. The results show that they remain in synchronism with the system generators and stay stable. The angular swings are also nominal and damp quickly.

## 8.4 Dynamic impact of Fault on 220 kV Primary System

### Three Phase Faults, Normal Clearing Time of 5 Cycles & Trip of 220 kV Circuits

Three- phase fault applied at Jhimir-New 220 kV bus bar, cleared in 5 cycles as normal clearing time i.e. 100 m seconds, followed by trip of 220 kV single circuit between Jhimpir- New and Matiari, which was significantly loaded in the pre-fault normal load flow case and its outage may cause severe impact.

**Fig 8.5.1** indicates the bus voltages in pre and post fault conditions at 220 kV and 132 kV substations in the vicinity of Iran-Pak WPP. We find that the voltages recover smoothly and quickly to their pre-disturbance values.

The system frequency indicated in **Fig. 8.5.2** shows very nominal excursions of frequency that damps down very quickly and smoothly

The MW and MVAR output of equivalent WTG get back to normal quickly after the fault clearance as shown in **Fig 8.5.3.**

The dynamic response of generator is shown in **Figs 8.5.4** showing the recovery of speed and mechanical power. We find that the WTG is robust enough to damp down transients in the generator speed and Pmech.

**Fig 8.5.5** shows that the aerodynamic torque that dips down after fault is recovered by pitch angle control which responds quickly and restores the aerodynamic torque to normal with good damping of oscillations after fault clearance.

**Fig. 8.5.6** shows no impact on shaft twist angle and quick damping of transients in aerodynamic power (Paero) on the rotor blade side.

**Fig. 8.5.7** indicates no impact on turbine rotor speed and quick recovery of generator speed.

**Fig. 8.5.8** shows the dynamic response of pitch control and pitch compensation that acts quickly to stabilize the WTG.

The outage of 220 kV single circuit between Jhimpir- New and Matiari causes significant loading on the intact Jhimpir- New and Matiari 220 kV Single Circuit. **Fig. 8.5.9** shows the transients of MW and MVAR flows on Jhimpir- New and Matiari 220 kV circuit which settles the transients quickly and acquires new steady state levels soon.

The angular stability of other conventional generators of the system can be seen in **Fig. 8.5.10**. The relative rotor angles of Kotri GTPS 132 kV, Lakhra 132 kV, Nooriabad 132 kV, Thatta 132 kV and Jamshoro 220 kV are plotted w.r.t. Hub 500 kV. The results show that they remain in synchronism with the system generators and stay stable. The angular swings are also nominal and damp quickly.

## 8.5 Conclusion of Stability Study

The transient stability analysis performed as discussed above indicates that the NTDC/HESCO system connecting to Iran-Pak WPP through the proposed scheme of interconnection is strong enough to absorb the worst disturbances on either side i.e. on Iran-Pak WPP side or the Grid side.

There are no constraints of connecting Iran-Pak WPP with the NTDC/HESCO grid in terms of transients or dynamic behavior of system under the disturbed conditions either on the Farm side or on the Grid side.

## 9- Power Quality

The issues of power quality are of particular importance to wind turbines that may cause flicker and distortions in the power supply due to harmonics and unbalance. These issues are more significant for weak systems of low short circuit strength. Therefore we have investigated these issues for the case of minimum short circuit of 2017-18 for the proposed scheme of interconnection. The same case has been re-evaluated with per unit MVA values and plotted for 3-phase faults in Exhibits 7.2.1 and 7.2.2 in Appendix-7

### 9.1 Flicker

We have used IEC61400-21 for the calculations of flicker levels for steady-state continuous operation and for switching conditions [1].

#### 9.1.1 Continuous Operation

The probability of $99^{th}$ percentile flicker emission from a single wind turbine during continuous operation for short time $P_{st\Sigma}$ and longer time flicker levels $P_{lt\Sigma}$ are assumed same and calculated by the following formula

$$P_{st\Sigma} = P_{lt\Sigma} = \frac{1}{S_k} \cdot \sqrt{\sum_{i=1}^{N_{wt}} (c_i(\psi_k, v_a) \cdot S_{n,i})^2}$$

where

$c(\psi_k, v_a)$ is the flicker coefficient of the wind turbine for the given network impedance phase angle, $\psi_k$ at the PCC, and for the given annual average wind speed, $v_a$ at hub-height of the wind turbine at the site;

$S_n$ is the rated apparent power of the wind turbine;

$S_k$ is the short-circuit apparent power at the PCC.

$N_{wt}$ is the number of wind turbines connected to the PCC.

PCC is the point of common coupling of WTGs that is MV bus of Iran-Pak Farm substation.

For minimum short circuit case we have assumed the same case as discussed in paragraph 7.1.1 of Chapter 7 in which output of Iran-Pak Wind farm reduced as low as

25 % of its rated capacity. Therefore taking one collector group as one equivalent generator of 5x3.3 MW we have calculated as follows;

$S_n$= 3.67 MVA at 0.90 PF

$N_{WT}$ = 5

$S_k$ for MV bus = 500 MVA

The value of c ($\psi_k$) at 10 minute average speed ($v_a$) is supplied by the manufacturer after filed measurements of $P_{St,\ fic}$ for different operating conditions using the following formula.

$$c(\psi_k) = P_{st,fic} \cdot \frac{S_{k,fic}}{S_n}$$

where

$S_n$ is the rated apparent power of the wind turbine;

$S_{k,fic}$ is the short-circuit apparent power of the fictitious grid.

The value of c ($\psi_k$) may not be greater than 1, therefore for the present analysis we may assume it as 1 for the worst case.

Putting this data in the above Equation, we find

$P_{st\Sigma} = P_{lt\Sigma}$= 0.016413 = 1.64 %

Whereas the acceptable value is 4 % as mentioned in Ref. [2]. Therefore we are much less than the maximum permissible level and the WTGs at Iran-Pak Wind farm would not cause any flicker problem during steady state operation even in the weakest system conditions of minimum short circuit level.

### 9.1.2 Switching Operation

The most common switching operations would be as follows;

a. Wind turbine start-up at cut-in speed

b. Wind turbine start-up at rated wind speed

c. The worst case of switching between the WTGs

The flicker emission from the wind farm of many machines can be calculated by the following equation as per IEC61400-21 (Section 8.3.2)

$$P_{st\Sigma} = \frac{18}{S_k} \cdot \left( \sum_{i=1}^{N_{wt}} N_{10,i} \cdot (k_{f,i}(\psi_k) \cdot S_{n,i})^{3.2} \right)^{0.31}$$

$$P_{lt\Sigma} = \frac{8}{S_k} \cdot \left( \sum_{i=1}^{N_{wt}} N_{120,i} \cdot (k_{f,i}(\psi_k) \cdot S_{n,i})^{3.2} \right)^{0.31}$$

where

| | |
|---|---|
| $N_{10,i}$ and $N_{120,i}$ | are the number of switching operations of the individual wind turbine within a 10 min and 2 h period respectively; |
| $k_{f,i}(\psi_k)$ | is the flicker step factor of the individual wind turbine; |
| $S_{n,i}$ | is the rated power of the individual wind turbine. |

The values of $N_{10}$ and $N_{120}$ are usually provided by the manufacturers based on field measurements, but if these are not available then IEC61400-21 proposes in section 7.6.3 to use as follows;

For switching conditions of (a) and (b)

$N_{10} = 10$

$N_{120} = 120$

For switching conditions of (c)

$N_{10} = 1$

$N_{120} = 12$

The value of flicker step factor $k_{f,i}$ ($\psi k$) is also provided by the manufacturer after the field and factory measurements; but for the present analysis we assume it to be equal to 1.

Substituting the numbers in the above equations, we find for switching conditions of (a) and (b) as follows;

$P_{st\Sigma} = 0.39367$

$P_{lt\Sigma} = 0.37800$

For switching conditions of (c) these values would be less as the frequency of occurrence assumed i.e. $N_{10}$ and $N_{120}$ are 10 times less.

Engineering Recommendation P28 (Electricity Association, 1989) specifies an absolute maximum of $P_{St}$ on a network from all sources to be 1.0 with a 2 hour $P_{St}$ value of 0.6. However, extreme caution is advised if these limits are approached as the risk of complaints increases when the limits are reached, therefore, an assessment method proposed in the same document is based on $P_{St}$ not exceeding 0.5. British 5tandard (1995) is less stringent specifying that over a one week period $P_{lt}$ must be less than 1 for 95 % of the time. Gardner (1996) describes $P_{St}$ limits from a number of utilities in the range of 0.25 to 0.5 [2].

The values evaluated above are less than the values recommended in the references of above standards.

## 9.2 Voltage Unbalance

### 9.2.1 Voltage Step-Change

The voltage step change would occur when a WTG will be energized, assuming just one WTG in the collector for the minimum No. of units in the collector being energized.

The limit on the voltage change is based on the impedance of the circuit between the point of connection and the MV transformer bus bar together with the apparent power of the wind turbine generators. The following equation needs to be satisfied [2];

$$\Delta V = \sum S_{WKA} [(1/S_{KE}) - (1/S_{KSS})] \leq 1/33 \text{ or } 3\ \%$$

Where

$S_{WKA}$ = MVA rating of the WTG

$S_{KE}$ = Short circuit MVA at connection point

$S_{KSS}$ = Short circuit MVA at MV bus of the wind farm substation

For the minimum short circuit case, we have calculated minimum fault levels in MVA as shown in Exhibit 7.2.2

$S_{WKA}$ = 3.67 MVA for the equivalent WTG of a collector group for the minimum case

$S_{KE1}$ for one WTG in collector group = 460 MVA (Exhibit 7.2.2)

$S_{KSS}$ = 480 MVA (Exhibit 7.2.2)

Substituting these values we get

$$\Delta V = 0.0003324 = 0.0332\ \%$$

Which is much less than the limit of 3 %

### 9.2.2 Voltage Fluctuation

For the limits of voltage fluctuation, we need to satisfy the following equation [2].

$$\sqrt{\sum (P_{WKA}/S_{KE})^2} \leq 1/25 \text{ or } 4\ \%$$

Where

$P_{WKA}$ = MW rating of the WTG

$S_{KE}$ = Short circuit MVA at connection point

Punching all the numbers in this equation, we get

Voltage Fluctuation = 0.007174 = 0.717%

Which is less than the maximum permissible specified as 4%.

## 9.3 Harmonics

Regarding harmonics, IEC61400-21 states as follows [1];

"A wind turbine with induction generator directly connected to the electrical system (i.e. without a power electronic converter) is not expected to cause any significant harmonic distortion. Hence this standard does not require any further assessment of these.

"For a wind turbine with a directly connected synchronous generator (without a power electronic converter)....the wind turbine will only give a very limited emission of harmonic currents, and hence this standard does not require any further assessment of these."

Therefore we have to look into the harmonic phenomena for a wind turbine with a power electronic converter. The important thing would be to see if the resonance of harmonics generated from the WTG occurs at or near odd-harmonic frequency or not. For this purpose we carried out frequency scan by employing a state of art software PSCAD / EMTDC. The system upto T.M. Khan Road and Jhimpir-New 220/132 kV has been modeled in detail however the system behind these nodes has been represented by an equivalent voltage source. These equivalents have been developed from the Short Circuit cases of PSS/E discussed earlier in Chapter 7.

The frequency has been scanned through a spectrum of impedance values of this equivalent circuit at the node of Iran-Pak WPP 33 kV, which is the medium voltage bus of the Wind Farm substation. If harmonic resonance is controlled at this node then all the emissions of harmonics are well contained within the Farm itself. The switched shunt capacitor banks installed at MV bus bar for voltage regulation would play an important role in causing or avoiding harmonic resonance. So we have carried out the frequency scan with and without the switched shunt capacitor banks at MV bus of 33 kV for a range of 0 to 2000 Hz i.e. from fundamental frequency to 40$^{th}$ harmonic. However, the results have been plotted in the figures for a frequency range up to 750 Hz i.e. upto 15$^{th}$ harmonic, because the frequencies beyond that value are of less importance, and once the resonant point occurs at some frequency up to that range, then it would normally not recur afterthat.

### 9.3.1 Without Switched Shunt Capacitor Banks

The frequency versus positive and zero sequence resistance and reactance i.e., $R_+$ $R_0$, $X_+$, $X_0$, are shown plotted in Figures 9.1.1, 9.1.2, 9.1.3 and9.1.4.

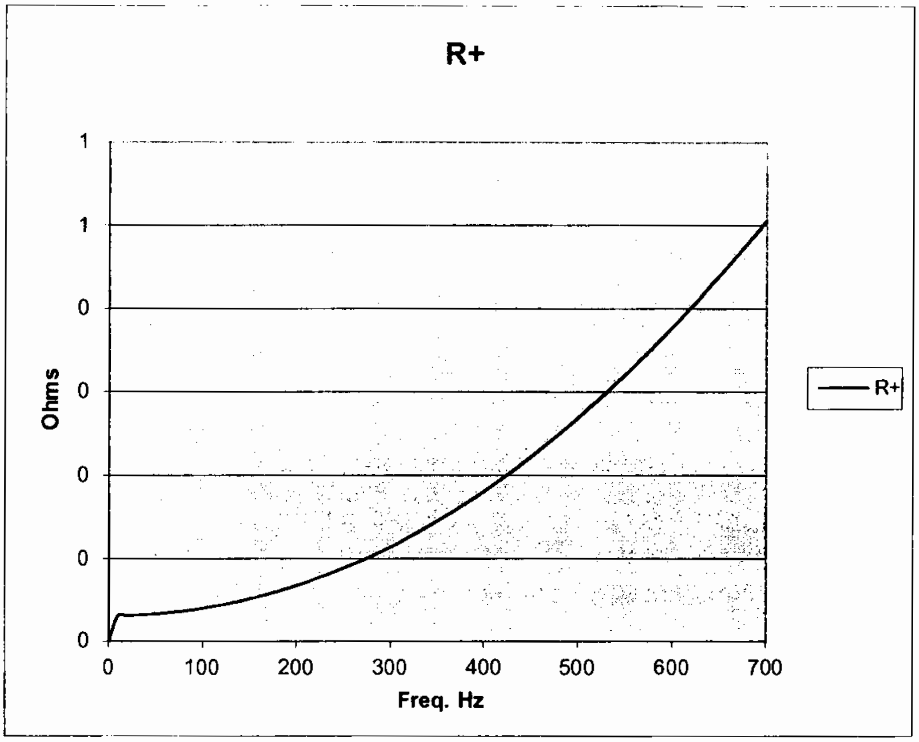



Fig 9.1.1

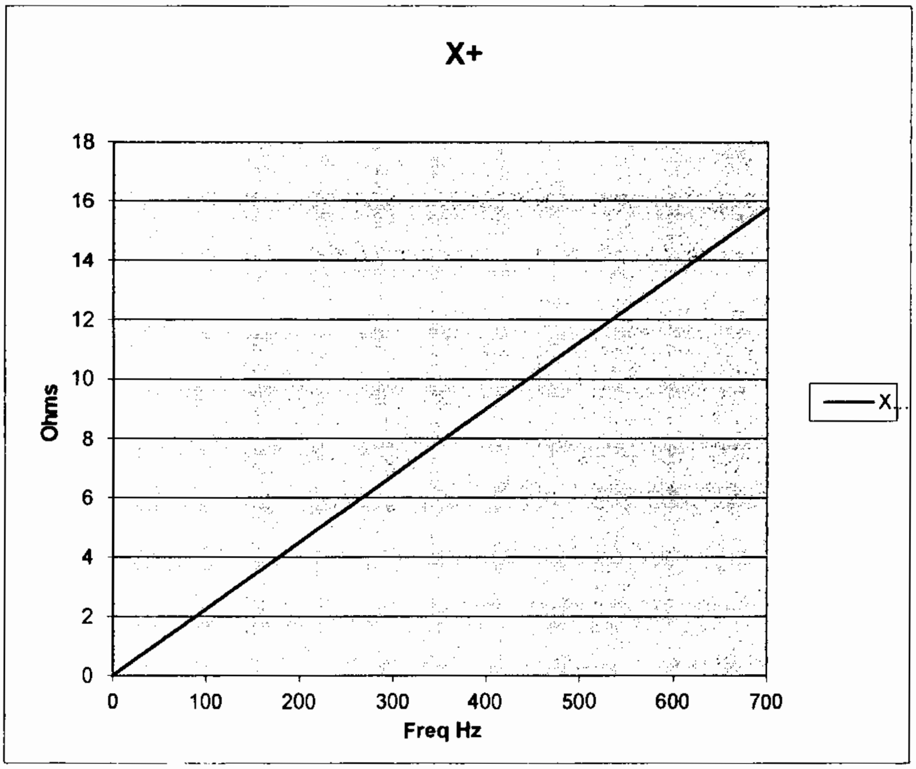



Fig 9.1.2

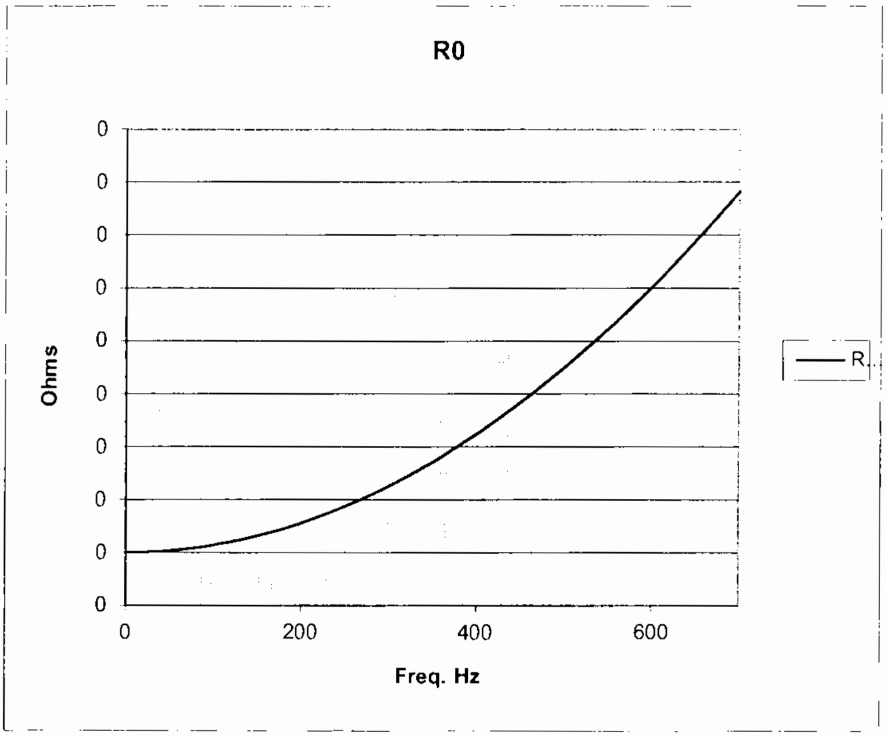



**Fig 9.1.3**

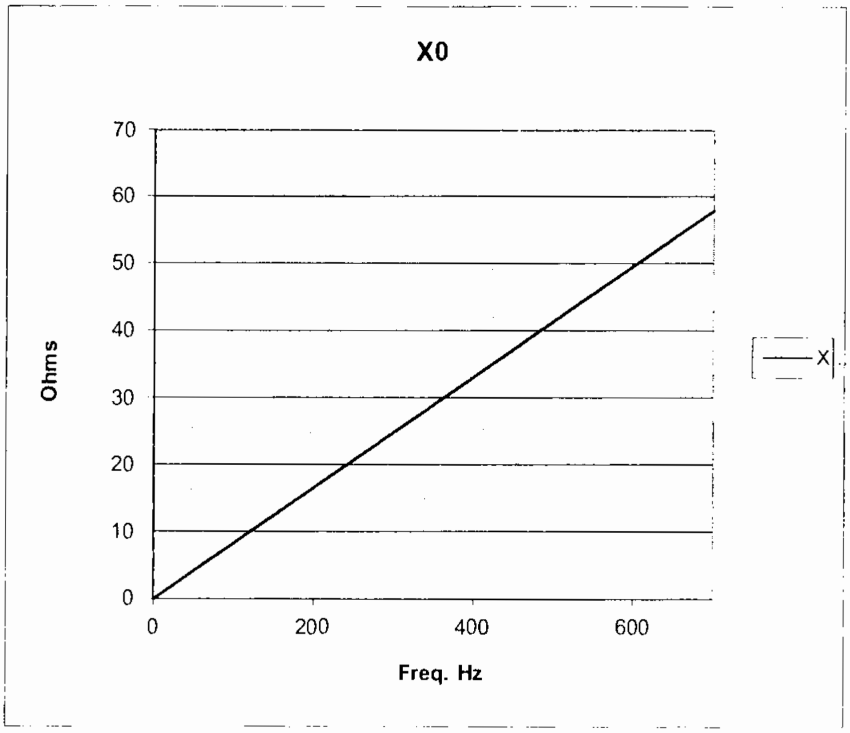



**Fig 9.1.4**

We find from the figures that up to 700 Hz i.e. 14th Harmonic no resonance phenomenon is seen. We will now investigate the same case with the proposed capacitor bank at the 33 kV Bus of Iran-Pak WPP.

### 9.3.2 With Switched Shunt Capacitor Banks

As we know that already we have proposed a switched shunt capacitor bank of 20 MVAR at MV bus of 33 kV for voltage regulation and reactive power compensation of the WTG consuming VARs. Therefore, we now see the impact of this capacitor bank on harmonic resonance. The PSCAD simulation has been run for frequency scanning and the results are shown plotted in Figs 9.2.1, 9.2.2, 9.2.3 and 9.2.4 respectively for positive and zero sequence resistance and reactance.

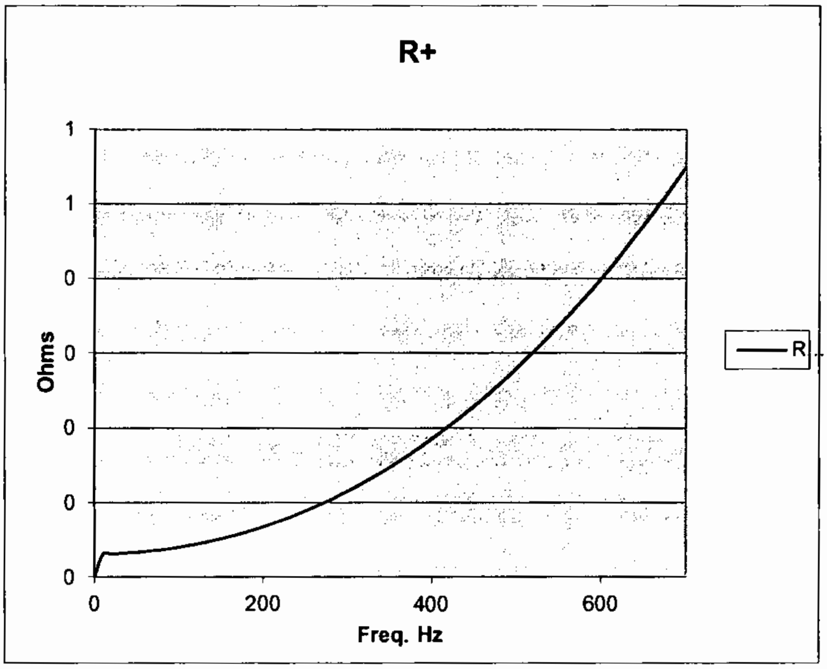



**Fig 9.2.1**

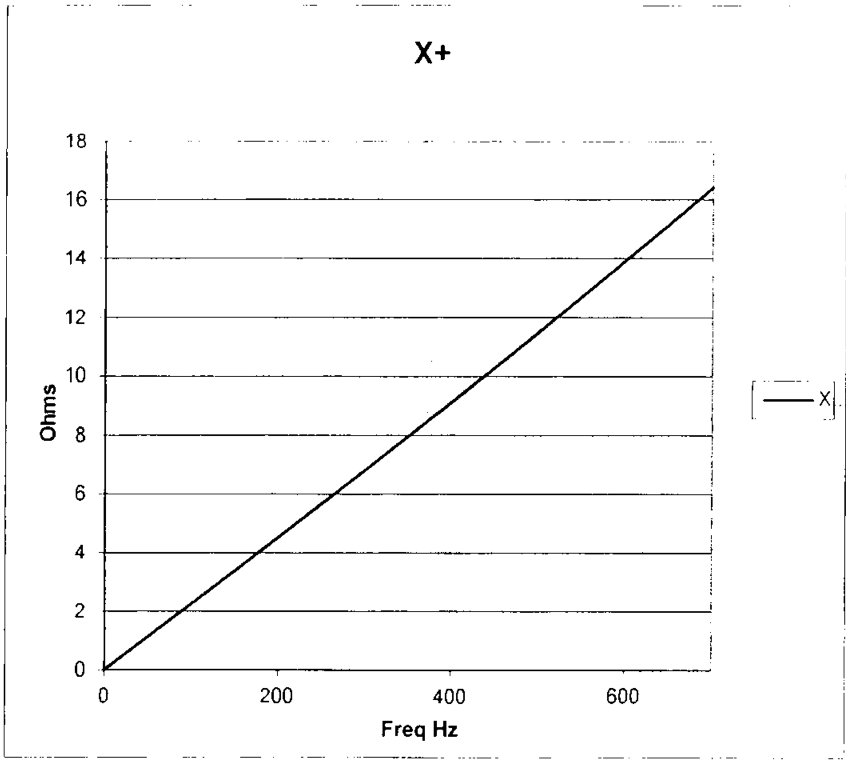



Fig 9.2.2

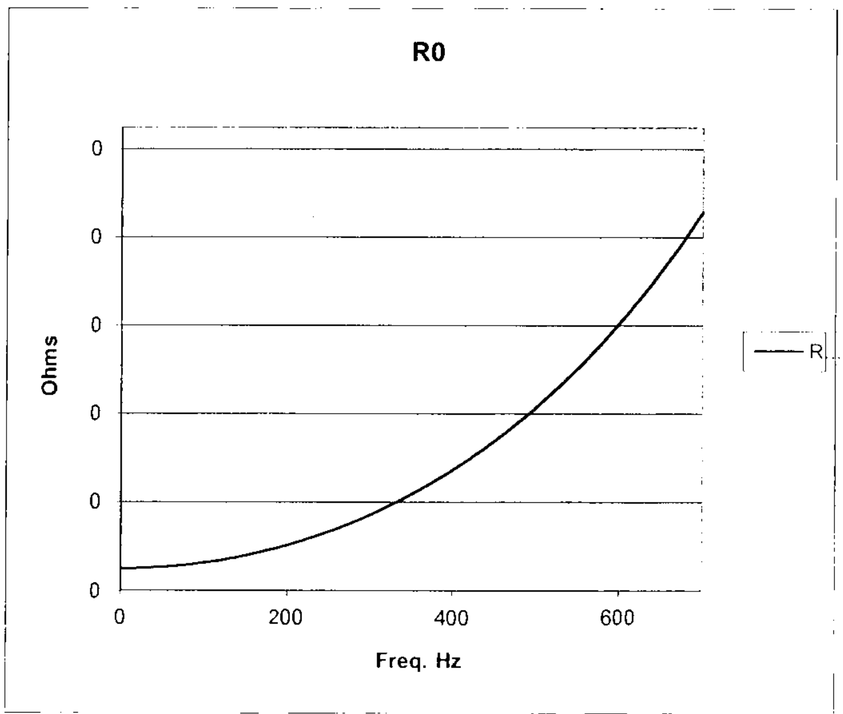



Fig 9.2.3

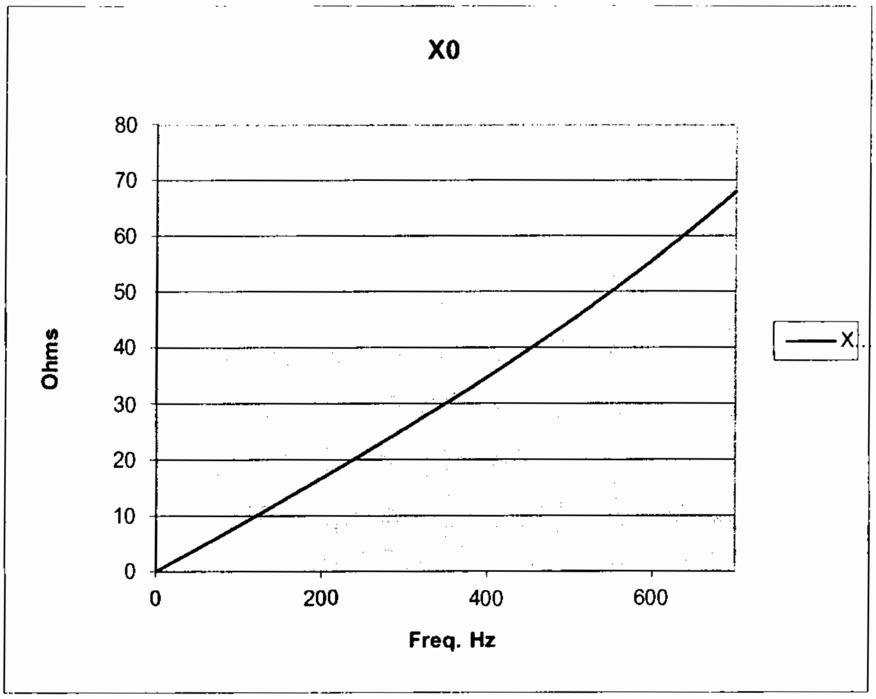



**Fig 9.2.4**

The results show that there is no zero crossing or change of signs of reactance or a maxima-minima of resistance showing no resonance i.e. the resonance point is detuned permanently not to occur at all.

## *References*


1- *Wind Turbine Generator Systems*, IEC61400-21 First edition 2001-12; Part 21; Chapters 6, 7 and 8.

2- *Wind Energy Handbook*; John Wiley & Sons Ltd. 2001, Chapter 10.

## 10- Conclusions & Recommendations

- Iran-Pak Wind Power Plant is expected to start commercial operation by the end of year 2017.
- A sixth sub cluster has been proposed at Jhimpir-New 220/132 kV collector substation to evacuate 200 MW power from four Wind Power Plants namely, Iran-Pak Wind Power Plant, Hatrford, Western Energy and DHA-City generating

  50 MW each. Therefore, the inrconnection of Iran-Pak WPP would be by connecting by a double circuit of 132 kV looping in-out with a sub cluster connecting Wind Power Plants of Hartford, Iran-Pak and DHA-City of 50 MW each to Jhimpir-New 220/132 kV collector substation.
- The scheme of interconnection of Iran-Pak WPP presupposes the following reinforcement already in place in Jhimpir and Gharo clusters.
  - 220/132 kV Jhimpir-New substation (now under construction)
  - 70 km long double circuit from Jhimpir-New 220 kV Substation to the existing T.M. Khan Road 220 kV Substation (now under construction)
  - A 132 kV double circuit of 82 km using Greeley conductor would be constructed to connect Jhimpir-New 220/132 kV Substation with T.M. Khan in HESCO network (now under construction).
  - 75 km long 220 kV double circuit from Gharo-New 220 kV Substation to Jhimpir-New 220 kV Substation (now under construction).
  - 220/132 kV Gharo-New substation at suitable location in Gharo cluster(now under construction)
  - The additional power injected into Jhimpir-New 220/132 kV grid station would require another outlet of 220 kV D/C because the ongoing 220 kV D/C from New-Jhimpir to TM Khan Rd. would already be reaching to its full capacity to evacuate already commissioned Wind Power Plants in Jhimpir cluster. The additional outlet is proposed as follows:
    - Addition of 22 kV level at the ongoing 500kV Matiari Collector Substation

- 100 km long 220 kV D/C from Jhimpir 220/132 kV to Matiari 500/220 kV grid station using Greeley conductor.

- Five sub-collectors groups will be connected to Jhimpir 220/132 kV collector substation through 132 kV double circuits using Greeley Conductor
- FFC and Zorlu looped in-out with Jhimpir-Nooriabad 132 kV circuit.
- Four WPPs in the collector system of Gharo 220/132 kV substation
- FWEL-I and FWEL-II through a 64 km long 132 kV D/C on Greeley conductor connected to Thatta
- Rehabilitation of the exiting 132 kV lines in the vicinity of WPP clusters, i.e. Jhimpir-Kotri, Jhimpir-Thatta, Thatta-Sujawal and Nooriabad-Jamshoro Old.

➢ The existing grid system of HESCO and NTDC in the vicinity of Iran-Pak WPP has been studied in detail by performing load flow, short circuit and dynamic analysis for the conditions prior to commissioning of Iran-Pak WPP and no bottlenecks or constraints have been found in the grid system.

➢ Wind Farm of Iran-Pak has been modeled considering Type-3 WTGs. They are Doubly Fed Induction Generators which are designated as Type-3 WTG. The terminal voltage is 0.65 kV. The medium voltage level of wind farm has been selected as 33 kV for unit step-up transformers, for collector circuits and step-up from MV to HV (132 kV) at Farm substation to connect to the HESCO/NTDC Grid.

➢ A conceptual design of scheme of 132/33 kV substation of Iran-Pak Wind Farm has been laid down as follows

iv. For 33 kV;

a. Two single bus-sections of 33 kV with a bus sectionalizer

b. Three breaker bays to connect three collector circuits from three collector groups of WTGs

c. Two breaker bays to connect two 132/33 kV transformers

d. Two breaker bays to connect two switched shunt capacitor banks of 2 x (4x2.5) MVAR, one in each bus section

e. Two breaker bays to connect two station auxiliary transformers 33/0.4 kV, 315 kVA

v. For 132 kV;

f. Single bus with Sectionalizer if Farm substation is GIS

g. Double bus bars with a Bus Coupler if Farm substation is AIS

h. Two breaker bays to connect two 132/33 kV transformers

i. The protection scheme would be designed in compliance of NTDC requirements sent by Chief Engineer Protection, vide letter No.3416-19/CE/SP/MN/50MW CWE WPP Jhimpir dated 23/07/2010

j. The telecommunication scheme would be designed in compliance of NTDC requirements sent by Chief Engineer Telecommunication, vide letter No. CE (Tel)/NTDC/232/4372 dated 27/08/2010.

vi. Other Equipment:

a. Two 132/33 kV, 31.5/40/50 MVA ONAN/ONAF1/ONAF2 OLTC transformers, 132±11×1%/22kV, to fulfill N-1 criteria of Grid Code

b. Two station auxiliary transformers of 33/0.4 kV, 315 kVA

c. Two switched shunt capacitor banks each of the size of 10 MVAR (4 x 2.5 MVAR) to provide 20 MVAR at 33 kV with contactors and PLC (Programmable Logic Controller).

d. Energy meters would be installed on HV side (132 kV) of the 132/33kV transformers.

- Load flow analysis has been carried out for June 2018 considering the COD targeted by Iran-Pak WPP, for the dispersal of load from Iran-Pak WPP into HESCO Grid at 132 kV level using the latest load forecast, generation and transmission expansion plans of NTDC and HESCO. The above mentioned interconnection scheme has been evolved by performing the load flow studies testing the steady state performance for normal as well as N-1 contingency conditions fulfilling the Grid Code criteria of Wind Power Plants. The reactive power requirement at point of common coupling to meet PF of ± 0.95, voltage and line loading criteria are fulfilled by these studies. The grid facilities of HESCO are found adequate to absorb output power of Iran-Pak WPP. The load flow results for these scenarios also establish that the proposed scheme of interconnection of Iran-Pak WPP shows no bottlenecks or capacity constraints in the adjoining 500 kV, 220 kV and 132 kV network in terms of absorbing all the output of Iran-Pak WPP under normal as well as the contingency conditions.

- Maximum and minimum short circuit levels for three-phase faults and single-phase faults have been evaluated. The maximum short circuit level has been evaluated for the year 2017-18 and the minimum short circuit level has been evaluated for 2017-2018 to evaluate the most stringent conditions, the fault levels of Iran-Pak 132 kV are 11.82 kA and 6.52 kA for 3-phase and single phase faults respectively for 2017-18. This is much less than the switchgear rating of 40 kA recommended for Iran-Pak Farm Substation as per NTDC requirements for 132 kV. The fault levels for Iran-Pak 33 kV are 11.80 kA and 10.14 kA for 3-phase and single-phase faults respectively for year 2017-18. Therefore the short circuit rating for 33 kV switchgear is recommended as 25 kA. It has been found that the proposed scheme provides maximum SC strength for the evacuation of Iran-Pak WPP power to the grid.

  The switchgear ratings for Iran-Pak WPP substation are as follows:

  **132 kV:**

  Short circuit rating = 40 kA (3 sec.)

  Continuous rating = 2500 A

  **33 kV:**

  Short circuit rating = 25 kA (3 sec.)

  Continuous rating = 2500 A

- Transient Stability analysis has been carried out for Iran-Pak WPP based on their selection of Type-3 WTGs, with connectivity of proposed scheme. Different disturbances have been simulated to apply stresses from the system faults on the wind farm and vice versa and it was found that Iran-Pak WTG unit's dynamic characteristics and the grid connectivity is strong enough to maintain stability under all disturbances. In turn, any disturbance from Iran-Pak WPP side did not cause any stress on the main grid or the power plants in HESCO area viz. Kotri, Lakhra or Jamshoro such that the whole system remained stable under all events.
- The LVRT requirements have been tested to fulfill 100 ms (5 cycles) under normal clearing time and 180 ms (9 cycles) for contingency condition of delayed fault clearing due to stuck- breaker (breaker failure) reason. The simulations have proved that the proposed machine fulfills the LVRT criteria as required in the Grid Code for Wind IPPs.
- The issues of power quality like flicker, unbalance and harmonic resonance have been studied in detail. The results have indicated that the levels of flicker and unbalance are within the permissible limits of IEC and other International Standards.
- There are no technical constraints whatsoever in the way of bringing in the 50 MW of Iran-Pak Wind Power Plant at the proposed site and scheduled time of commissioning, in any respect of steady state (load flow) or short circuit or dynamic performance (stability) or power quality issues related to this plant.

**In the Name of GOD**

IPWPPL

50 MW Wind Power Plant Project

In district Thatta, Sindh Province, Pakistan

# Feasibility Study

**Client:**

IRAN – PAK WIND POWER (Pvt.) LIMITED (IPWPPL) Company

**Engineer:**

Ghods Niroo Engineering Company (GNEC)

# Executive Summary

The Iran - Pak Wind Power Private Limited (IPWPPL) Company is seeking investment in 50 MW wind power project in the Sindh province, of Pakistan. IPWPPL appointed the Ghods-Niroo Engineering Company (GNEC) for providing consultancy for the wind power feasibility study.

GNEC then prepared the detailed feasibility study for the 50 MW wind power project located in the Sindh province, Pakistan. Detailed comparative study of the central and state governments wind power policies were presented in the report along with the description of wind power technology, selection of wind turbine and wind farmable sites. The proposed wind farm site of Iran - Pak is 18 km north of Thatta city, in the Sindh province of Pakistan.

In addition IPWPPL proposed wind farm land leased for a period of 30 years from Thatta District Administration, and after that two 80m wind masts were installed. Met masts are the primary tool for wind data gathering and specification of wind regime and wind directions.10 minutes interval data from wind masts for a period of 518 days gathered and used in this feasibility study (09/01/2013 - 01/31/2015). According to their data, the annual average wind speeds are 7.9 m/s, 8.1 m/s respectively (see table 1).

This feasibility study includes the review of central government and state government's policies on wind power in Pakistan. Feasibility study also include cost estimates of the wind power project, financial assessment including determination of IRR and payback period for the Iran - Pak site and the selected wind turbine, sensitivity analysis and the recommendation on the selection of wind turbine. The study carried out by WindPRO and WAsP software (with RISO Benchmark) and the result of this study shows that four wind turbines that selected based on their ratings, performance power curves, and other characteristics had the best performance in Iran - Pak site location. The selected VESTAS wind turbine is given in Table 2. Total wind energy of proposed Iran–Pak Wind Power Plant with mentioned wind turbine, estimated and illustrated in table 3.

**Table 1: Summary of processed data on sites**

| Site | Time Series | Record Interval | Recovery Rate (%) | W.S. (80m) | W.D. (80m) | Power Low (α) | Power Density (W/M$^2$) |
|---|---|---|---|---|---|---|---|
| **No.1** | 01/09/2013 to 31/01/2015 | 10 Minute | 100 | 7.9 | WSW | 0.167 | 430.7 |
| **No.2** | | | 100 | 8.1 | WSW | 0.150 | 481.5 |

**Table 2: selected wind turbine**

| No. | Wind Turbine | Capacity (MW) |
|---|---|---|
| 1 | VESTAS V126 | 3.3 |

**Table 3: Estimated Electricity Produced of VESTAS V126 - 3.3 MW wind Turbine**

| Name | VESTAS V126/ 3.3 MW |
|---|---|
| Wind Farm Capacity (MW) | 49.5 |
| **net annual energy (considering all losses & uncertainties) (MWh/y)** | **174762** |
| Park Efficiency (%) | 92.2 |

| | |
|---|---|
| **Park Capacity Factor (%)** | **39.9** |

Based on the estimated energy generation and cost of wind power project, the financial analysis has been carried out. The results of IRR and payback period for the case of sale to utility for both the cases are given in Table 4.

**Table 4: project summary**

| | | |
|---|---|---|
| 1 | Type of the project | Wind (farm) power plant |
| 2 | Company | IRAN – PAK WIND POWER (Pvt.) LIMITED (IPWPPL) |
| 3 | Farm capacity | 49.5 MW |
| 4 | Land area | 1250 acres |
| 5 | Construction period | 2 years |
| 6 | Production period | 20 years |
| 7 | Turbine type | VESTAS V126 - 3.3 MW |
| 8 | Wind Data Validity Period | 09/01/2013 to 01/31/2015 |
| 9 | Project location | Near "Janabad" Gharo, District Thatta, Sindh, Pakistan |

# Acknowledgements

Iran-Pak Wind Power Pvt Ltd Company intends to setup a 50 MW Wind Farm in Thatta District of Sindh Province. So Iran - Pak hired GNEC as their consultant. The Feasibility Study Report was produced by the Ghods-Niroo's Energy Department in 2014.

Energy Department through the Ghods-Niroo promotes the use of renewable energy and sustainable building practices through technology demonstration, hands-on instruction and renewable energy education in Middle East; especially in Iran.

Energy Department qualified itself by obtaining several certificates from Executive Office of the President and other international and local organizations.

Renewable energy can have significant economic development, security and reliability benefits and opportunities for Pakistan communities and individuals in the development of these resources. This report helps that community with establishing and developing the wind energy in Sindh Province of Pakistan.

Special thanks are giving to the Iran - Pak Office and Research staff for their cooperating and expertise. Also, we'd like to thank Khurram Sayeed, Iran Pak's Chief Executive/ Director .

More information about the parties is shown in table below.

| Parties | Sub Parties | Manager | Postal Addresses | Tel/Fax | E-Mail address |
|---|---|---|---|---|---|
| CLIENT (Iran-Pak) | Sunir | Dr. Mehdi Doostkam | No.1 Mozhdehi Alley, Somayeh St. Tehran, Iran | +982142741630 | doostkam@sunir.com |
| | | | Postal Code: 1581761185 | | |
| | Planet Group | Mr Khurram Sayeed | Suite No.414, 4th Floor, Progressive Plaza, Beaumont Road, Karachi, Pakistan | +922135657456<br>+922135657457 | planetgroup@cyber.net.pk |
| ENGINEER (GNEC) | ---- | Mrs. Fataneh Doustdar | No.82, After Sohrevardi Crossroad on Ostad Motehary Ave. Tehran-IRAN. Postal Code: 1566775353 | +982188442482 | Direct<br>fdoustdar@ghods-niroo.com<br>Extra<br>jrsahmi1@gmail.com |

# Approval Sheet

**Developed by:**

| |
|---|
| **Ghods Niroo Engineering Company (GNEC)** |
| **On behalf of study team:** |

| **Name** | **Position** | **Signature** |
|---|---|---|
| Javad Raheli Salimi | Meteorologist & Wind Expert | |
| Seyed Mohammad Mahdi Mousavi | Renewable Energy Engineer | |
| Mohammad Mahdi Motedayen | Financial Expert | |
| Mohsen Dehghan | Environmental & GIS Expert | M. Dehghan |
| Saman Ramin | Mechanical Expert | |

**Checked by:**

| **Name** | **Position (Post)** | **Signature** |
|---|---|---|
| Fataneh Doustdar | Project Manager | |

**Reviewed and Approved by:**

| |
|---|
| **IRAN-PAK Wind Power Plant Limited (IPWPPL)** |
| **On Behalf of Reviewing Team:** |

| **Name** | **Position (Post)** | **Signature** |
|---|---|---|
| Khurram Sayeed | Chief executive officer (CEO & Director ) of Iran-Pak | |
| Mehdi Doostkam | Project Manager | Doost Kam |
| Ehsan Nadjafi | Member of board of Iran-Pak | Nadjafi |
| | | |

**Head of the Team:**

| **Name** | **Signature** |
|---|---|
| Mehdi Doostkam (project manager) | Doost Kam |

# Table of Contents

# Nomenclature

| | |
|---|---|
| AEDB: | Alternative Energy Development Board |
| CFD: | Computational Fluid Dynamics |
| EMP: | Environment Management Plan |
| EPA: | Energy Purchase Agreement |
| EMD: | A software and consultancy company within the field of environmental and energy projects |
| EWTS | European Wind Turbine Standards II |
| FFC: | Fauji Fertilizer Company Ltd |
| GNEC: | Ghods Niroo Engineering Company |
| IEC: | International Electrotechnical Commission |
| IPWPPL: | Iran-Pak Wind Power Pvt Limited |
| MOU: | Memorandum of Understanding |
| NEQs: | National Environmental Quality Standards |
| NEPRA: | National Electric Power Regulatory Authority |
| NEQs: | National Environmental Quality Standards |
| OGDCL: | Oil and Gas Development Company Limited |
| PMD: | Pakistan Meteorological Department |
| RISO (DTU): | National Laboratory for Sustainable Energy (at Denmark Technical University) |
| SWT Class: | Value ***specified*** by the Wind Turbine designer in IEC Class |
| WAsP: | Wind Atlas Analysis and Application Program |
| WFDT: | Wind Farm Design Tools |
| WTG: | Wind Turbine Generator |
| ZVI: | Zone of Visual Influence |

# CHAPTER I:

## Introduction to Sindh, Pakistan

## 1-1- Introduction (General overview)

Islamic Republic of Pakistan is a country in South Asia situated between the latitudes 23° and 36° north and between the longitudes of 61° and 75° east. With a population exceeding 180 million people, it is the sixth most populous country and with an area covering 796,095 $km^2$ (307,374 sq mi), it is the 36th largest country in the world in terms of area. Pakistan has a 1,046-kilometre (650 mi) coastline along the Arabian Sea and the Gulf of Oman in the south and is bordered by India to the east, Afghanistan to the west and north, Iran to the southwest and China in the far northeast. It is separated from Tajikistan by Afghanistan's narrow "Wakhan Corridor" in the north, and also shares a marine border with Oman (see Figure 1-1) [1]

Pakistan extends some 1,700 km northward to the origins of the Indus among the mountains of the Himalayas, Hindu Kush and Karakoram. Many of their peaks exceed 8,000 m including K-2, at 8,611 m, the second highest in the world. Pakistan has a coastline of about 1,046 km with 22,820 $km^2$ of territorial waters and an Exclusive Economic Zone of about 196,600 $km^2$ in the Arabian Sea [2].

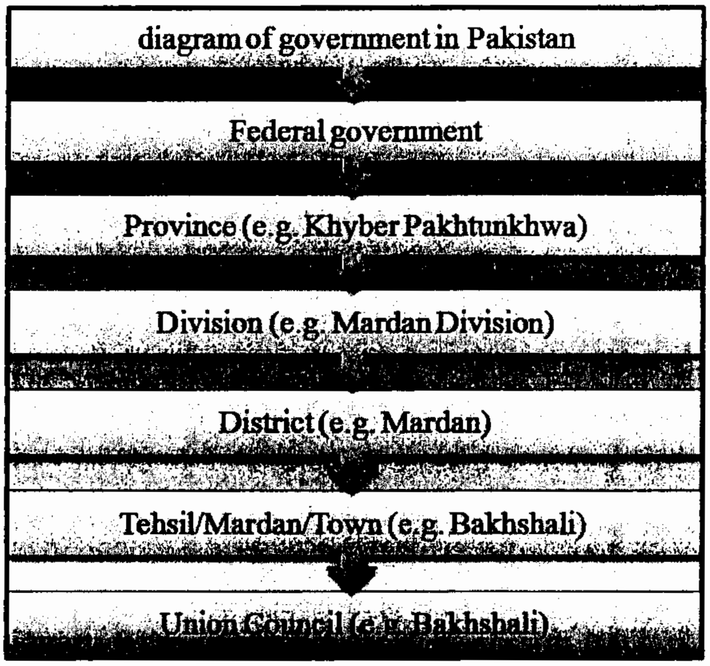
The administrative units of Pakistan consist of five provinces, one federal capital territory, two autonomous territories and a group of federally administered tribal areas. Below this top tier, there are four more tiers of government, including 27 divisions, more than a hundred districts (zillahs), more than four hundred sub-districts (Tehsils), and several thousand union councils [3].


**Figure 1-1: Pakistan Map**

The provinces are sub-divided into 105 districts called zillahs (Urdu language ضلع). Zillahs are further subdivided into sub-districts called tehsils (Urdu language تحصيل) (roughly equivalent to counties). The term "Tehsil" is used everywhere except in Sindh province, where the term taluka (Urdu language تعلقہ) predominates. Tehsils may contain villages or municipalities. Pakistan has over five thousand local governments. Since 2001, these have been led by democratically elected local councils, each headed by a Nazim (Urdu language ناظم) ("supervisor" or "mayor"). Women have been allotted a minimum of 33% of the seats on these councils. Some districts, incorporating large metropolitan areas, are called City Districts. A City District may contain subdivisions called Towns and Union Councils.

The diagram (1-1) outlines the six tiers of government in Pakistan, together with an example.

**Diagram (1-1): outlines the six tiers of government in Pakistan**




## 1-2- Geography of Sindh

### 1-2-1- Topography

The neighboring countries of Pakistan are India, Iran, China and Afghanistan. Mountains and desert get the prime importance, as Pakistan is a land of mountains and deserts. Pakistan Mountains in the north Pakistan remain snow capped throughout the year. The important mountains in Pakistan, which range between the height of 8000 and 9000 meters are K2, Nanga Parbat, Gasherbrum I, Broad Peak and Gasherbrum II. Pakistan Geography is a great combination of lush vegetation and desert landscapes. The large expansive deserts are stretched along for Kilometers. .Pakistan Land comprises of desert in the southern part. Due to lack of rainfall, the temperature shoots up to 45°C or even more during the summer. The topography of the region helps in keeping the climate hot and dry. Through the land of Pakistan flow river Indus and its tributaries Jhelum, Chenub and Ravi as well as the Beas and Sutlej.

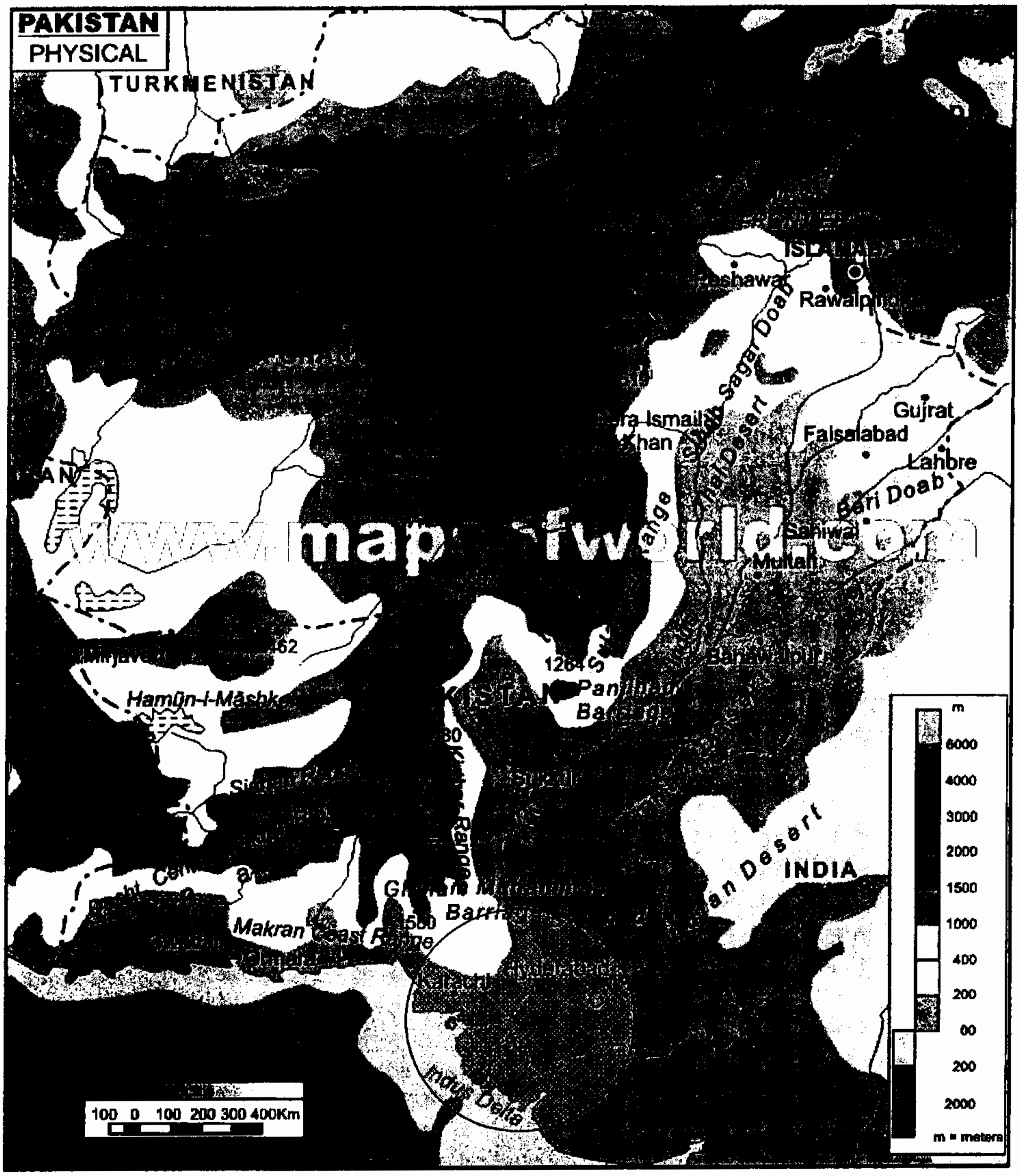



**Figure (1-2): Pakistan Physical map (Elevation)**

The Province of Sindh is located on the western corner of South Asia, bordering the Iranian plateau in the west. Geographically it is the third largest province of Pakistan, comprises of

23.7% of Pakistan's population and 18% of its land area stretching about 579 km from north to south and 442 km (extreme) or 281 km (average) from east to west, with an area of 140,915 square kilometers of Pakistani territory. Sindh is bounded by the Thar Desert to the east, the Kirthar Mountains to the west, and the Arabian Sea in the south. In the centre is a fertile plain around the Indus River. Sindh is linked with Baluchistan in the west and north, Punjab to the north, Gujarat and Rajasthan of India in the southeast and east, and the Arabian Sea in the south.

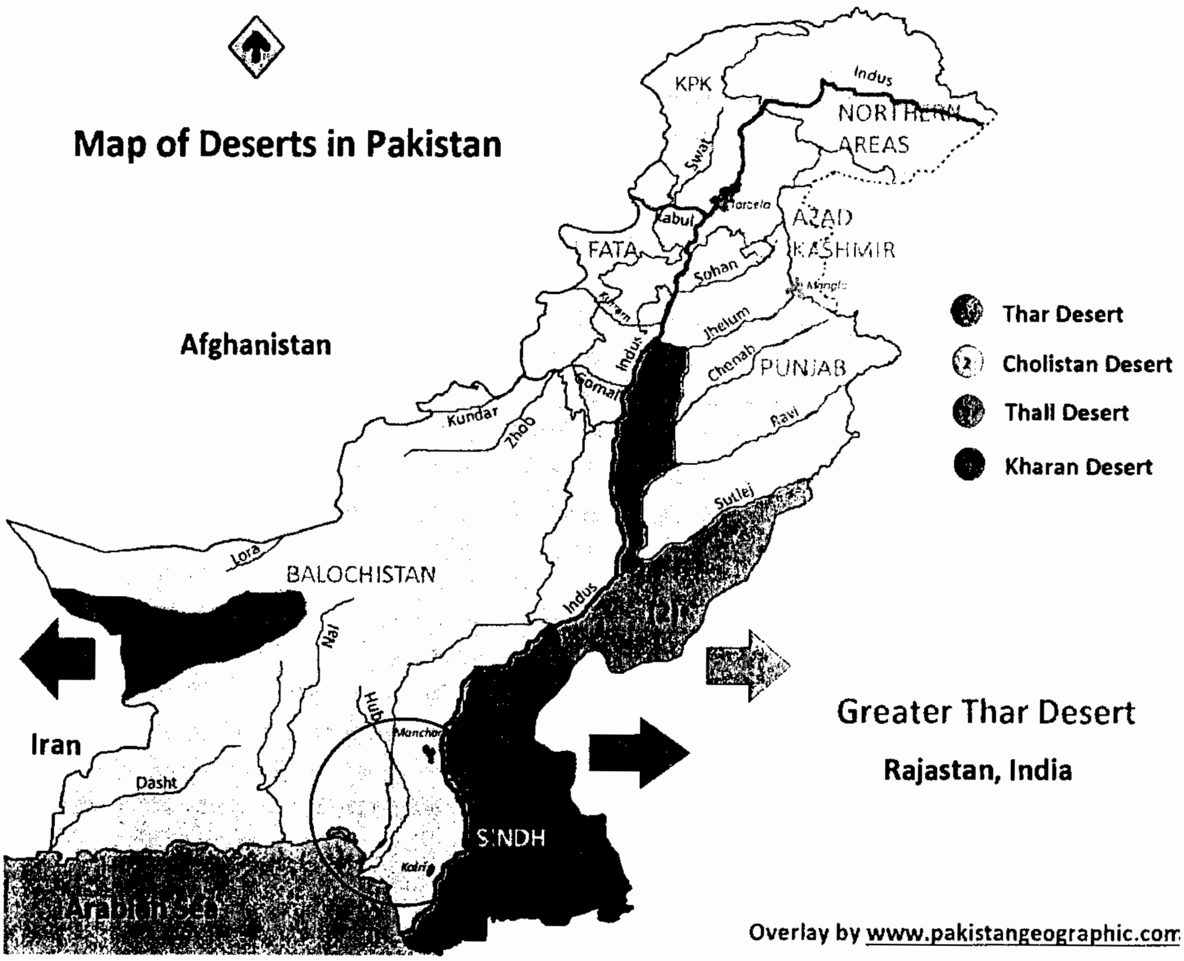



**Figure (1-3): Pakistan Physical map (Deserts)**

## 1-2-2- Vegetation

The province is mostly arid with scant vegetation except for the irrigated Indus Valley. The dwarf palm, Acacia Rupestris (kher), and Tecomella undulata (lohirro) trees are typical of the western hill region. In the Indus valley, the Acacia nilotica (babul) (babbur) is the most dominant and occurs in thick forests along the Indus banks. The Azadirachta indica (neem) (nim), Zizyphys vulgaris (bir) (ber), Tamarix orientalis (jujuba lai) and Capparis aphylla (kirir) are among the more common trees.

Mango, date palms, and the more recently introduced banana, guava, orange, and chiku are the typical fruit-bearing trees. The coastal strip and the creeks abound in semi-aquatic and aquatic plants, and the inshore Indus deltaic islands have forests of Avicennia tomentosa (timmer) and Ceriops candolleana (chaunir) trees. Water lilies grow in abundance in the numerous lake and ponds, particularly in the lower Sindh region [4].

## 1-2-3- Flora and fauna

Among the wild animals, the Sindh ibex (sareh), wild sheep (urial or gadh) and black bear are found in the western rocky range, where the leopard is now rare. The pirrang (large tiger cat or fishing cat) of the eastern desert region is also disappearing. Deer occur in the lower rocky plains and in the eastern region, as do the striped hyena (charakh),jackal, fox, porcupine, common gray mongoose, and hedgehog. The Sindhi phekari, ped lynx or Caracal cat, is found in some areas.

Phartho (hog deer) and wild bear occur particularly in the central inundation belt.There are a variety of bats, lizards, and reptiles, including the cobra, lundi (viper), and the mysterious Sindh krait of the Thar region, which is supposed to suck the victim's breath in his sleep. Crocodiles are rare and inhabit only the backwaters of the Indus and the eastern Nara channel. Besides a large variety of marine fish, the plumbeous dolphin, the beaked dolphin, rorqual or blue whale, and a variety of skates frequent the seas along the Sind coast. The pallo (sable fish), though a marine fish, ascends the Indus annually from February to April to spawn.

Although Sindh has a semi arid climate, through its coastal and riverine forests, its huge fresh water lakes and mountains and deserts, Sindh supports a large amount of varied wildlife.

Due to the semi arid climate of Sindh the left out forests support average population of jackals and snakes. The national parks established by the Government of Pakistan in collaboration with many organizations such as World Wide Fund for Nature and Sindh Wildlife Department support a huge variety of animals and birds. The Kirthar National Park in the Kirthar range spreads over more than 3000 km² of desert, stunted tree forests and a lake. The KNP supports Sindh Ibex, wild sheep (urial) and black bear along with the rare leopard. There are also occasional sightings of The Sindhi phekari, ped lynx or Caracal cat. There is a project to introduce tigers and Asian elephants too in KNP near the huge Hub dam lake.

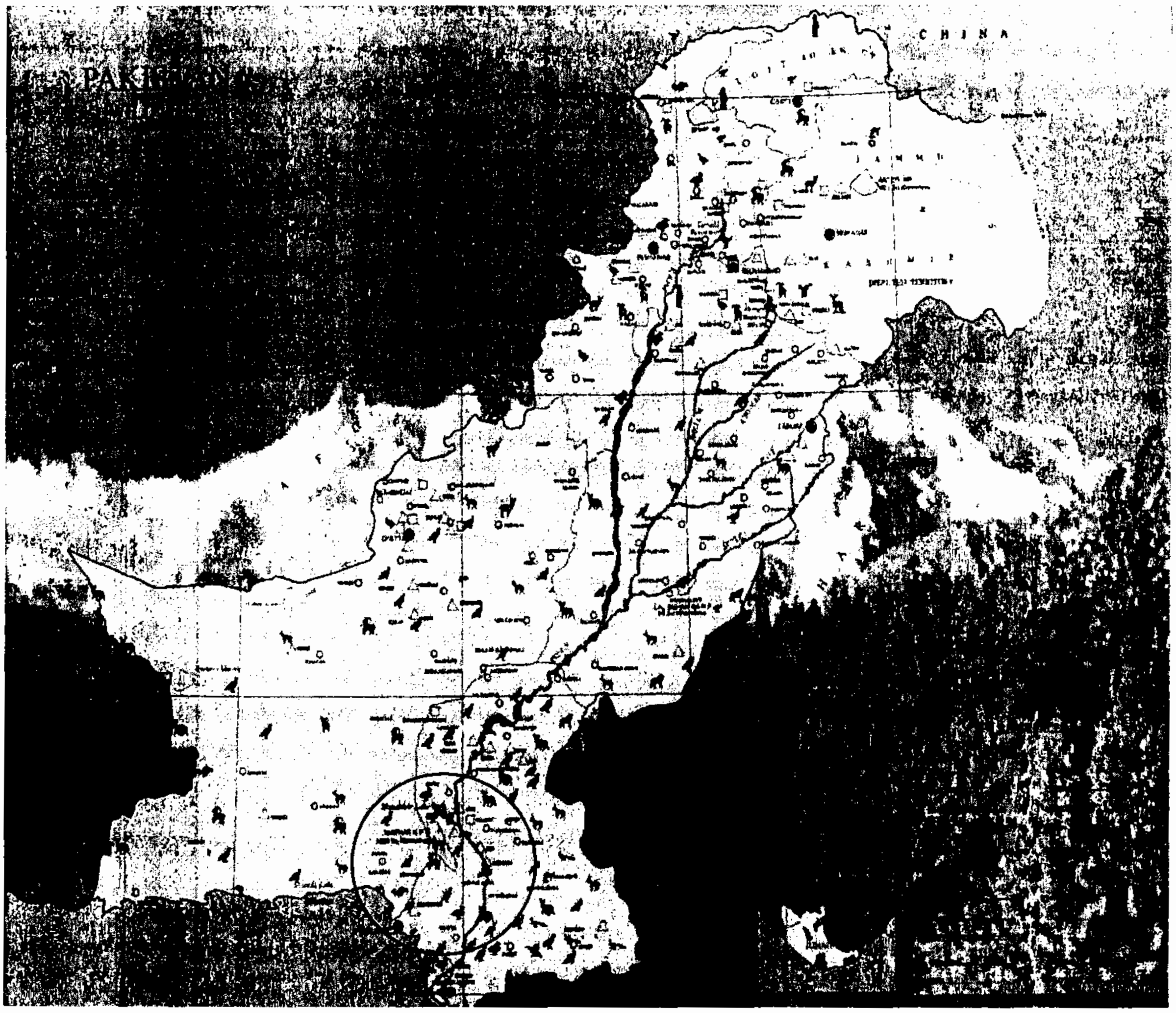



**Figure (1-4): Pakistan Wild life**

Crocodiles are rare and inhabit only the backwaters of the Indus, the eastern Nara channel and some population of Marsh crocodiles can be very easily seen in the waters of Haleji Lake near Karachi. Besides a large variety of marine fish, the plumbeous dolphin, the beaked dolphin, rorqual or blue whale, and a variety of skates frequent the seas along the Sindh coast. The pallo (sable fish), though a marine fish, ascends the Indus annually from February to April to spawn. The rare Houbara Bustard also find Sindh's warm climate suitable to rest and mate.

## 1-2-4- Cities in Sindh

There are 23 districts in Sindh, Pakistan. Karachi became capital of Sindh in 1936, in place of the traditional capitals of Hyderabad and Thatta (figure (1-5)).

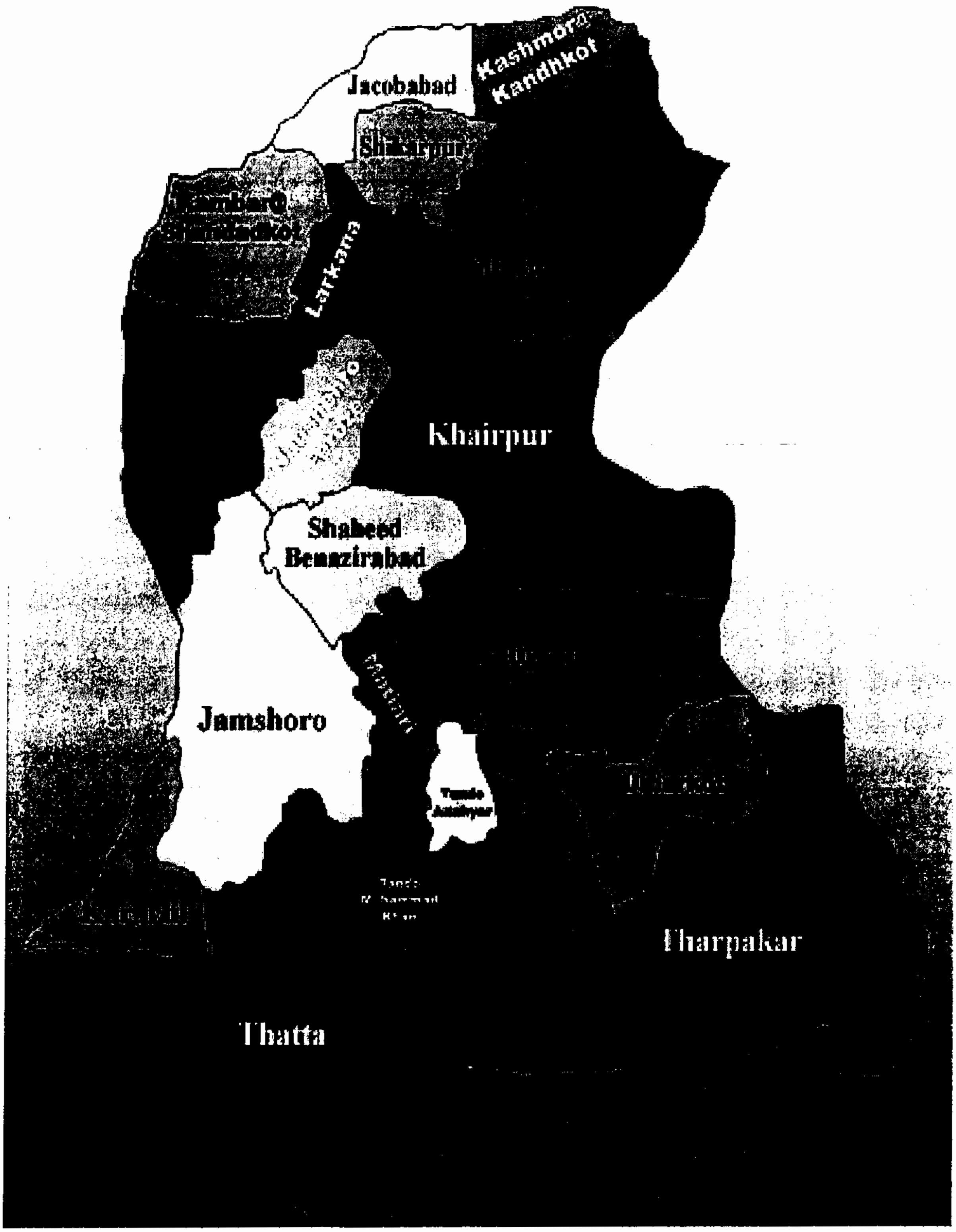



**Figure (1-5): Map of Sindh province (Districts)**

Important cities are described below :

**Table (1-1): Districts and Major cities in Sindh province**

| | |
|---|---|
| Districts | Karachi - Jamshoro - Thatta - Badin - Tharparkar - Umerkot - Mirpur Khas - Tando Allahyar - Matiari - Tando Muhammad Khan - Hyderabad - Sanghar - Khairpur - Nawabshah - Dadu - Naushahro Feroze - Larkana - Sukkur - Ghotki - Shikarpur - Jacobabad - Qambar Shahdadkot -Kashmore |
| Major cities | Daharki - Diplo - Ghotki - Dadu - Hala - Hyderabad - Jacobabad - Jamshoro - Karachi - Kashmore - Khairpur - Kotri - Larkana - Nawabshah - Naushahro Feroze (Padidan) - Shahdadkot - Raharki - Ranipur - Ratodero - Sanghar - Sehwan - Sekhat - Shikarpur - Sobhodero - Sukkur - Rohri |

**Karachi**: The largest city of Sindh Province ; it is located in the south. With its 18 million population it is the largest city of Pakistan. Most of the International flights come to Quaid-e-Azam International airport.

**Hyderabad**: The second largest city of Sindh was the former capital of the area. It is 170 Kilometers from Karachi and offers interesting options for culture tours.

**Thatta**: The formal capital of Sindh; the cradle of literature history and prosperity for the province is now a very small town having ruminants of its rich past and the famous cemetery of Makli and Shahjehan Mosque.

**Sukkur**: The central city of Sindh located on the bank of the Indus River. It was also once a historical city of the area. The city has many archeological sites, shrines and a clock tower from the English times. It is 500 kilometers from Karachi.

**Larkana**: The home to the popular political party of Pakistan the people's party. It's given more importance due to its proximity with Moen Jo Daro; the ancient city of Indus civilization.

**Mirpurkhas**: The south eastern city of Mirpurkhas is 70 kilometers from Hyderabad. It is home to the rich agriculture farms and the famous mangos from the area.

**Thar Desert:** The eastern desert of Sindh is rich in culture and natural beauty due to its sand dunes.

**Jacobabad:** The town in the western Sindh.

**Sehwan**: The city of the one of the most popular Sufi of Pakistan Hazrat Lal Shahbaz Qalandar.

**Khairpur**: The city of Kot DG, the beautiful fort and archeological site of Kot DG (Pre Indus civilization).

**Nawab Shah**: It is a city in Shaheed Benazir Abad District of Sindh province, Pakistan. It is the headquarters of Shaheed Benazir Abad District and has a population of 1,135,131.

## 1-3- District Thatta

Thatta is a historic town of 220,000 inhabitants in the Sindh province of Pakistan, near Lake Keenjhar, the largest freshwater lake in the country. Thatta's major monument, the necropolis at Makli is listed among the World Heritage Sites. The Shah Jahan Mosque, Thatta is also mentioned separately on the tentative list since 1993. Thatta is Located about 98 kilometers east of the provincial capital of Sindh; Karachi, it makes for a practical escape for people from the city seeking to visit the picturesque old town.

That was the capital of three successive dynasties and later ruled by the Mogul emperors of Delhi. Thatta was constantly embellished from the 14th to the 18th century. The remains of the city and its necropolis provide a unique view of civilization in Sindh. Once Thatta served as capital of Sindh and as a center for Islamic arts. Since the 14th century four Muslim dynasties ruled Sindh from Thatta, but in 1739 the capital was moved elsewhere and Thatta declined. It was believed that this was the place where Alexander the Great rested his legions after their long march. The town is dominated by the Great Mosque built by the Mogul Emperor Shah Jehan which has been carefully restored to its original condition. The mosque's 33 arched domes give it superb acoustics and the tile work, a whole range of shades of blue, is equally fine. Situated on the outskirts of the new town, it is surrounded by narrow lanes and multi-story houses made of plaster and wood which are topped by badgers, the wind catchers designed to funnel cool breezes down into the interiors of buildings. They are also quite common in Hyderabad.


**Figure (1-6): Map of Thatta Districts**

The bazaars of Thatta are known for hand-printed fabrics, glass bangles and Sindhi embroidery work in laid with tinny mirrors, one of the more world known handicrafts of Pakistan. Thatta is a fascinating town which appears to have scarcely moved out of the 18th century and is only slowly catching up with the modern world The shifting nature of the Indus makes it difficult to discern the exact location of ancient Thatta, but the name indicates its strong relation to the Indus. Thatta, derived from Thatti, Thatt or Thatto, a Sindhi word for a small settlement on riverbanks, was an important medieval city locally known as Nagar-Thato. All historic accounts paint Thatta as a populous and flourishing trading post and a refuge of saints and scholars.

Thatta is famous for its necropolis, which covers 10 $km^2$ on the Makli Hill, which assumed its quasi-sacred character during Jam Nizamu-d Din's rule. The site became closely interlinked with the lives of the people. Every year thousands perform pilgrimage to this site to commemorate the saints buried here. The graves testify to a period of four centuries when Thatta was a thriving center of trade, religion and scholarly pursuits and the capital of Sind. In 1768, Thatta's per-eminence was usurped by Hyderabad. Though many of the mausoleums and graves are dilapidated, many are still exquisite architectural examples with fine stone carving and glazed tile decoration.

Post-independence Thatta is rapidly growing and suffers from a severe lack of basic services. A heavy demand on the resources of the city, coupled with the general apathy on the part of the local administration, has resulted in the neglect of the city's historic center. The Makli monuments and other historic mosques, although of touristic value, are disregarded with nothing being done to preserve them.

Jam Nizamu-d Din or Jam Ninda, as he was affectionately known, ruled in Sindh's golden age as the leader of Samma-dynasty from 866 to 1461. The rise of Thatta as an important commercial and cultural center was directly related to his patronage and policies. The Samma-civilization contributed significantly to the evolution of the prevailing architectural style that can be classified as Sindhi-Islamic.

Jam Nizamu-d Din's death was followed by a war of succession carried out between the cousins, Jam Feroz and Jam Salahu-d Din. The Moghul army took the opportunity and Thatta came under the Arghun dynasty. The refined tastes of the Arghun and later the Tarkhan, who came from the Timurid cities of Khurasan and Central Asia enhanced Thatta's cultural and architectural landscape.

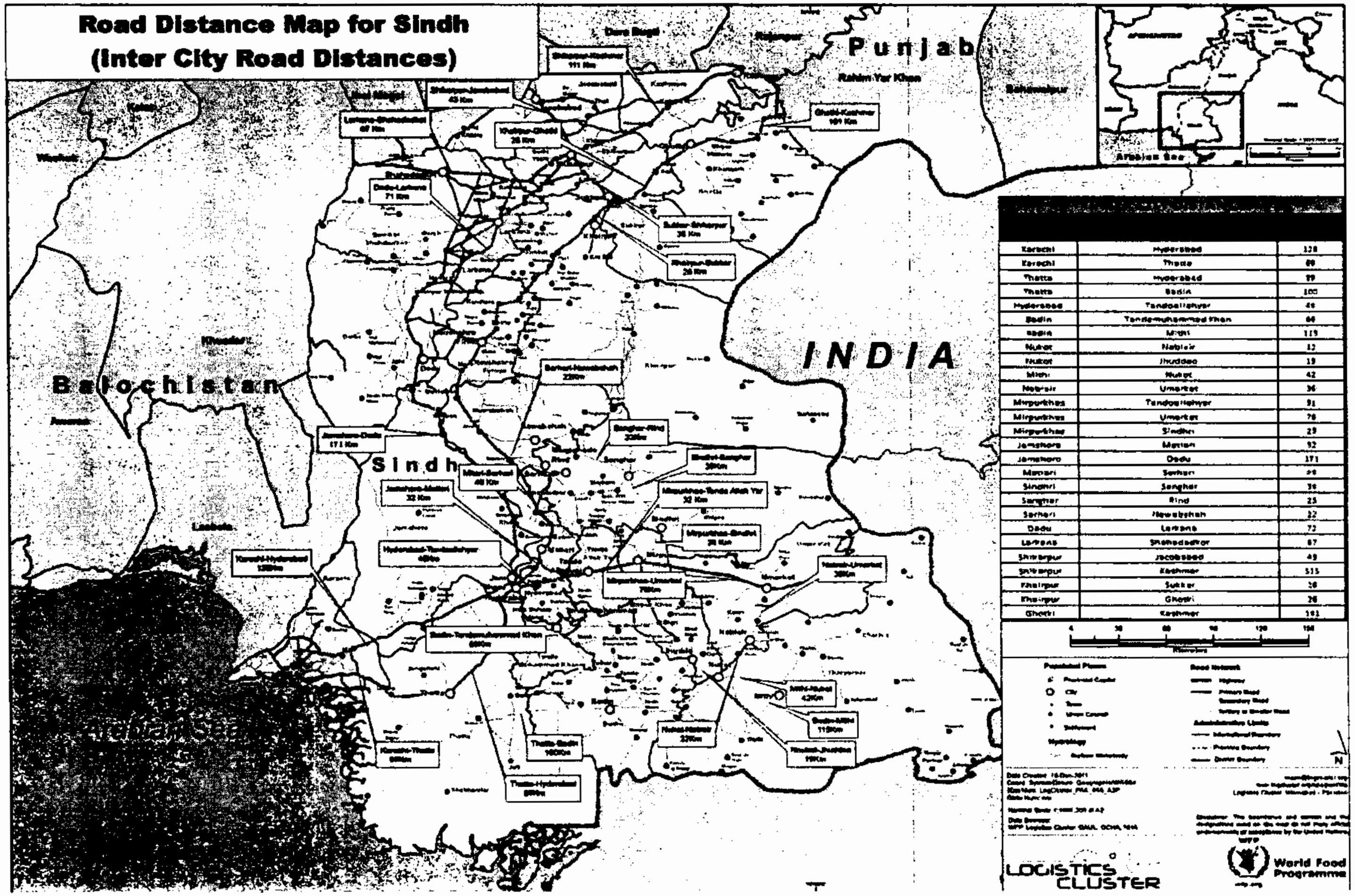



**Figure (1-7): Map of Sindh province (Districts)**

The reign of Mirza Isa Tarkhan's son Mirza Baki however, was one of persecution. He became reputed as one of the cruelest rulers of Sind. Thatta witnessed the cold-blooded murder of the Arghuns and the persecution of people claiming nobility, or religious or scholarly eminence. Mirza Jani Beg is known to have worked to restore what Mirza Baki had destroyed. However, when Emperor Akbar sent Nawab Khan Khanan to subjugate Thatta, Mirza Jani Beg is said to have removed the people to Kalan Kot, a fortified town built for such occasions, and ordered Thatta to be razed.

Mirza Jani Beg negotiated with Mughals, and was taken to Emperor Akbar court where he was confirmed as the governor of Thatta, and in 1591, Sindh was annexed by the Mughal Empire. Mughal rule lasted till 1736 when Thatta passed into the hands of the Kalhoras. Thatta's importance began to gradually decline as the Indus River began to shift away and in 1768, Hyderabad was made the capital of Sindh by the Talpur rulers.

The British annexed Sindh in 1843 and their immediate concern was to establish a communication network throughout Sindh. The municipality of Thatta was established by the British in 1854 and several vernacular and private schools, as well as a post office, a dispensary and a subordinate jail were built. The British established their residential areas away from the main city, on higher grounds, west of Makli necropolis. Thatta regained prosperity because of an improved communication infrastructure, though the city was never completely revived its prior importance as capital. The late nineteenth century saw a new class of merchants who took full advantage of the British need for services and goods. These merchants became rich and commissioned many buildings inspired by the elegant mansions constructed by the British throughout the British Empire

**Table (1-2): Districts Geographical Highlights**

| SPOKEN LANGUAGES | | LOCAL TRIBES | | | |
|---|---|---|---|---|---|
| **Sindhi** | 68% | Memon | Kahya | Soomro | Palijo |
| **Urdu** | 6% | Syed/Shah | Mirbahar/ Mallah | Jokhio | Jatoi |
| **Punjabi** | 3% | Bambhro | Abro | Jatt | Malkani |
| **Pashto** | 2% | Shoro | Brohi | Jalbani | Jakhro |
| **Baluchi** | 1% | Baran | Charan | Qazi | Pirzada |
| **Seraiki** | 5% | Kumbhar | Khuwaja | Khatri | Khombati |
| **Other** | 15% | Khaskheli | Abbasi | Kalhora | Khushik |
| | | Jamali | Umrani | Chang | Jamari |
| | | Sarki | Lashari | Magsi | Manganhar |

**Table (1-3): Districts Geographical Highlights**

| | |
|---|---|
| Area (sq: K.M) of Thatta: | 17355 |
| No of Talukas | 09 |
| No of UCs | 55 |
| Population | 1113194 |
| Male | 589341 |
| Female | 523853 |
| Literacy Rate (Male/Female) | 22.1 |
| No of Universities | Nil |
| No of Schools (Primary/Secondary) | 2498 |
| No of Newborn (0-12 months) | 43.8 |
| Population (1-14) | 53.2 |
| Population (15-49) | 53.2 |
| Population (60 and above) | 4.8 |
| Population Growth Rate | 2.26 |
| Density per sq km | 64.1 |
| Total fertility Rate | 5.2 |
| No of Taluka Hospital | 05 |
| No of RHCs | 09 |
| No of BHUs | 49 |
| Family Size | 5.2 |
| House Hold Size | 5.1 |

# Chapter 2: Energy Status in Pakistan

## 1-4- Energy Deficiency in Pakistan:

Electricity net consumption has increased from 47 billion kilowatt-hours (kWh) in 2000 to 74 billion kWh in 2010. According to the latest World Bank estimates, Pakistan had an electrification rate of 67 percent in 2010 [5].

Pakistan is a net importer of crude oil and refined products. Oil production in Pakistan has fluctuated between 55,000 to 70,000 barrels per day (bbl/d) since the 1990s.The country produced 62,000 bbl/d of oil in 2012. Oil consumption has grown over time and averaged

440,000 bbl/d in 2012. Pakistan currently has six oil refineries with a total crude oil distillation capacity of 186,000 bbl/d, which run mostly on imported crude oil.

The Oil and Gas Development Company Limited (OGDCL) dominates Pakistan's oil industry. The Pakistani government owns a majority share in OGDCL, with the remainder owned by the public. BP and Eni are the leading foreign oil firms operating in Pakistan.

Dry natural gas production has grown by more than 70 percent over the past decade from 809 billion cubic feet (Bcf) in 2002 to 1,383 Bcf in 2011, all of which was domestically consumed. Despite the growth of natural gas production, the country's demand is still constrained. Pakistan currently does not import natural gas because it lacks the infrastructure. The country plans to build a liquefied natural gas (LNG) regasification plant to relieve some pressure from its growing demand, although development efforts to build a terminal have moved slowly.

Pakistan's main natural gas producers include Pakistan Petroleum Ltd. (PPL) and OGDCL, as well as international companies such as BP, ENI, OMV, and BHP. The leading gas distributors are Sui Southern Gas Company (SSGC) and Sui Northern Gas Pipelines (SNGP).

The Pakistani government has stated that overcoming the energy crisis in the country is a primary goal. Potential policy options include increasing imports of energy efficient items such as hybrid cars and LED bulbs, resolving the circular debt issue in the energy industry, and increasing production and imports of alternative fuel sources.

The demand for energy has increased in tremendous proportions in the last few decades in Pakistan; the same is expected to increase further in the coming years. At present; the gap between supply and demand stands at 4000MW. The primary sources of energy available in Pakistan are oil, natural gas, hydro and nuclear Power. At present oil accounts for approximately 45% of total commercial energy supply. The share of natural gas is 34% while that of hydel power remains roughly at 15%. The increase in cost of fossil fuel and the various environmental problems of large scale power generation have lead to increased appreciation of the potential of electricity generation from non-conventional sources. This has provided the planners and economists to find out other low cost energy resources.

Wind and Solar energies are the possible clean and low cost renewable resources available in the country. The potential, for the use of alternative technologies, has never been fully explored in Pakistan. Wind power provides opportunity to reduce dependence on imported fossil fuel and at the same time expands the power supply capacity to remote locations where grid expansion is not practical.

As part of Energy Security Action plan 2006, the Honorable President and the Prime Minister of Pakistan have tasked the Alternative Energy Development Board to have share of at least

5% of total National On-Grid Power generation capacity through wind energy by year 2030 (production of 9,700MW wind power by 2030).

Recently conducted survey of Wind Power Potential along coastal areas of the country by Pakistan Meteorological Department (PMD), indicates that a potential exists for harvesting wind energy using currently available technologies, especially along Sindh coast.

According to official documents, the wind power potential in Pakistan that has been identified in Sindh and Baluchistan is more than 50,000 MW while Punjab has potential of producing almost 1,000 MW.

Sindh has the 2nd largest economy in Pakistan. Endowed with coastal access, Sindh is a major centre of economic activity in Pakistan and has a highly diversified economy ranging from heavy industry and finance centered in and around Karachi to a substantial agricultural base along the Indus. Manufacturing includes machine products, cement, plastics, and various other goods. Historically, Sindh's contribution to Pakistan's GDP has been more than 30% and generates almost 30% of the total national tax revenue.

## 1-5- Wind Energy in Sindh

Pakistan is fortunate to have something many other countries do not, which is high wind speeds near major centers. Near Islamabad, the wind speed is anywhere from 6.2 to 7.4 meters per second (between 13.8 and 16.5 miles per hour). Near Karachi, the range is between 6.2 and 6.9 (between 13.8 and 15.4 miles per hour). In addition to Karachi and Islamabad, there are other areas in Pakistan that receive a significant amount of wind [6] [7].

In only the Baluchistan and Sindh provinces, sufficient wind exists to power every coastal village in the country. There also exists a corridor between Gharo and Keti Bandar that alone could produce between 40,000 and 50,000 megawatts of electricity.

Given this surplus potential, Pakistan has much to offer with regards to wind energy. In recent years, the government has completed several projects to demonstrate that wind energy is viable in the country. Three projects of 50MW have already achieved COD in the Thatta District. In Sindh alone, hundreds of micro turbines have been installed to power thousand homes. The Alternative Energy Development Board (AEDB) has also acquired more than 20,000 acres for sub-letting to potential investors for installing more wind parks [8].

In addition to high wind speeds near major centers as well as the Gharo and Keti Bandar corridor, Pakistan is also very fortunate to have many rivers and lakes. Wind turbines that are situated in or near water enjoy an uninterrupted flow of wind, which virtually guarantees that power will be available all the time. Within towns and cities, wind speeds can often change quickly due to the presence of buildings and other structures, which can damage wind turbines. In addition, many people do not wish for turbines to be sited near cities because of noise, though these problems are often exaggerated. Wind turbines make less noise than an office and people comfortably carry on conversations while standing near them.

All the international agencies and investors require bankable long term wind data to develop feasibility studies. AEDB shared the wind data collected by Pakistan Meteorological Department (PMD) with private investors/project developers, but they raised reservations that the data had not been collected according to standard international procedures for collecting wind data.

Therefore, in order to facilitate the growth of wind energy and to minimize the uncertainties related to wind data, AEDB along with UNDP under the GEF funded Wind Energy Program, has started to install wind measuring wind masts in the potential wind energy areas of Pakistan. In the first phase of this project AEDB and UNDP (WEP) are installing five (5) masts in the Gharo-Keti Bandar Wind Corridor (Figure below) identified by "AEDB" and "PMD".

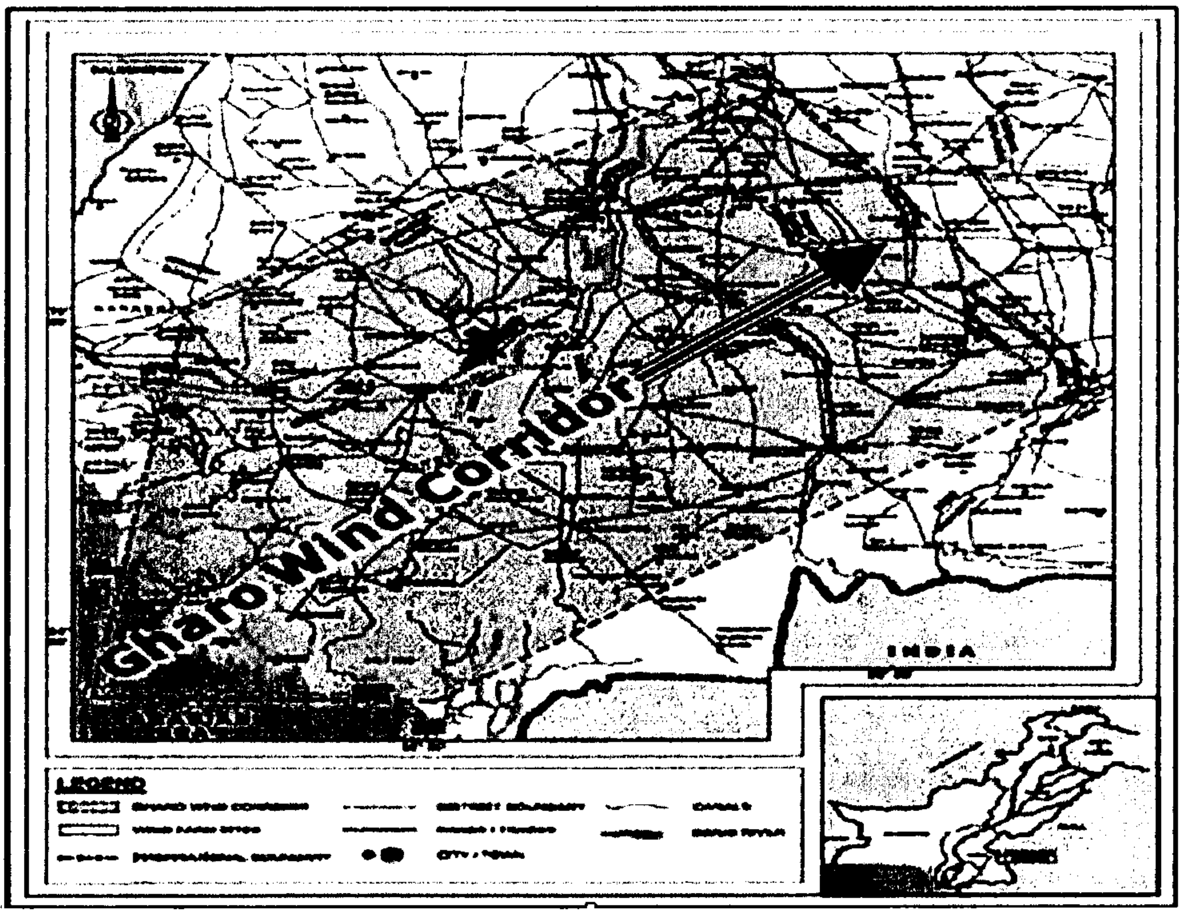



**Figure 1-8: Gharo-Keti Bandar Wind Corridor**

Out of five masts, four wind measuring masts have been installed in the said corridor. This report deals with the wind data analysis of three mast sites and their comparison with each other. We understand the wind potential was good enough to establish wind farms to produce significant electricity power.

Figure below shows the location of the four AEDB UNDP (WEP) masts, indicated in red triangles. A detailed description of each mast site is presented in later parts of this report. Apart from publishing the data analysis reports, AEDB and UNDP will provide wind data of these masts free of charge to interested organizations and individuals for the development of wind energy in the country.

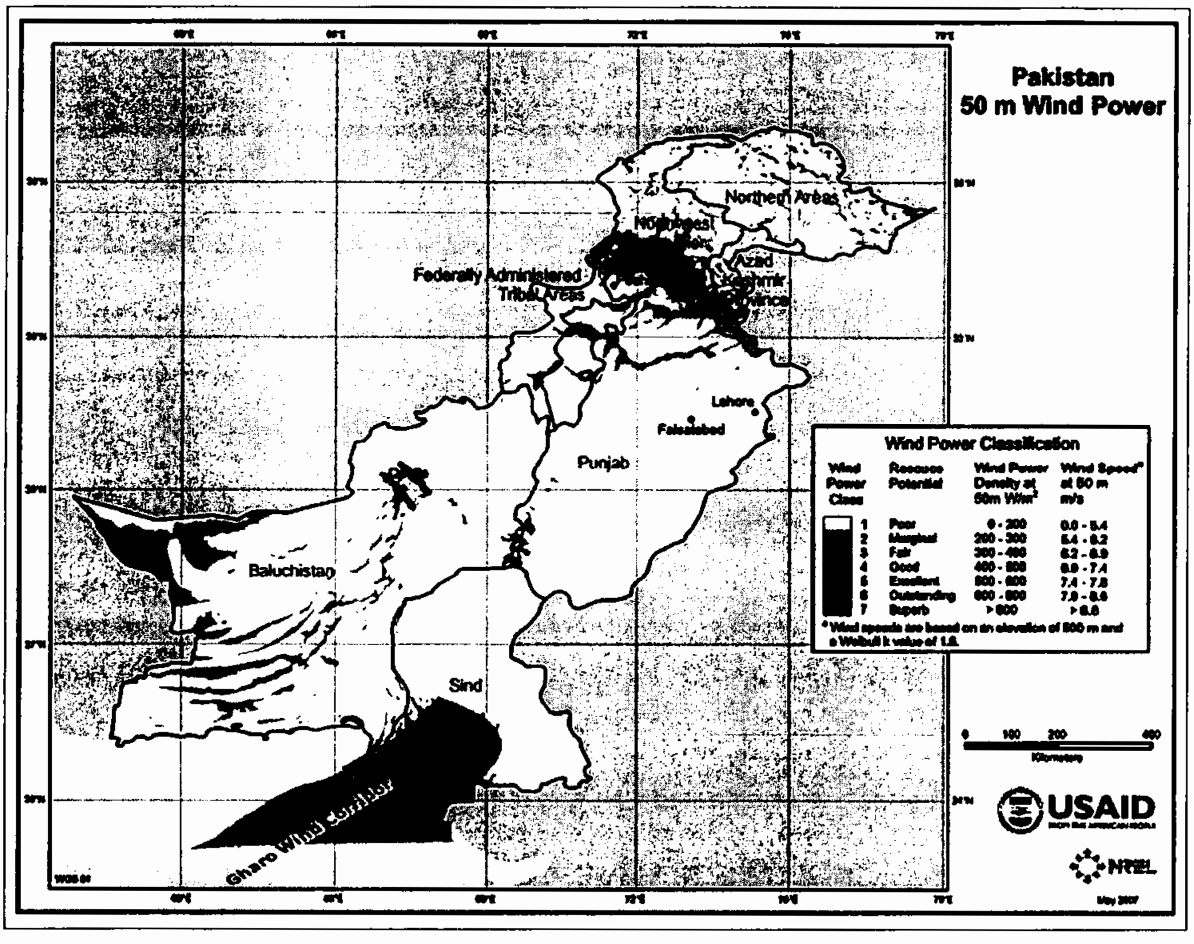



**Figure 1-9: Wind map of Pakistan developed by National Renewable Energy Laboratory (NREL), USA in collaboration with USAID**

The coastline in the southern parts in the Sindh Province near Karachi also enjoys high wind speeds, specially the areas of Southeast, from Hyderabad to Gharo in the Southern Indus valley and the Coastal areas south of Karachi. Other spots will be the Hills and ridges between Karachi and Hyderabad.

In all, estimated potential of Wind Power has been put at 131,800 MW by USAID. The estimate is based in numerical models and is a bold assumption.

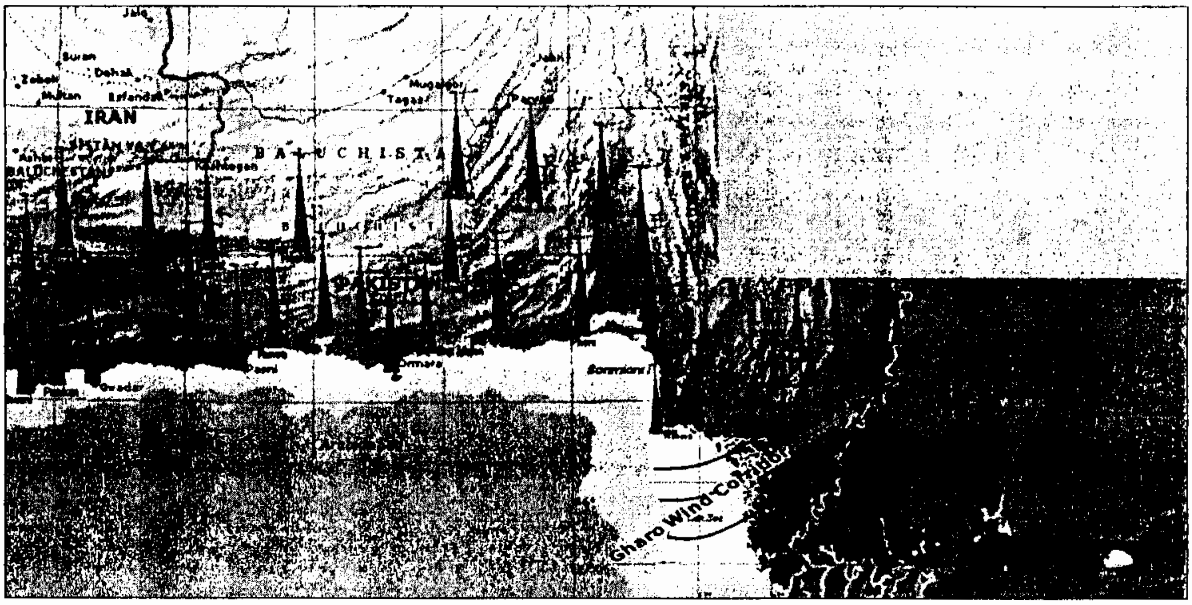



**Figure1-10: Location of Wind mast of Pakistan for Development of benchmark wind speed for Gharo**

The local Meteorological Department of Pakistan and the Alternative Energy Development board have also given their estimates and they put the potential in Sindh alone at 43,871 MW. After making Land & Infrastructure studies, they estimate that 11000 MW is very much possible and should be achieved given present conditions.

Pakistan made a small contribution to worldwide wind energy capacity in 2008 by establishing 6 MW wind power project in Jhimpir, Sindh. Total capacity installed at the end of 2012 was 106 MW from two 50 MW wind farm and the third Wind farm of 50MW has been made operational in the first quarter of 2015.

In recent years, the government has completed several small projects to demonstrate that wind energy is viable in the country. In Mirpur Sakro, 85 micro turbines have been installed to power 356 homes. In Kund Malir, 40 micro and small turbines have been installed, which power 111 homes.

# CHAPTER II:

## Project Overview

4

## 2-1- Introduction

Iran-Pak Wind Power Pvt Ltd intends to setup a 50MW Wind Farm in Thatta District of Sindh Province. Sindh Board of Investment has committed providing facilitation to Iran-Pak Wind Power (Pvt) Ltd through a memorandum of understanding (MOU) signed between the parties on the occasion of the Sindh Investment Conference held at Karachi.

This is the first time that the Sindh Government has directly committed to assisting a consortium of foreign and local investors.

On behalf of Iran-Pak Wind Power, Khurram Sayeed, Chief Executive and Ehsan Nadjafi and Reza Allamie signed the MOU while Younus Dagha, Secretary Sindh Board of Investment, signed on behalf of the Sindh Government.

The MOU was signed in the presence of Syed Qaim Ali Shah, Chief Minister of Sindh and Chairman Sindh Board of Investment. Also present on the occasion were Mohammad Hussain Zamani, Consul General of Iran, Rauf Siddiqui, Minister Industries Sindh Government, Zubair Motiwala, Adviser to Chief Minister on Investment and Tariq Sayeed, Chairman Planet Group.

The project involves construction, erection and operation of 50 MW of wind generation capacity, on allocated land of 1,250 acres of Deh Kohistan 7/3 Tapo Jungshahi Taluka Thatta at the wind corridor of Gharo- Jhimpir, Thatta District. The project will sell electricity to the national grid under 20-year off take contract.

### 2-1-1- Scope of project

The scope of this project (50 MW wind Farm in district Thatta, Sindh Province, Pakistan) will be the following 7 phases:

Phase 1 - Feasibility Study and Pre-design of Sites (Engineering service)

Phase 2 – Selection of EPC (or EPCF) Contractor

Phase 3 – Implementation & Preparation of site

Phase 4 – Shipping and delivery to the site

Phase 5 – Installation and Pre-commissioning

Phase 6 – Operation and Maintenance (during the guarantee period)

Phase 7 – Documentation & Training of Staff

## 2-1-2- Project goals

The purpose of the Iran-Pak wind power is to utilize wind resources for electricity generation through the construction of a wind farm with a total capacity of 50 MW and to deliver the electricity generated from the project to NTDC through CPPA on behalf of WAPDA distribution companies. By replacing the electricity supplied by the WAPDA grid, which is heavily dominated by fossil fuel fired power plants, with electricity generated from wind power; the proposed project activity will achieve obvious GHG emission reductions by avoiding $CO_2$ emissions.

In summary the project goals are:

- ✓ Construction, erection and operation of 50 MW of wind power plant in proposed wind farm.
- ✓ Sell electricity to the national grid.

## 2-2- History of the project

Pakistan has been working to develop its renewable power sector especially to produce the electricity. Since , power shortages have plagued the country recently. In 2003, the government set up Alternative Energy Development Board (AEDB) in order to help the country reach a target of 10% of energy coming from renewable sources. Wind; specifically has been pursued, with the government targeting the production of 9,700 MW by 2030.

One of the key means to achieving these objectives has been by working to attract private sector investment into the development of renewable generating capacity

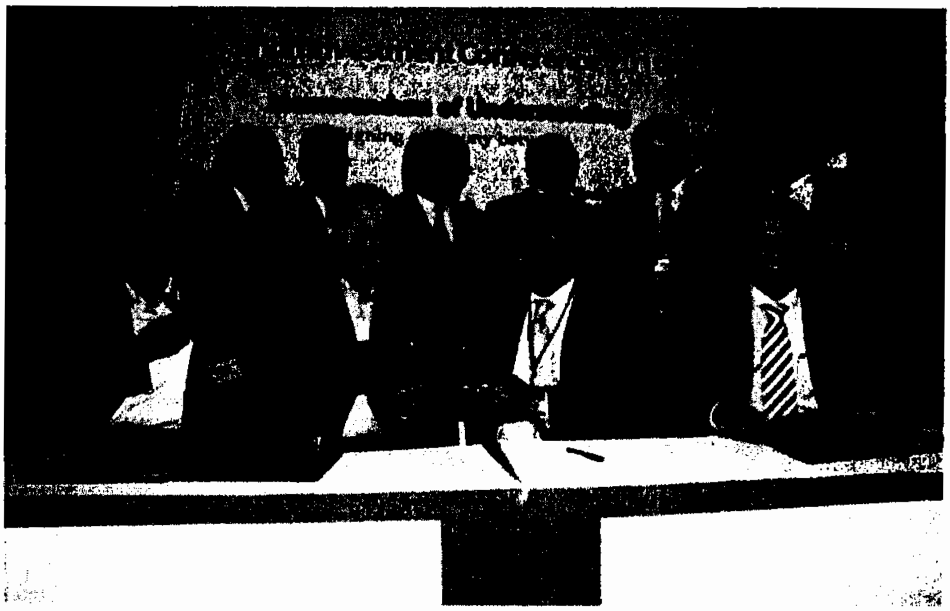
SUNIR Co., one of the largest water and power industries equipment and services export companies of Iran showed interest to setup a 50 MW wind farm in Pakistan on a Joint-Venture basis along with Planet Group back in 2007. (Also SUNIR Co is already active in Pakistan as an EPC contractor for the Iran-Gwadar power transmission line and is also winners of the EPC tender for laying the Daddu-Khuzdar transmission line. They have considerable experience working with WAPDA & NTDC.)

SUNIR Co and Planet Group decided to cooperate to install a 50 MW wind power plant in Pakistan and signed the first MOU in Feb 2007. A follow up MOM was signed during the visit of the Iranian Energy Minister, Eng Parviz Fattah on 31st Dec 2008. Also Mr. Raja Pervez Ashraf, the then Minister of Water & Power and H.E. Mr. Mashalla Shakeri, the Ambassador of Iran in Pakistan were present during signing ceremony. A second follow up MOM was signed with Planet Group in (July 2009).

As per the MOU, on 15th December 2009, both companies (partners) jointly incorporated a company under the name of **"IRAN – PAK WIND POWER (Pvt.) LIMITED (IPWPPL)"** with equal shareholding to execute and invest in developing a 50MW wind farm in Pakistan with the specific location of the farm being dependent upon land allocations by AEDB.

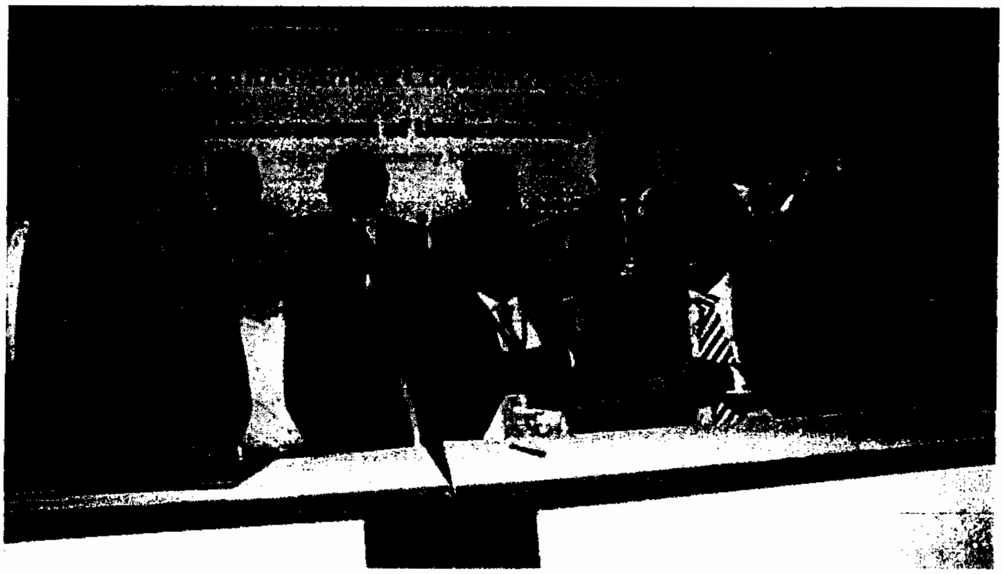
### 2-2-1- Progress of the land allotment

Under the Renewable Energy Policy, the AEDB in Islamabad was to facilitate the allotment of Land for the Wind Farm but unfortunately they could not do anything. Therefore, IPWPPL's Pakistani partners M/s Planet Energy Pvt Ltd (Planet Group) conducted its own site studies and directly approached the Chief Minister Sindh for allocation of the land as the project is located in Sindh Province. Finally, an MOU with Sindh Board of Investment was signed on April 10th 2010 and as per the terms of the said MOU, the Planet Energy identified, surveyed and IPWPPL approved the land near "Janabad" Thatta District, within the stipulated time and on their part SBI was to complete the allotment proceedings after getting necessary approvals from the Board of Revenue (BOR).

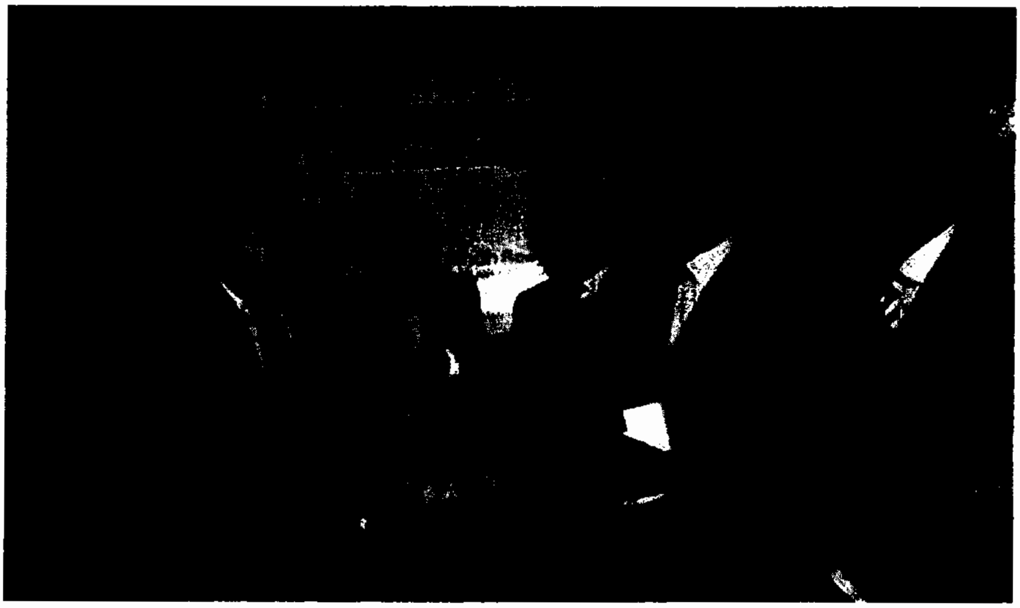


**Picture taken on the occasion of MOU Signing Ceremony between Iran-Pak Wind Power (Pvt) Ltd and Sindh Board of Investment at the Sindh Investment Conference 2010 shows, Mr. Khurram Sayeed, Chief Executive, Mr. Ehsan Nadjafi, Director and Mr. Reza Allamie, Director Iran-Pak Wind Power and Member Board of Directors, Sunir Co. exchanging the MOU with Mr. Younus Dagha, Secretary SBOI. Also witnessing the ceremony were Sindh Chief Minister and Chairman SBOI Syed Qaim Ali Shah, Minister for Industries, Mr. Rauf Siddiqui, the Consul General of Iran Mr. Mhd. Hussain Zamani, Advisor to C.M. Mr. Zubair Motiwala, Chairman, Planet Group Mr. Tariq Sayeed and Mr. Ahmed Fassihi, Commercial Attache of Iran.**

**Fig. 2-1: Pictures of Signing Ceremony between IRAN – PAK WIND POWER (Pvt.) LIMITED and Sindh Board of Investment at the Sindh Investment Conference 2010**



**Picture taken on the occasion of MOU Signing Ceremony between Iran-Pak Wind Power (Pvt) Ltd and Sindh Board of Investment at the Sindh Investment Conference 2010, shows Mr. Reza Allamie, Mr. Ehsan Nadjafi, Directors and Mr. Khurram Sayeed, Chief Executive exchanging the MOU with Mr. Younus Dagha, Secretary SBOI. Also witnessing the ceremony were Sindh Chief Minister and Chairman SBOI Syed Qaim Ali Shah, Minister for Industries, Mr. Rauf Siddiqui, the Consul General of Iran Mr. Mhd. Hussain Zamani, Advisor to C.M. Mr. Zubair Motiwala and Chairman, Planet Group Mr. Tariq Sayeed.**



**Picture shows Mr. Reza Allamie, Director Iran-Pak Wind Power (Pvt) Ltd and Member Board of Directors, Sunir Co presenting a gift to Syed Qaim Ali Shah, Chief Minister Sindh. Also seen are Mr. Khurram Sayeed (right), Chief Executive IPWPPL, Mr. Mhd. Hussain Zamani, (Middle) Consul General of Iran and Mr. Rauf Siddiqui, Minister of Industries, Government of Sindh.**

**Fig. 2-1: continued**

On 2nd February 2011, the allotment of land was done and , IPWPPL received the letter for the same from the Chief Minister Sindh.

Finally on 30th October 2013, the land lease was signed between IPWPPL and Thatta District Administration. The land is leased for a period of 30 years.

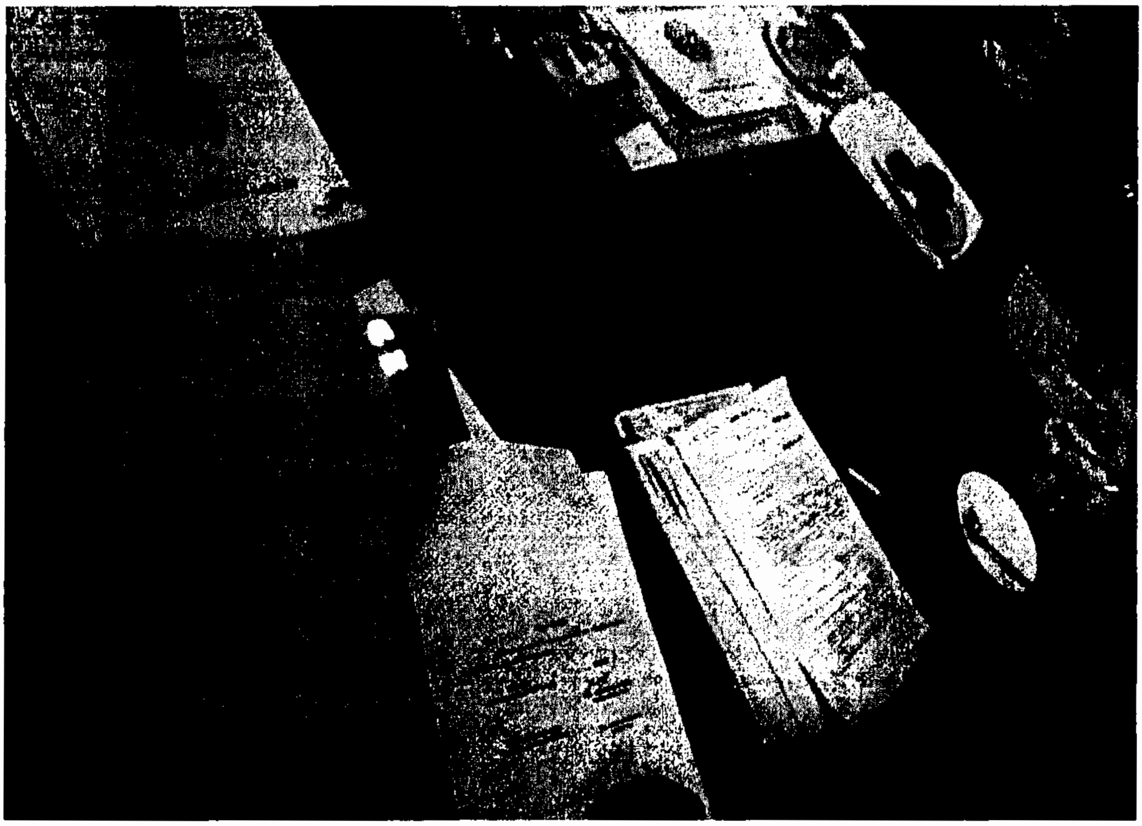


**Fig. 2-2: Pictures of Signing the allotment of the land leasing between IRAN – PAK WIND POWER (Pvt.) LIMITED and Thatta District administration**

## 2-2-2- Location and Physical Environment

Iran-Pak wind power site is located about 20 km from Jhimpir in Thatta District of Sindh province in Pakistan, 100 km North-East of Karachi. The land; in which the proposed wind farm is to be located is 1,250 acres at Deh Kohistan, 7/3 Tapo Jungshahi Taluka Thatta at the wind corridor in Jhimpir, Thatta District with the following coordinates of table 2-1 (also see figure 2-3 and 2-4).

**Table 2-1: The 50 MW Iran – Pak Wind Power Plant Site Coordinates**

| Points | East | North | Elevation (m) |
|---|---|---|---|
| **a** | 67° 53' 33.47" | 24° 55' 33.94" | 50.9 |
| **b** | 67° 53' 36.16" | 24° 55' 24.68" | 50.1 |
| **c** | 67° 53' 54.68" | 24° 53' 50.88" | 56.5 |
| **d** | 67° 53' 10.38" | 24° 53' 26.96" | 43.4 |
| **e** | 67° 52' 33.26" | 24° 54' 48.27" | 47.8 |
| **Reference Point 1** | 67° 53' 29.44" | 24° 55' 30.90" | 51.4 |
| **Reference Point 2** | 67° 53' 27.66" | 24° 55' 28.75" | 51.6 |
| **Total Area 1249.99 acres** | | | |

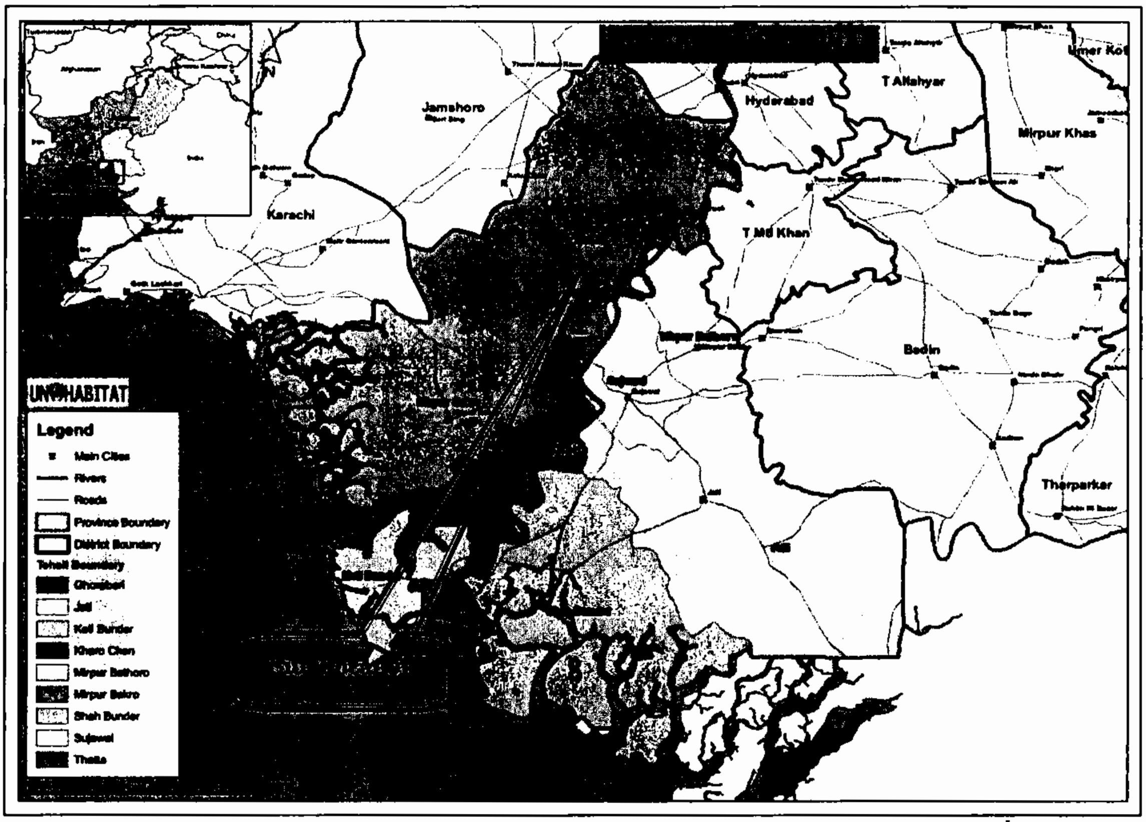



**Figure 2-3: Site location on Thatta District map**

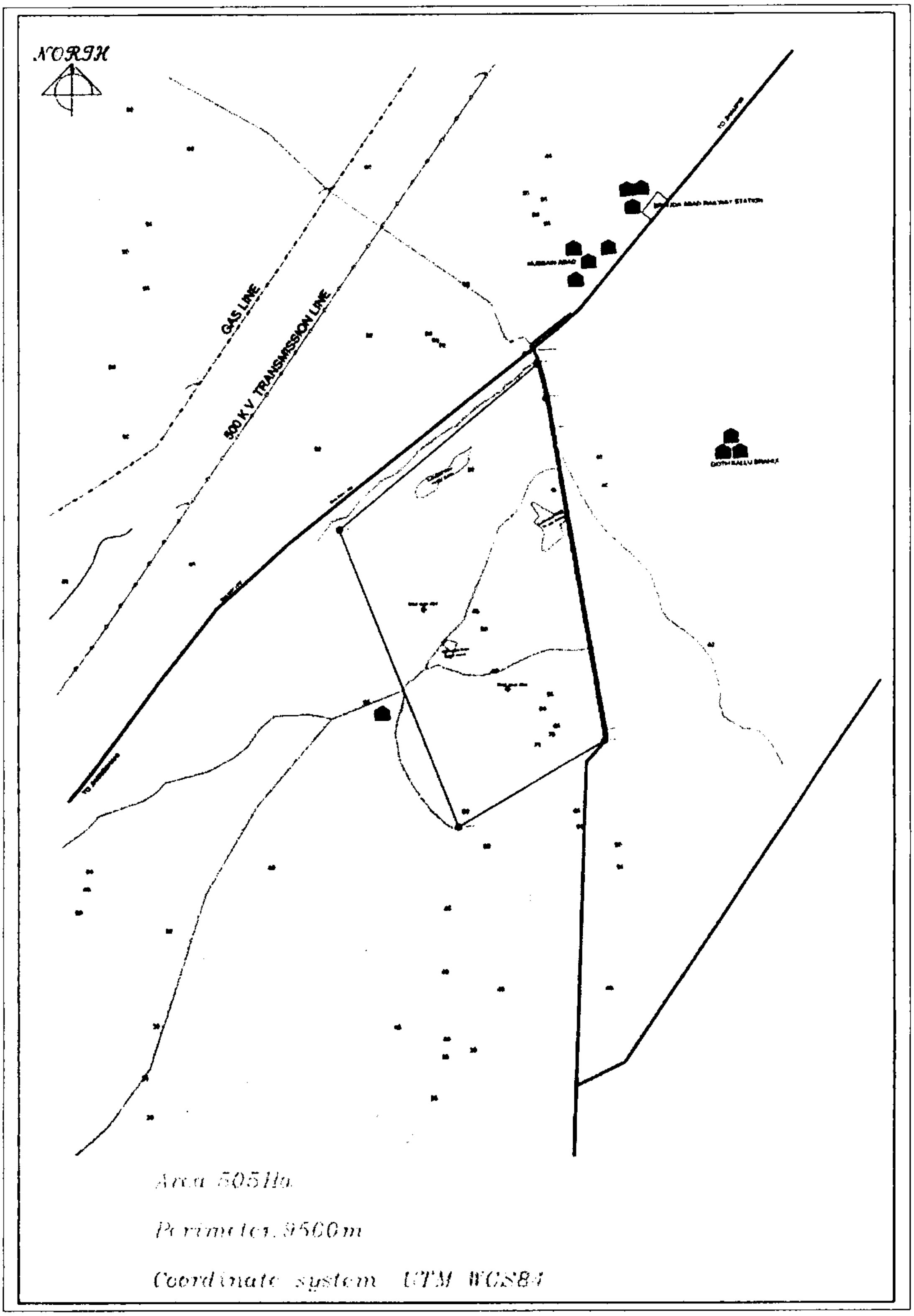



**Fig. 2-4: map of Iran - Pak wind farm**

Met masts are the primary tool for wind data gathering and specification of wind regime and wind directions. In this project two wind masts were installed. The table 2-2 and Figure 2-5 illustrate the wind masts locations.

**Table 2-2: wind masts locations**

| Wind mast | Latitude | Longitude | Site Elevation |
|---|---|---|---|
| No. 1 | 024° 54.829' N | 067° 53.206' E | 47 m |
| No. 2 | 024° 53.836' N | 067° 53.641' E | 87 m |

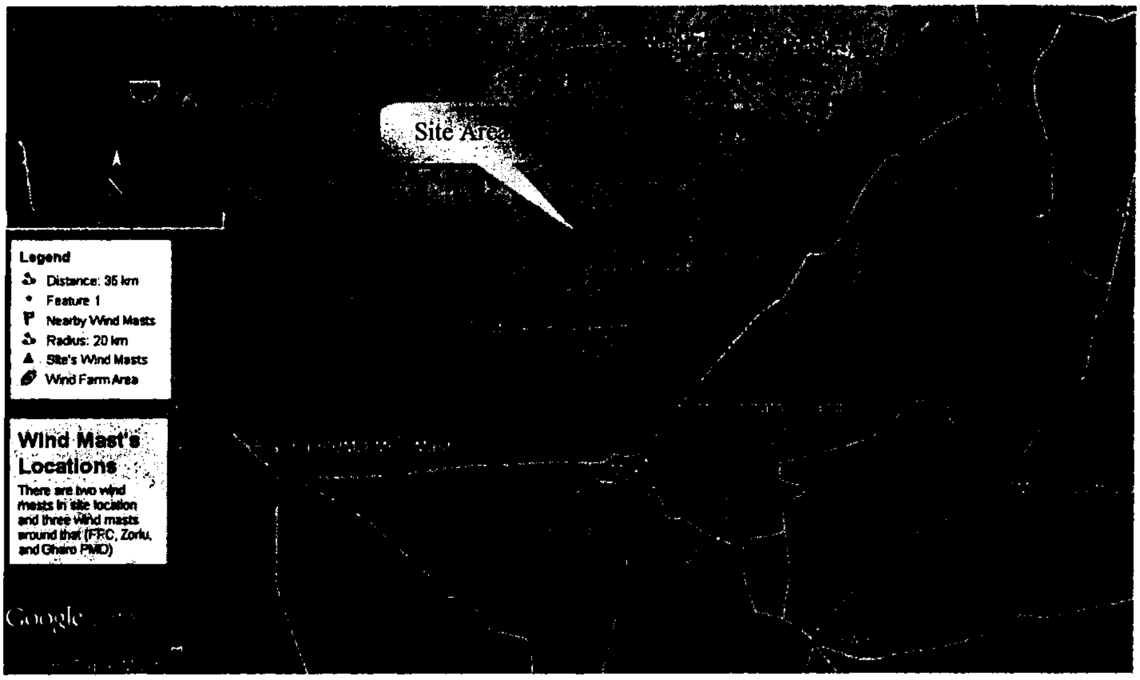



**Figure 2-5: Met-mast locations on site and site neighborhood**

The physical environment in which the proposed wind farm is to be located will be characterized as follow.

The land is flat and barren in most of site area except some little patches at the north of site which have dry farming at rainy seasons. The plant cover of site is sparse and scattered across the site and includes shrubs and herbs which are almost Halophytic. There is no reserved forest site or sanctuary located within the project land area that needs to be demolished. The nearest wild life sanctuary to the site, is Keenjhar lake at about 10 km from the site, that also is known as a Ramsar convention site.

The proposed wind site area is covered under the Eocene Sedimentary and Unconsolidated Surfical Deposits of silt, sand and gravel geologic formations belonging to the Tertiary and Quaternary ages respectively.

The recently developed (after the October 2005 earthquake) seismic zone map of Pakistan has divided the country into four seismic zones ranging in term of major, moderate, minor and negligible zones with respect to ground acceleration values. Under this zoning the wind site area is included under the moderate hazard zone with minor damaging affect. There is no noticeable fault lines present in the Wind site area, except for the northwest trending fault in the valley west of Jhimpir called 8 Jhimpir's fault which is far from the wind site. This fault is probably active, since a number of epicenters are located on this fault trace.

The soil of wind farm site is also classified as mainly loamy saline and part gravely. The soil is similar in nature to the soil of Gharo area. However the soils in some patches may be different with a slight salinity (between 4dSm-1 to 8dSm-1). This type of soil is usually neutral (with a pH of 6.6 to 7.3), and moderately calcareous (with CaCO content in the range of 3% to 15%). The remaining portion of the land consists of severely saline area incapable of agriculture.

The land area of wind farm site consists of complex agriculturally non-productive (rock) land and some poor grazing (gravely land), Class VIII, VII. This area is also incapable of agriculture as the soil underneath mainly consists of rock and gravel. Some part of this land is capable of agriculture being fed by torrent water whereas the remaining portion comprises of grazing area (capable of growing grass and shrubs).

The land use of the wind farm is based on the nature and characteristics of the soil classified in these areas as well as proximity to the surface or ground water sources. Wind farm site consists of areas that have variable land use. The rocky and gravely soil formation devoid the major land area for any agricultural use. However the land area is also influenced by perennial grazing consisting of short grasses shrubs and scrubs.

A few patches of cultivated land also exist in the close vicinity and surroundings of the wind farm site which comes under the torrent water restricted cropping. This area is dependent on residual moisture from torrent overflows

It was observed that the area is highly underdeveloped and there is no industrialization in the area thus the baseline emissions are very low. There are no well developed drainage systems in the area. The conventional source of fuel is wood or kerosene oil. Nearest settlements of human habitats are located 3 to 5 Km away from the land.

The site area generally includes 3 habitats as follows; Flat plains, Dry stream beds and Hillocks/foot hills.

The flat plains habitat occupies a major portion of the project area. The flat plains are mainly gravely in nature while in depressions (where rain water accumulates), vegetation was observed. A total of 22 plant species belonging to 16 families have been identified within the site area. The faunal attributes found within this typical habitat were Ratel/Honey badger (*Mellivora capensis*), Asiatic jackal (*Canis aureus*), Common red fox (*Vulpes vulpes pusilla*), Indian fox (*Vulpes bengalensis*), Indian porcupine (*Hystrix indica*), Houbara bustard and other raptor species, etc.

Dry stream bed is also an important habitat observed in the site area. The stream beds are ephemeral in nature and are fed only through rain water. A total of 37 floral species have been identified within this habitat of which the most frequently occurring species include *Acacia jacquemontii*, *Aerva javanica, Cressa cretica* and *Dactyloctenium aegyptium*. A number of common wildlife species were also recorded from the habitat including Ashy crowned Finch Lark (*Eremopterix grisea*), Blue cheeked Beeeater (*Merops superciliosus*), Common Babbler (*Turdoides caudatus*), Asiatic Jackal (*Canis aureus*), Indian Grey Mongoose (*Herpestes edwardsi*), Gerbils, rats and mouse species and etc.

Small hills are located towards the south and southeast sides of proposed wind farm. The hillocks spans from center to south direction. A total 13 floral species belonging to 14 families has been identified from this habitat of which the most frequently occurring species include *Prosopis cineraria, Salvadora oleoides* and *Indigofera oblongifolia*. Some of wildlife species found within the habitat are Yellow bellied Prinia (*Prinia flaviventris*), Wood Sandpiper (*Tringa glareola*), Whiskered Tern (*Chlidonias hybridus*), Little Green Bee-eater (*Merops orientalis*), Common Moorhen (*Gallinula chloropus*) and Indian Fringed- toed Sand Lizard (*Acanthodactylus cantoris*) and etc.

According to physical survey and site visit, there are no houses and settlement center on the project land. So according to this subject, it does not need any movement plan at site area or shifting the people living near the site. Also this project has a plan to give the adjacent population centers jobs as per their skill level or employ them as labors/ security guards if totally unskilled. The nearest villages; Barudabad and Burfat village is located at about 3 and 9 km north east and south west of the project land respectively.

There are very negligible impacts on the noise, air and water quality during the construction phase of project which is temporary and will be finished by completion of this phase. Furthermore the nearest population center has distance of about more than 5 km from the site area and can't be affected by the project activities. The project site is located in remote area with very little social and commercial activity, which minimizes the long term impacts on the social side. In another aspect commissioning the project can have positive effects on development of the region by producing the electricity and prepare the way for promotion.

Wind Power Project is a green energy project and, therefore, there is no major impact of the project on the environment of the site. Air quality of the area may be disturbed only during construction phase of the project. There is no damage foreseen to the surface water and ground water conditions of the area. No resettlement of human habitat is required. There is no archeological site present in the location of project.

It is observed from the international practices around the world that birds get used to such heighted structures like any other electrical tower, aviation towers e.tc and ratio of bird hit with turbines is very low. Also the nearest important habitat of birds (Kinjhar lake) is located far from the site (in distance of about 10 Km) and seems that the turbine operation during the day have little effect on their flight rout. Moreover the sign and warning utilities are installed on the different parts of turbine thus decreasing chances of bird collision.

Noise impacts will be less than 70 db (A) which are within the range as per National Environmental Quality Standards (NEQs) of Pakistan. No exceeds of shadow from the permissible limits occurs at site area.

The environmental disturbance normally associated with construction activities will be minimized through an Environment Management Plan (EMP), implementation of which will continue during project operation and which includes monitoring arrangements. The project has no carbon, sulfur, nitrogen emissions; nor their oxides, thus not a threat to the environment.

It is concluded that the project will be a positive development in the area and improve the socio economic conditions of area through generation of employment opportunities and opening of ways for the development of this area.

There are no permanent negative environmental impacts of the project, rather it is a green energy project and contribute in environmental sustainability of the area. The project will also help to promote renewable energy in Pakistan and meeting energy supply demand of the country.

The Figure 2-6 demonstrates a typical view of the region's physical environment.

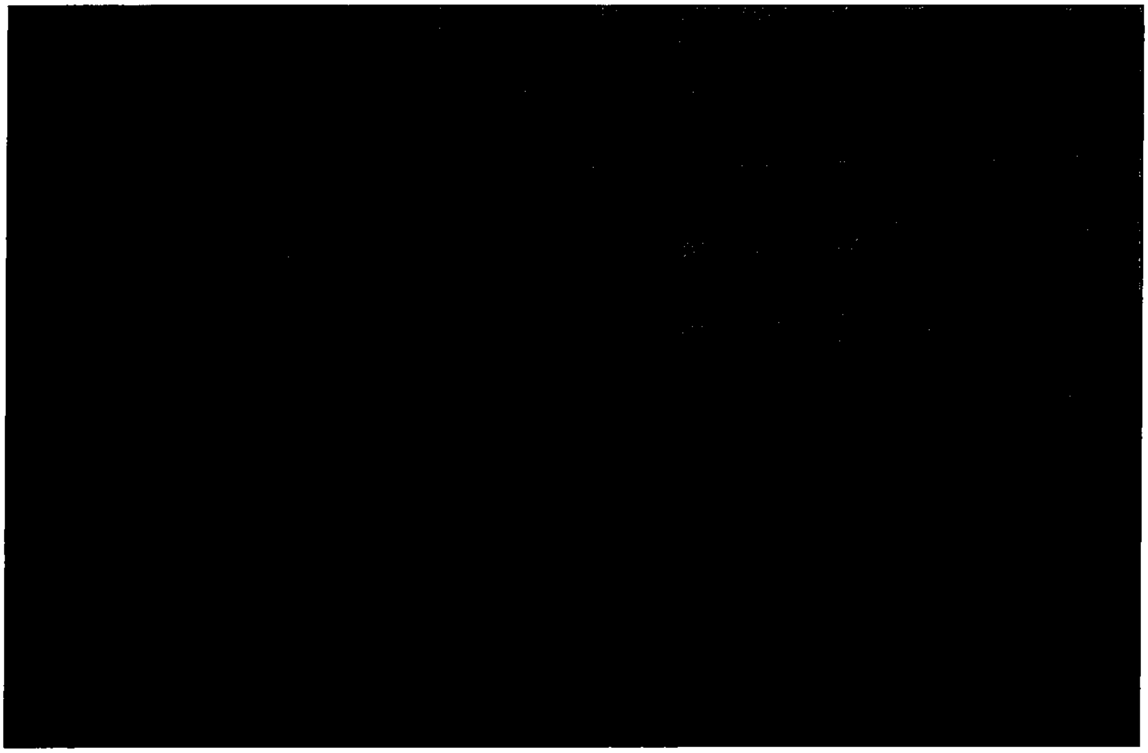
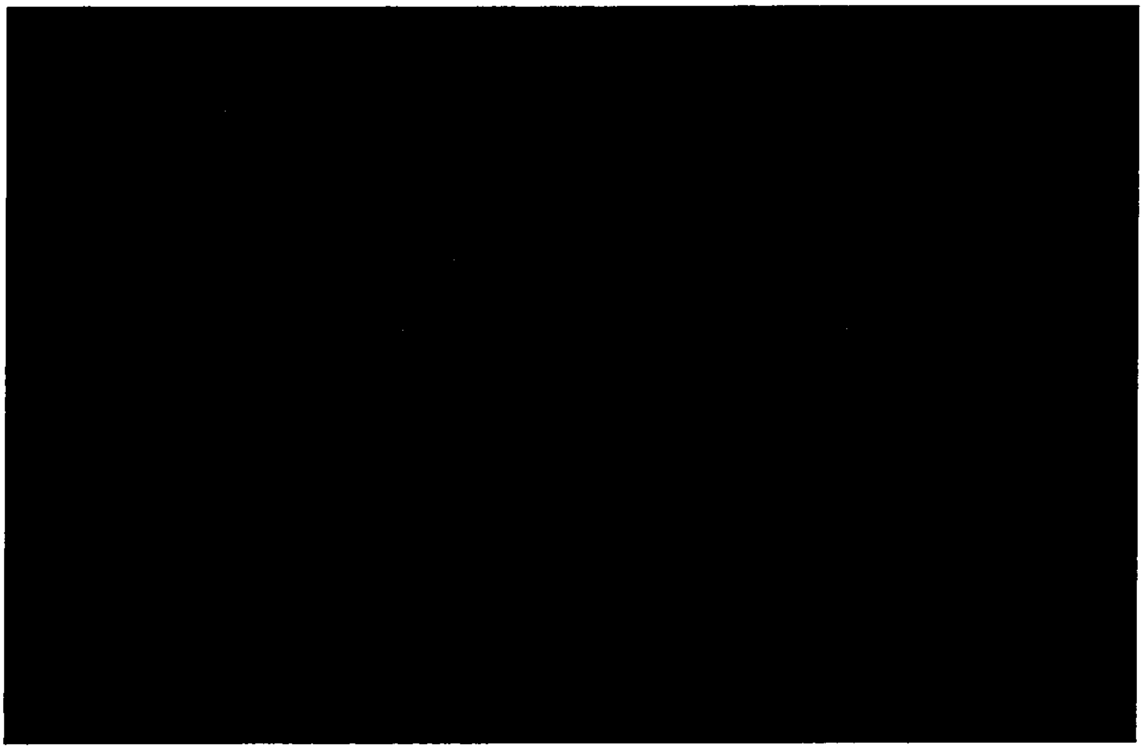
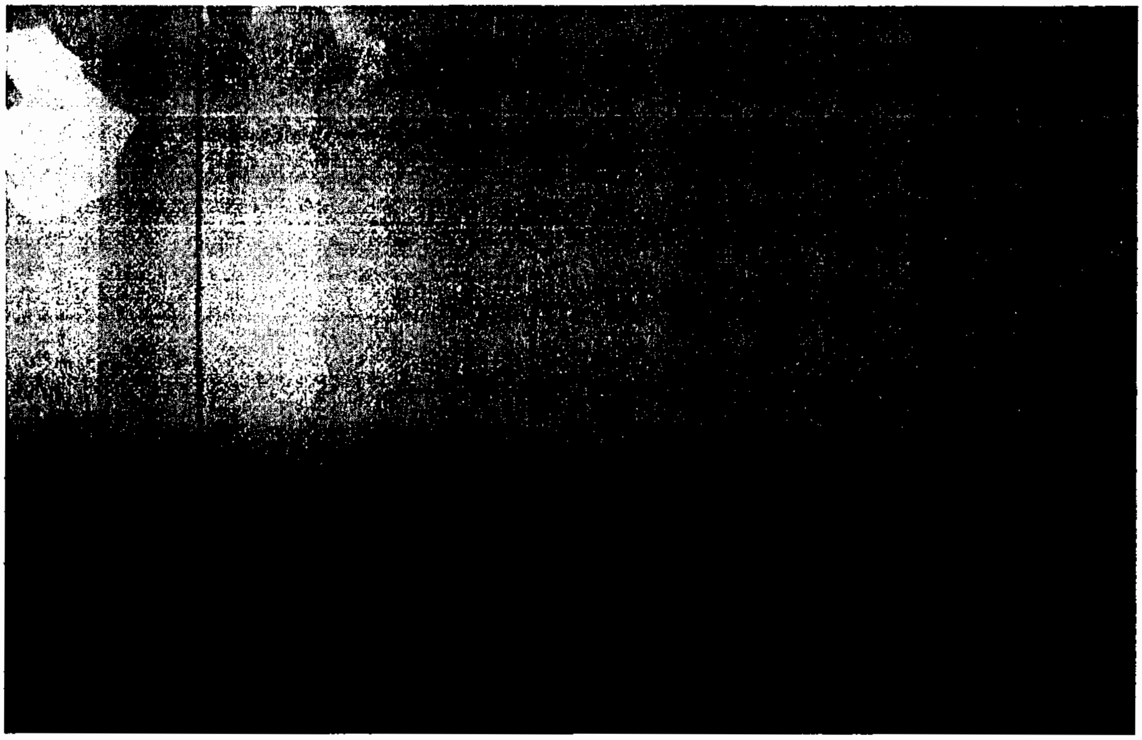


**Figure 2-6: A typical view of the region's physical environment**



**Continued figure 2-6**



**Continued figure 2-6**

# CHAPTER III:

## Climate Study

## 3-1- Introduction

Wind turbines operate under a wide range of environmental conditions, including extremes such as 100% humidity and ambient temperatures from -40°C to 85°C. All of the electronic equipment and circuits installed in the turbine must be designed to operate reliably over the entire temperature range. It is so important to know the weather conditions to provide years of operation while operating over the entire temperature range. As the Nacelle is located at the top of the turbine tower with the rest of the equipment, humidity and condensation can be factors affecting reliability; so in this part climate condition of Iran-Pak proposed wind farm was obtained.

## 3-2- Climate of Pakistan

As Pakistan is located on a great landmass north of the tropic of cancer (between latitudes 25° and 35° N), it has a continental type of climate characterized by extreme variations of temperature, both seasonally and daily. Very high altitudes modify the climate in the cold, snow-covered northern mountains; temperatures on the Baluchistan Plateau are somewhat higher. Along the coastal strip, the climate is modified by sea breezes.

In the rest of the country, temperatures reach great heights in the summer and hot winds called Loo (wind) blow across the plains during the day. Trees shed their leaves to avoid loss of moisture. The dry, hot weather is broken occasionally by dust storms and thunderstorms that temporarily lower the temperature. Evenings are cool; the diurnal variation in temperature may be as much. Winters are cold, with minimum mean temperatures in Punjab in January, and sub-zero temperatures in the far north and Baluchistan.

Due to the location, Pakistan Climate is temperate. Pakistan has recorded one of the highest temperatures in the world 53.5 °C on 26 May, 2010. It is not only the hottest temperature ever recorded in Pakistan, but also the hottest reliably measured temperature ever recorded in the continent of Asia.

Climate of Pakistan has great regional variation. The difference in temperature between day and night is immensely substantial. The temperature in the southern part goes up to 45°C or even more in the summers. Scanty rainfall makes the place all the more dry and barren. The climate in Pakistan is characterized by hot summers and cold winters. The northern part of Pakistan is generally cold as there exists the snow capped mountains and peaks while the southern part is dry with deserts all around.

Pakistan Climate is divided into four seasons; the hot dry spring, from March to May, summer rainy season from June to September, retreating monsoon in October and November and the cold dry winter from December to February. Temperature in Islamabad, which is the capital city of Pakistan, varies from 2°C in the winter in January to 40°C in June. So the climate of Pakistan can be called as extreme. The average rainfall during monsoon is about 255 millimeters.

The monsoon and the Western Disturbance are the two main factors which alter the weather over Pakistan; otherwise, Continental air prevails for rest of the year. Following are the main factors that influence the weather over Pakistan.

Western Disturbances mostly occur during the winter months and cause light to moderate showers in southern parts of the country while moderate to heavy showers with heavy snowfall in the northern parts of the country. These westerly waves are robbed of most of the moisture by the time they reach Pakistan. Fog occurs during the winter season and remains for weeks in upper Sindh, central Khyber Pakhtunkhwa and Punjab.

Southwest Monsoon occurs in summer from the month of June till September in almost whole Pakistan excluding western Baluchistan, FATA, Chitral and Gilgit-Baltistan. Monsoon rains bring much awaited relief from the scorching summer heat. These monsoon rains are quite heavy by nature and can cause significant flooding, even severe flooding if they interact with westerly waves in the upper parts of the country.

Each year before the onset of monsoon that is 15 April to 15 July and also after its withdrawal that is 15 September to 15 December, there is always a distinct possibility of the cyclonic storm to develop in the north Arabian Sea. Cyclones formed in the Arabian Sea often results in strong winds and heavy rainfall in Pakistan's coastal areas. However tornadoes mostly occur during spring season that is March and April usually when a Western Disturbance starts affecting the northern parts of the country. It is also speculated that cycles of tornado years may be correlated to the periods of reduced tropical cyclone activity.

Tropical Storms usually form during the summer months from late April till June and then from late September till November. They affect the coastal localities of the country.

Dust storms occur during summer months with peak in May and June, they are locally known as Andhi. These dust storms are quite violent. Dust storms during the early summer indicate the arrival of the monsoons while dust storms in the autumn indicate the arrival of winter.

Heat waves occur during May and June, especially in southern Punjab, central Baluchistan and interior Sindh. Thunderstorms most commonly occur in northern Punjab, Khyber Pakhtunkhwa and Azad Kashmir. Continental air prevails during the period when there is no precipitation in the country.

Pakistan has four seasons: a cool, dry winter from December through February; a hot, dry spring from March through May; the summer rainy season, or southwest monsoon period, from June through September; and the retreating monsoon period of October and November. The onset and duration of these seasons vary somewhat according to location.

These natural patterns have recently changed somewhat with the construction of dams and barrages on the Indus River. In 2005, Hyderabad received 37 cm in just 11 hours.

The climate in the capital city of Islamabad varies from an average daily low of 2°C in January to an average daily high of 38°C in June. Half of the annual rainfall occurs in July and August, averaging about 255 millimeters in each of those two months. The remainder of the year has significantly less rain, amounting to about fifty millimeters per month. Hailstorms are common in the spring.

Pakistan's largest city, Karachi, which is also the country's industrial center, is more humid than Islamabad but gets less rain. Only July and August average more than twenty-five millimeters of rain in the Karachi area; the remaining months are exceedingly dry. The temperature is also more uniform in Karachi than in Islamabad, ranging from an average daily low of 13°C during winter evenings to an average daily high of 34°C on summer days. Although the summer temperatures do not get as high as those in Punjab, the high humidity causes the residents a great deal of discomfort.

## 3-3- Climate of Region (Site Nearby)

The Iran-Pak wind farm's climate condition from synoptic stations of Karachi and two installed meteo mast on its site, is mentioned in this part. Data collection period was 17 months (2013/09/01 to 2015/01/31).

The average temperature for the year in site nearby is 26.9°C. The warmest month, on average, is June with an average temperature of 32.3°C. The coolest month on average is January, with an average temperature of 18.1°C (Figure 3-1 and table 3-1).

The average amount of relative humidity for the year in site nearby is 56.4 %. The month with the highest relative humidity on average is July with around 70 %. The month with the lowest relative humidity on average is January with an average of 42 % (Figure 3-2).

The average amount of pressure for the year in site nearby is 998.4 mb. The month with the highest pressure on average is January with 1005.1 mb. The month with the lowest pressure on average is July with an average of 990 mb (Figure 3-3).

The average amount of precipitation for the year in site nearby is 198.4 mm. The month with the most precipitation on average is July with 78.5 mm of precipitation. The month with the least precipitation on average is October with an average of 1.5 mm (Figure 3-4).

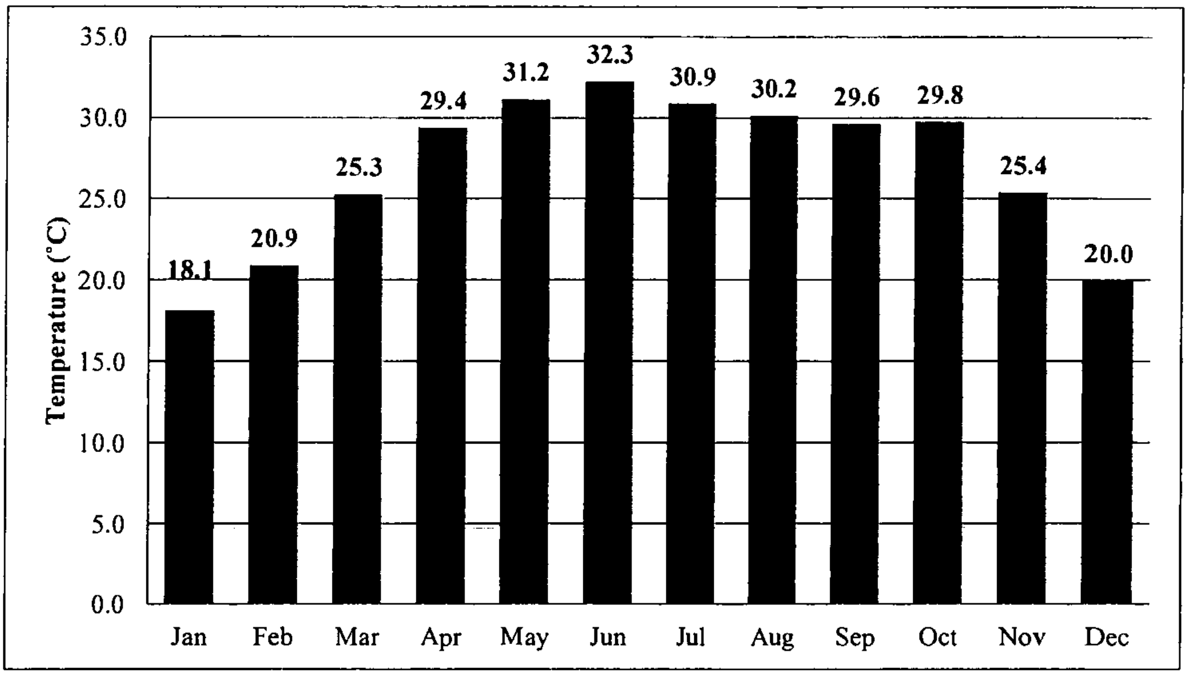



**Figure 3-1: Average Temperature of Region**

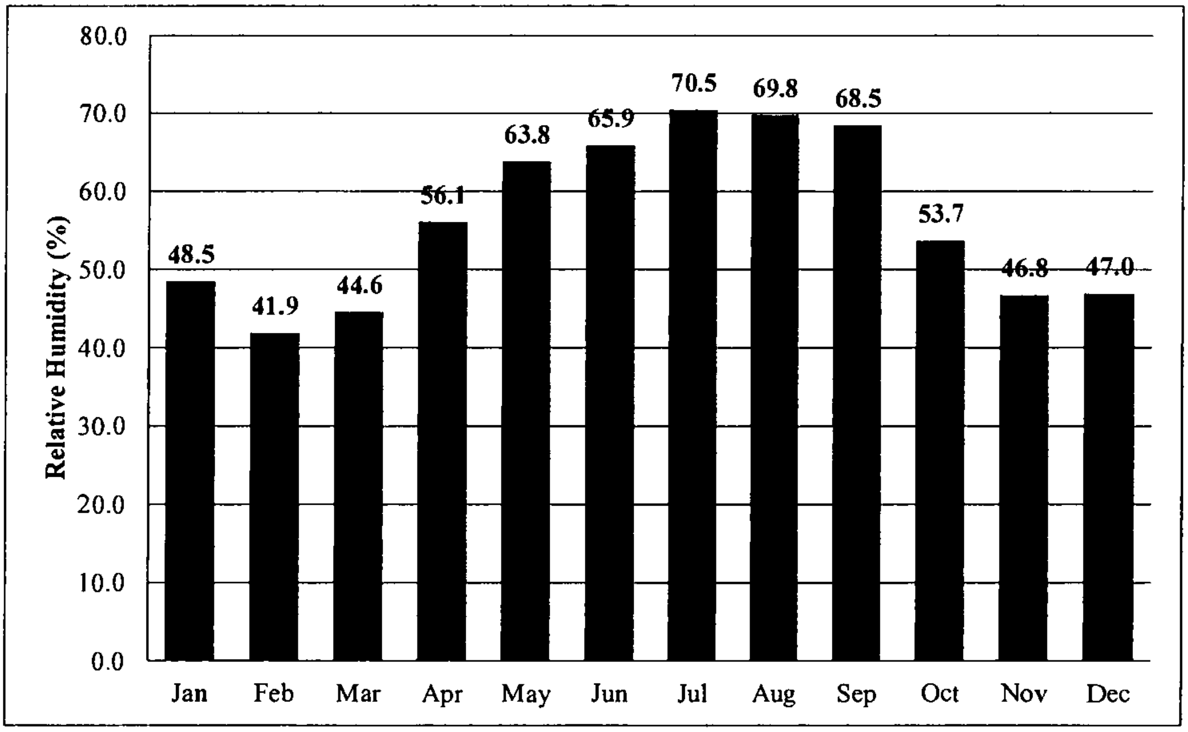



**Figure 3-2: Average Relative Humidity of Region**

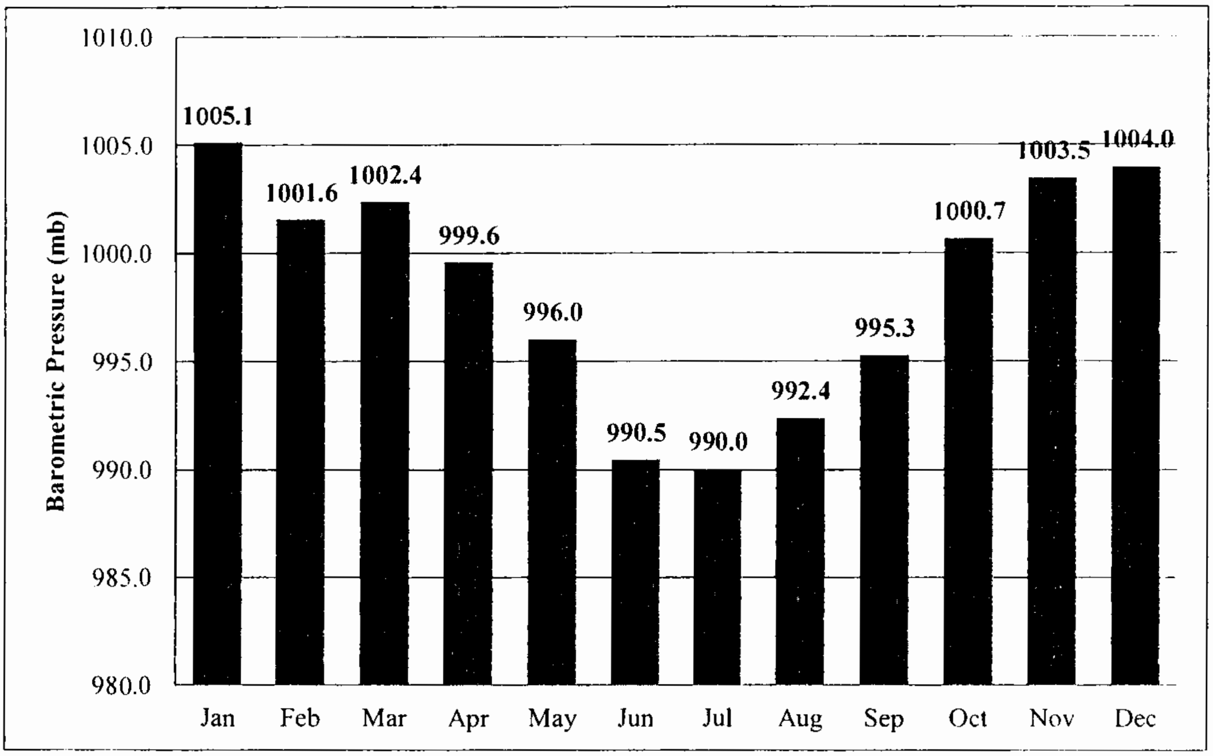



**Figure 3-3: Average Pressure of Region**

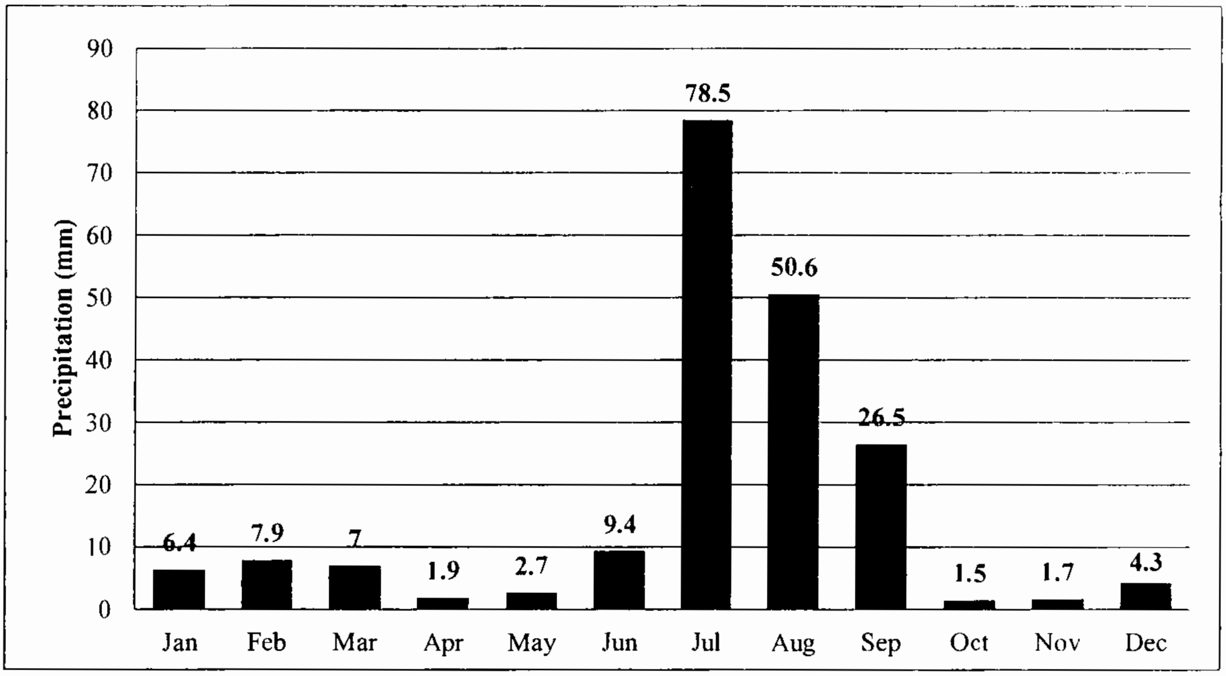



**Figure 3-4: Average Precipitation of Region**

**Table 3-1: average value of Temperature, Humidity, Pressure and Precipitation in wind farm area**

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Temperature (°C) | 18.1 | 20.9 | 25.3 | 29.4 | 31.2 | 32.3 | 30.9 | 30.2 | 29.6 | 29.8 | 25.4 | 20.0 |
| Average Relative Humidity (%) | 48.5 | 41.9 | 44.6 | 56.1 | 63.8 | 65.9 | 70.5 | 69.8 | 68.5 | 53.7 | 46.8 | 47.0 |
| Average Barometric Pressure (mb) | 1005.1 | 1001.6 | 1002.4 | 999.6 | 996.0 | 990.5 | 990.0 | 992.4 | 995.3 | 1000.7 | 1003.5 | 1004.0 |
| Average Precipitation (mm) | 6.4 | 7.9 | 7 | 1.9 | 2.7 | 9.4 | 78.5 | 50.6 | 26.5 | 1.5 | 1.7 | 4.3 |

The average values that used in this section came from the average of two installed wind mast in wind farm area in period of **518 days, 09/01/2013 - 01/31/2015** (See part 3-1-1).

## 3-3-1- Meteo Masts

Two meteo masts were installed in site area according to the Energy Purchase Agreement (EPA) standard . One installed in lowest altitude of site (meteo mast No. 1) and the other installed in highest altitude of site (meteo mast No. 2). These two meteo masts are the same. They are equipped with five wind anemometers, two wind vans, one temperature sensor, one pressure sensor, one relative humidity sensor and one solar radiation sensor (pyranometer). Their equipments are listed in table 3-2 and table 3-3.

Wind mast full equipments, listed as follow:

- **Wind anemometer**: Anemometers measure wind speed, either by simple rotational cup or by the change in reflective properties of light or sound waves due to air movement. There are 4 wind cup anemometers in each met-mast. Tables 3-2 and 3-3 illustrates the height on each tower. Those 4 anemometer type is Class1 Wind Anemometer.

  It should be mentioned that for standardizing and comparison of wind data, one set of wind anemometer with "measnet" calibration is installed at the top (80m) of wind masts (based on IEC61400-12). This anemometer type is WindSenP2546C.

- **Wind vane**: Wind direction is normally measured by the rotation of a well-balanced, low friction vane. There are two wind vanes in each met-mast with mentioned heights in tables 2, 3. This equipment type is NRG #200P Wind Direction Vane, 10K with Boot.

- **Pressure, Temperature & Humidity:** These ancillary instruments measure the detailed wind climate properties to provide a greater certainty of the wind energy potential of a site and the operating environment of the future turbine. There is one sensor for measuring air temperature, one sensor for barometric pressure, and one for relative humidity. The exact location of each is mentioned in tables 2-3. The temperature sensor type is NRG #110S Temperature Sensor with Radiation Shield. The pressure sensor and humidity sensor's type are NRG #BP20 Barometric Pressure Sensor and RH-5X Relative Humidity Sensor respectively.

- **Telecommunication Information:** All data is transferred to the IPWPPL company's head office and GNEC office via internet using a GSM cellular company services through the Symphonie iPackGPS (GSM/GPRS).

- **Contact Information: M/s Mobilink, Mobilink House,Plot # 44-A, NTO Building Block-6, P.E.C.H.S, Manager Noman Ahmed Karachi, Pakistan Mobile: +92-300-8274868**

- **Other:** Stainless steel Shelter Box, Wiring Harness for Sensors, Solar Aviation Tower Light, SCM card for sensors, NRG SymphoniePLUS3 Logger, Li-Cor#LI-200SZ Pyranometer, power system.

**Table 3-2: Equipments of Meteo Masts No. 1**

| Sensors | Height | Scale Factor | Offset | Unit |
|---|---|---|---|---|
| **WindSenP2546C** | 80 m | 0.62 | 0. 244 | m/s |
| **Class1 wind Anemometer** | 80 m | 0. 763 | 0.23 | m/s |
| **Class1 wind Anemometer** | 65 m | 0.765 | 0.22 | m/s |
| **Class1 wind Anemometer** | 50 m | 0. 765 | 0.23 | m/s |
| **Class1 wind Anemometer** | 35 m | 0. 764 | 0.23 | m/s |
| **Wind vane** | 78 ms | 0.351 | 0 | Deg. |
| **Wind vane** | 48 m | 0.351 | 0 | Deg. |
| **Barometric Pressure** | ≈3 m | 0.426 | 653.094 | mb |
| **Temperature** | 10 m | 0.136 | -86.379 | °C |
| **Relative Humidity** | ≈ 3 m | 0.097 | 0 | % |
| **Solar Radiation** | ≈ 3 m | 1.32 | 0 | W/m$^2$ |

**Table 3-3: Equipments of Meteo Masts No. 2**

| Sensors | Height | Scale Factor | Offset | Unit |
|---|---|---|---|---|
| **WindSenP2546C** | 80 m | 0.619 | 0. 247 | m/s |
| **Class1 wind Anemometer** | 80 m | 0. 763 | 0.23 | m/s |
| **Class1 wind Anemometer** | 65 m | 0.765 | 0.22 | m/s |
| **Class1 wind Anemometer** | 50 m | 0. 765 | 0.23 | m/s |
| **Class1 wind Anemometer** | 35 m | 0. 764 | 0.23 | m/s |
| **Wind vane** | 78 m | 0.351 | 0 | Deg. |
| **Wind vane** | 48 m | 0.351 | 0 | Deg. |
| **Barometric Pressure** | ≈3 m | 0.426 | 649.547 | mb |
| **Temperature** | 10 m | 0.136 | -86.379 | °C |
| **Relative Humidity** | ≈ 3 m | 0.097 | 0 | % |
| **Solar Radiation** | ≈ 3 m | 1.32 | 0 | W/m$^2$ |

**Figure 3-5 : Installed Meteo-Mast in Site**

**Table 3-4: Meteo Mast No.1 Weather Information**

| Meteo No.1 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Temperature (°C) | 18.1 | 20.9 | 25.4 | 29.6 | 31.4 | 32.5 | 31.1 | 30.3 | 29.9 | 29.9 | 25.4 | 19.9 |
| Average Relative Humidity (%) | 48.6 | 41.8 | 44.2 | 55 | 62.7 | 62.4 | 69.9 | 69.2 | 67.6 | 53.7 | 47.1 | 47.4 |
| Average barometric Pressure (mb) | 18.1 | 20.9 | 25.4 | 29.6 | 31.4 | 32.5 | 31.1 | 30.3 | 29.9 | 29.9 | 25.4 | 19.9 |

**Table 3-5: Meteo Mast No.2 Weather Information**

| Meteo No.2 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Temperature (°C) | 18.1 | 20.9 | 25.2 | 29.2 | 30.9 | 32.0 | 30.7 | 30.0 | 29.4 | 29.6 | 25.4 | 20.1 |
| Average Relative Humidity (%) | 48.5 | 42.1 | 45.0 | 57.2 | 65.0 | 69.4 | 71.2 | 70.4 | 69.4 | 53.7 | 46.4 | 46.5 |
| Average barometric Pressure (mb) | 1003 | 1000 | 1000 | 998 | 994 | 988 | 988 | 990 | 993 | 999 | 1001 | 1002 |

According to above tables, all parameters have variation; therefore that will be important to consider these variations in specifying wind turbine type.

# CHAPTER IV

## Benchmark Wind Survey

## 4-1- Introduction

Wind resource assessment is the most important step in planning a wind project because it is the basis for determining initial feasibility and cash flow projections, and is ultimately vital for acquiring financing. Wind survey is one on the most important step in wind resource assessment in each project.

An acceptable wind resource for a project is very site specific. It depends on many factors that relate to the total installed cost of the project, the incentives available to the project, the rate at which the energy might be sold, and the investors' required rate of return.

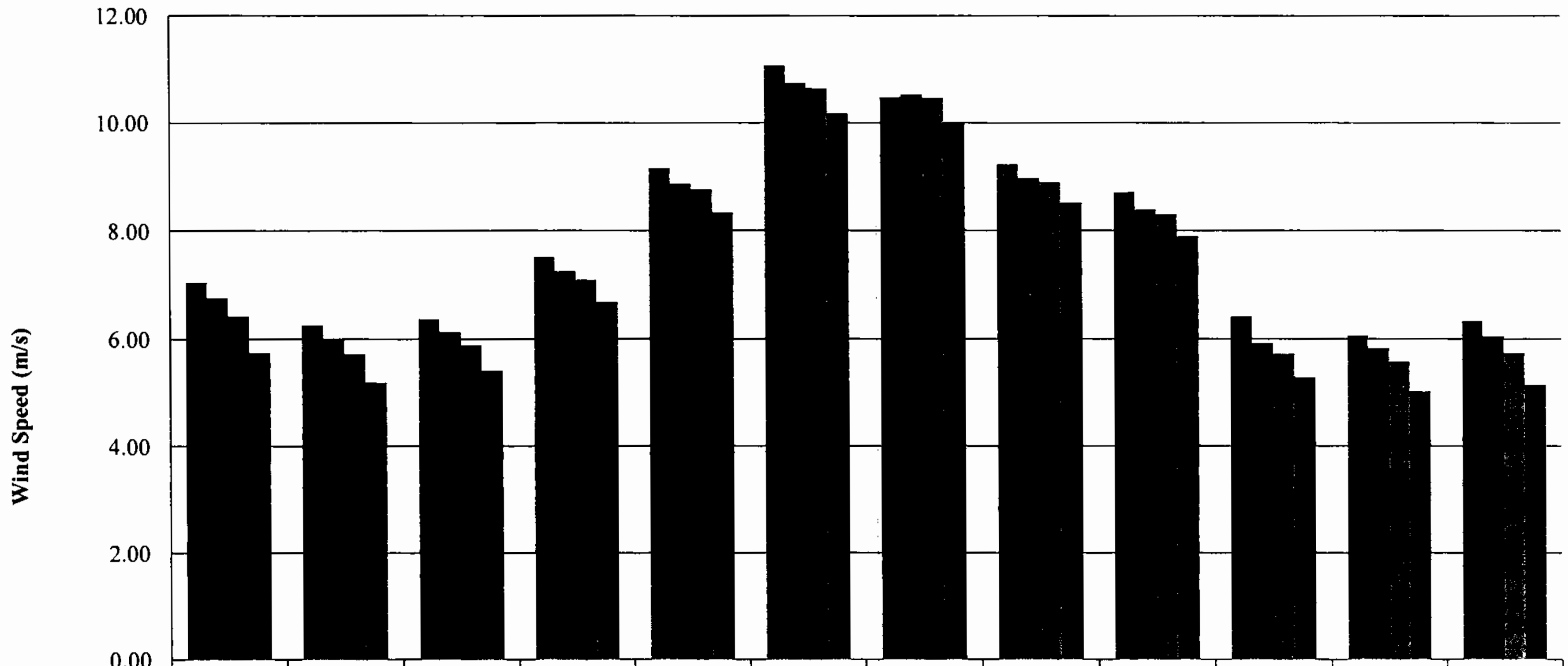
## 4-2- Data Acquisition

### 4-2-1- The project team's original intent was to gather meteorological data through the installation of two meteorological towers (met masts) in the site location. Two standard meteo masts installed in site and 10 minutes interval data transferred online to Engineer every hour. Monthly averages of wind speed;

The plot of the monthly average wind speeds shows the trends in the wind speed over the year.

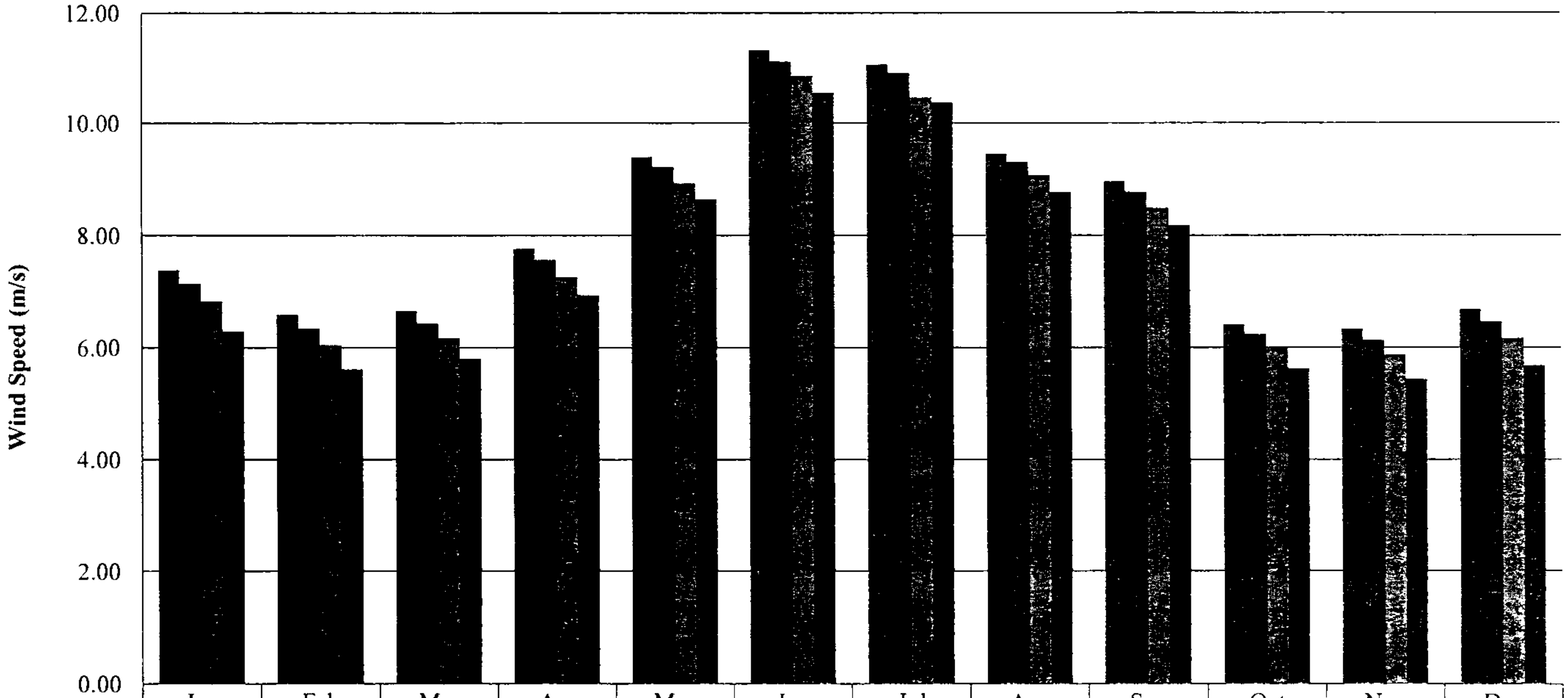
Monthly average wind speed will inform the banker (Owners, Client and financier) how the wind resource at this site varies over the course of the year and how seasonal variations will affect the project cash flow. As shown in Figure 4-1 and 4-2, the monthly average wind speeds at 30, 50, 65 and 80 meters above the ground should be reported as well as extrapolations to the expected turbine hub height utilizing site-specific wind shear estimates (Wind Benchmarks).

In Iran - Pak wind farm area, total mean wind speed of year by averaging of two wind masts is **8.03 m/s** at 80 m, **7.78 m/s** at 65 m, **7.56 m/s** at 50 m and **7.13 m/s** at 35 m above the ground. The month with maximum mean wind speed is Jun with 11.20 m/s wind speed at 80 m above the ground. From Jun till November mean wind speed decrease steady. The month with the minimum mean wind speed is November with 6.08 m/s wind speed at 80 m above the ground. November to January wind speed increase, but in months February wind speed decrease slightly. Later in month of March wind speed increases again till the wind speed reach the maximum June. (See figure 4-3)



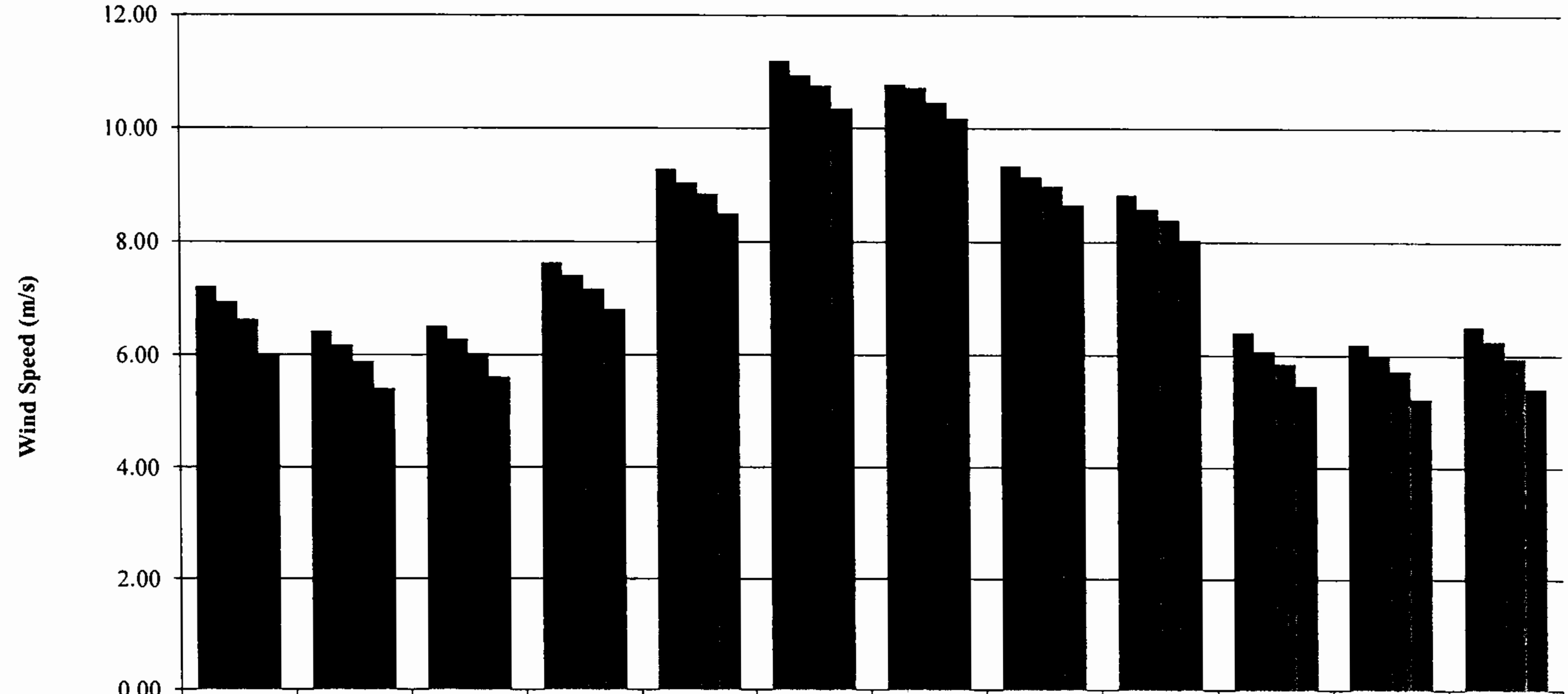

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ■ Wind Speed at 80 m (m/s( | 7.05 | 6.26 | 6.37 | 7.51 | 9.16 | 11.07 | 10.48 | 9.23 | 8.72 | 6.42 | 6.06 | 6.34 |
| ■ Wind Speed at 65 m (m/s( | 6.76 | 6.00 | 6.13 | 7.25 | 8.87 | 10.75 | 10.53 | 8.98 | 8.39 | 5.92 | 5.83 | 6.05 |
| ■ Wind Speed at 50 m (m/s( | 6.42 | 5.72 | 5.89 | 7.09 | 8.77 | 10.65 | 10.47 | 8.90 | 8.31 | 5.72 | 5.58 | 5.73 |
| ■ Wind Speed at 35 m (m/s( | 5.75 | 5.18 | 5.41 | 6.68 | 8.34 | 10.18 | 10.00 | 8.52 | 7.89 | 5.28 | 5.02 | 5.13 |

**Figure 4-1: Benchmark wind speed (Measurement monthly averages) in different heights from wind mast No. 1**




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wind Speed at 80 m (m/s( | 7.38 | 6.58 | 6.65 | 7.76 | 9.40 | 11.32 | 11.07 | 9.45 | 8.96 | 6.42 | 6.34 | 6.69 |
| Wind Speed at 65 m (m/s( | 7.13 | 6.34 | 6.43 | 7.56 | 9.22 | 11.12 | 10.91 | 9.31 | 8.77 | 6.24 | 6.13 | 6.46 |
| Wind Speed at 50 m (m/s( | 6.82 | 6.05 | 6.17 | 7.25 | 8.93 | 10.86 | 10.46 | 9.07 | 8.49 | 5.99 | 5.87 | 6.16 |
| Wind Speed at 35 m (m/s( | 6.29 | 5.61 | 5.80 | 6.93 | 8.64 | 10.55 | 10.37 | 8.77 | 8.19 | 5.62 | 5.43 | 5.68 |

**Figure 4-2: Benchmark wind speed (Measurement monthly averages) in different heights from wind mast No. 2**

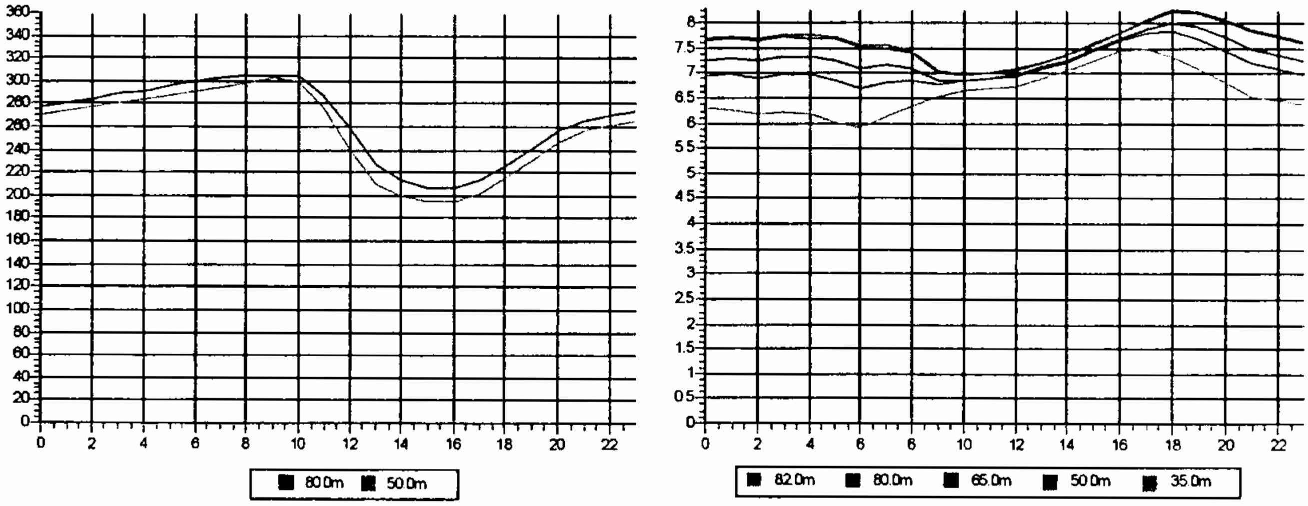



| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ■ Wind Speed at 80 m (m/s( | 7.21 | 6.42 | 6.51 | 7.63 | 9.28 | 11.20 | 10.78 | 9.34 | 8.84 | 6.42 | 6.20 | 6.51 |
| ■ Wind Speed at 65 m (m/s( | 6.95 | 6.17 | 6.28 | 7.41 | 9.05 | 10.94 | 10.72 | 9.15 | 8.58 | 6.08 | 5.98 | 6.25 |
| ■ Wind Speed at 50 m (m/s( | 6.62 | 5.88 | 6.03 | 7.17 | 8.85 | 10.76 | 10.47 | 8.99 | 8.40 | 5.85 | 5.72 | 5.95 |
| ■ Wind Speed at 35 m (m/s( | 6.02 | 5.39 | 5.60 | 6.80 | 8.49 | 10.37 | 10.19 | 8.65 | 8.04 | 5.45 | 5.22 | 5.41 |

**Figure 4-3: Benchmark wind speed in different heights (average of two wind masts)**

## 4-2-2- Daily Mean Wind Speed and Direction

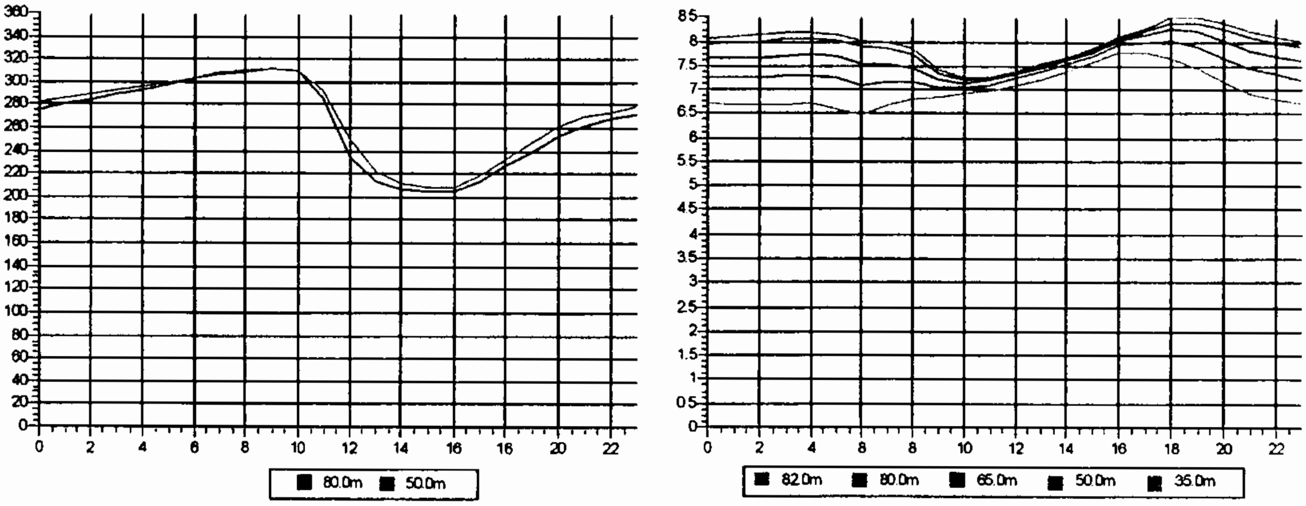
Daily mean wind speed helps financers to have a good estimation about the hours that wind turbines work in a day. Daily mean wind speed of Iran - Pak wind farm illustrated in figure 4-4 and 4-5. The minimum of daily mean wind speed is around 6 m/s at 35 m above the ground and around 7 m/s at 65 m. The daily mean wind speed graph of Iran -Pak wind farm is perfect, because it never goes under 5 or less (See figures b-4-4 and b-4-5). The daily change in wind direction on site is also illustrated in motion. The wind direction is around WSW (240°) in early morning and slightly changes to SSW (210°) in the afternoon and back to WSW in the evening (See figures a-4-4 and a-4-5).




a) mean wind direction

b) mean wind speed

**Figure 4-4 : Daily mean wind speed and direction in different heights of wind mast No. 1**




a) mean wind direction

b) mean wind speed

**Figure 4-5 : Daily mean wind speed and direction in different heights of wind mast No. 2**

## 4-2-3- Mean wind speed in different directions

The mean wind speed in different directions, provide unique information to investors, manufactures and contractors. The below tables (tables 4-1 and 4-2) show the mean wind speed in 12 different sectors which are calculated by using Weibull distribution method. According to these tables all heights follow the same regime in each wind mast. The highest mean wind speed in this year occurred in WSW direction in each meteo masts.

**Table 4-1: mean wind speed by Weibull distribution in different direction for wind mast No. 1**

| Wind mast No.1 | Mean wind speed [m/s] | | | |
|---|---|---|---|---|
| Sector \ Height(m) | 80 | 65 | 50 | 35 |
| 0-N | 8.541 | 8.032 | 7.410 | 6.291 |
| 1-NNE | 6.913 | 6.733 | 6.374 | 5.813 |
| 2-ENE | 4.960 | 4.853 | 4.725 | 4.452 |
| 3-E | 4.055 | 3.982 | 3.971 | 3.785 |
| 4-ESE | 3.083 | 2.970 | 3.014 | 2.928 |
| 5-SSE | 3.297 | 3.308 | 3.452 | 3.325 |
| 6-S | 4.561 | 4.561 | 4.716 | 4.581 |
| 7-SSW | 7.156 | 7.008 | 7.535 | 7.243 |
| 8-WSW | 9.272 | 8.960 | 8.745 | 8.268 |
| 9-W | 5.968 | 5.687 | 4.830 | 4.232 |
| 10-WNW | 4.435 | 4.217 | 3.948 | 3.506 |
| 11-NNW | 4.136 | 4.117 | 4.434 | 4.124 |
| **Mean** | **7.645** | **7.376** | **7.168** | **6.639** |

**Table 4-2: mean wind speed by Weibull distribution in different direction for wind mast No. 2**

| Wind mast No.2 | Mean wind speed [m/s] | | | |
|---|---|---|---|---|
| Sector \ Height(m) | 80 | 65 | 50 | 35 |
| 0-N | 7.496 | 7.124 | 7.487 | 6.652 |
| 1-NNE | 8.274 | 8.011 | 7.305 | 6.743 |
| 2-ENE | 5.922 | 5.826 | 5.443 | 5.167 |
| 3-E | 4.347 | 4.315 | 4.174 | 3.988 |
| 4-ESE | 3.271 | 3.179 | 3.143 | 3.045 |
| 5-SSE | 3.608 | 3.616 | 3.501 | 3.413 |
| 6-S | 6.299 | 6.122 | 4.411 | 4.287 |
| 7-SSW | 8.408 | 8.208 | 6.987 | 6.771 |
| 8-WSW | 9.457 | 9.247 | 9.033 | 8.757 |
| 9-W | 7.109 | 6.826 | 6.727 | 6.119 |
| 10-WNW | 4.956 | 4.697 | 4.428 | 3.982 |
| 11-NNW | 4.242 | 4.190 | 4.200 | 4.046 |
| **Mean** | **7.901** | **7.688** | **7.427** | **7.025** |

## 4-2-4- Mean wind speed (or wind power) classification

Classification of wind power density which can be used to compare locations depends on site climate condition such as mean yearly temperature and site elevation. The average wind power density is based on the entire spectrum of observed 10m winds for a location, not just its mean wind speed.

**Wind Power Classification**

| Wind Power Class | Resource Potential | Wind Power Density at 50 m W/m 2 | Wind Speed[a] at 50 m m/s | Wind Speed[a] at 50 m mph |
|---|---|---|---|---|
| 1 | Poor | 0 - 200 | 0.0 - 6.0 | 0.0 - 13.4 |
| 2 | Marginal | 200 - 300 | 6.0 - 6.8 | 13.4 - 15.2 |
| 3 | Fair | 300 - 400 | 6.8 - 7.5 | 15.2 - 16.8 |
| 4 | Good | 400 - 500 | 7.5 - 8.1 | 16.8 - 18.1 |
| 5 | Excellent | 500 - 600 | 8.1 - 8.6 | 18.1 - 19.3 |
| 6 | Outstanding | 600 - 800 | 8.6 - 9.5 | 19.3 - 21.3 |
| 7 | Superb | > 800 | > 9.5 | > 21.3 |

[a] Wind speeds are based on a Weibull k of 2.4 at 500 m elevation.

**Figure 4-6: Wind power classification**

(a): Vertical extrapolation of wind speed based on the 1/7 power law

Mean wind speed is based on Rayleigh speed distribution of equivalent mean wind power density. Wind speed is for standard sea-level conditions. To maintain the same power density, speed increases 3%/1000 m elevation. It notes that, each wind power class should span two power densities. For example, Wind Power Class = 3 represents the Wind Power Density range between 150 W/m$^2$ and 200 W/m$^2$. The offset cells in the first column attempt to illustrate this concept. Based on tables (4-1) and (4-2), mean wind speed measured at 50 m height of site in wind mast No.1 and No.2 respectively are 7.428 and 7.168 m/s. Therefore (without considering increasing Mean wind speed by elevation) site wind (power) class will be "5" and considered as excellent.

## 4-2-5- Wind Rose

A wind rose shows the direction that the wind blows and the frequency of that direction at a particular location. Wind roses are used in wind projects to portray the amount of energy that comes into the wind project from various directions. The wind rose helps developers site the turbines in such a way as to minimize wake losses from other turbines at the site. The banker will want to make sure that the layout of the project optimizes output. Engineers always use the wind rose while explaining the layout of the project.

With prevailing southwesterly winds in the Thatta region, it was expected, going into this study, that the Iran-Pak wind resources would be coming from somewhere in the western hemicycle. Figure 4-7 and 4-8 depicts the percentage of time wind was blowing from each 30° interval of the compass for the months at the site.

As it mentioned in pervious parts, the most wind direction is from WSW. There is some different wind direction from W, SSW, NNE, ENE, but the main wind direction on site is WSW (almost 40 %).

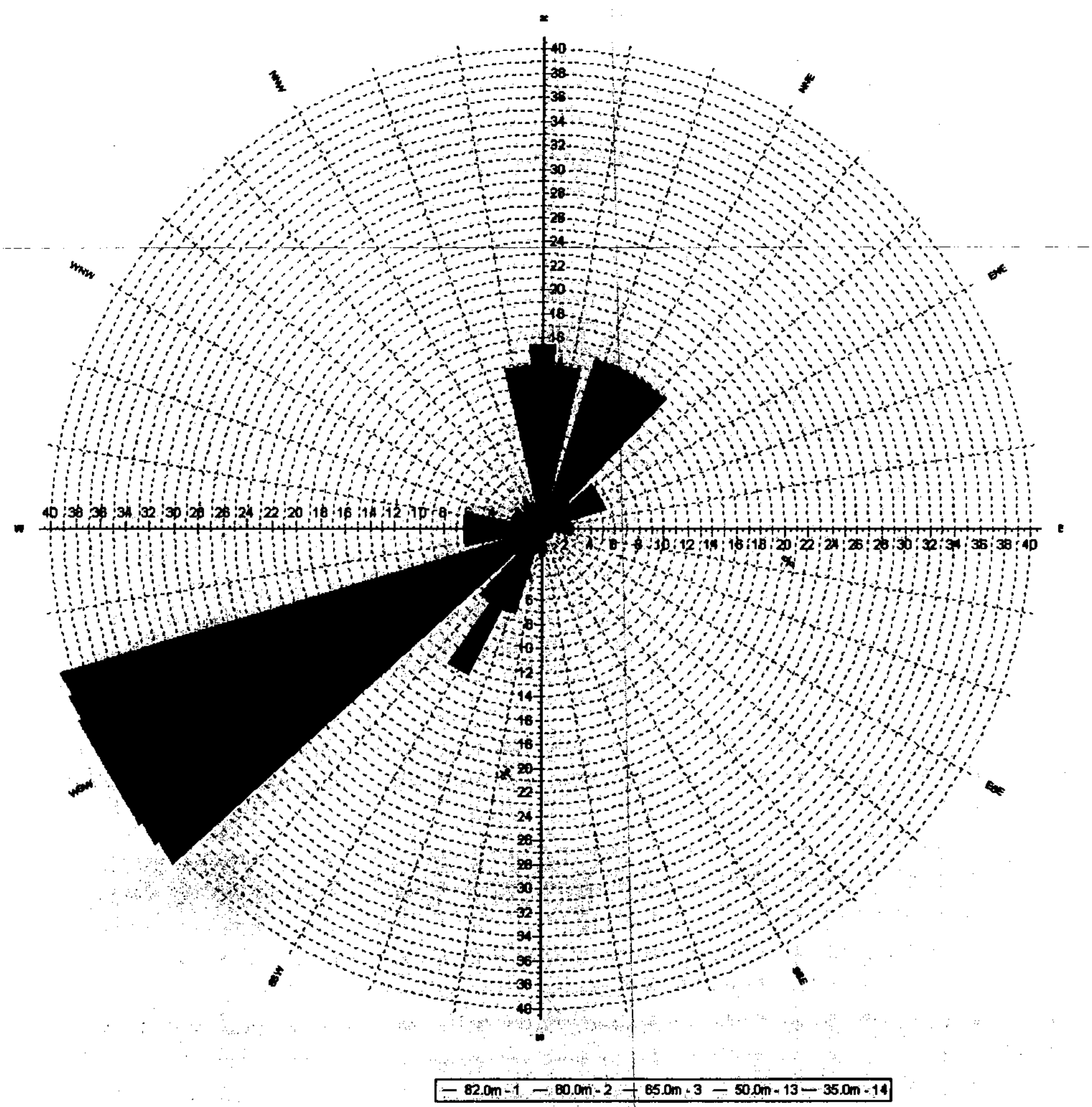



**Figure 4-7: Wind rose based on frequency of wind blows from any direction (in 12 sector) on wind mast No. 1**

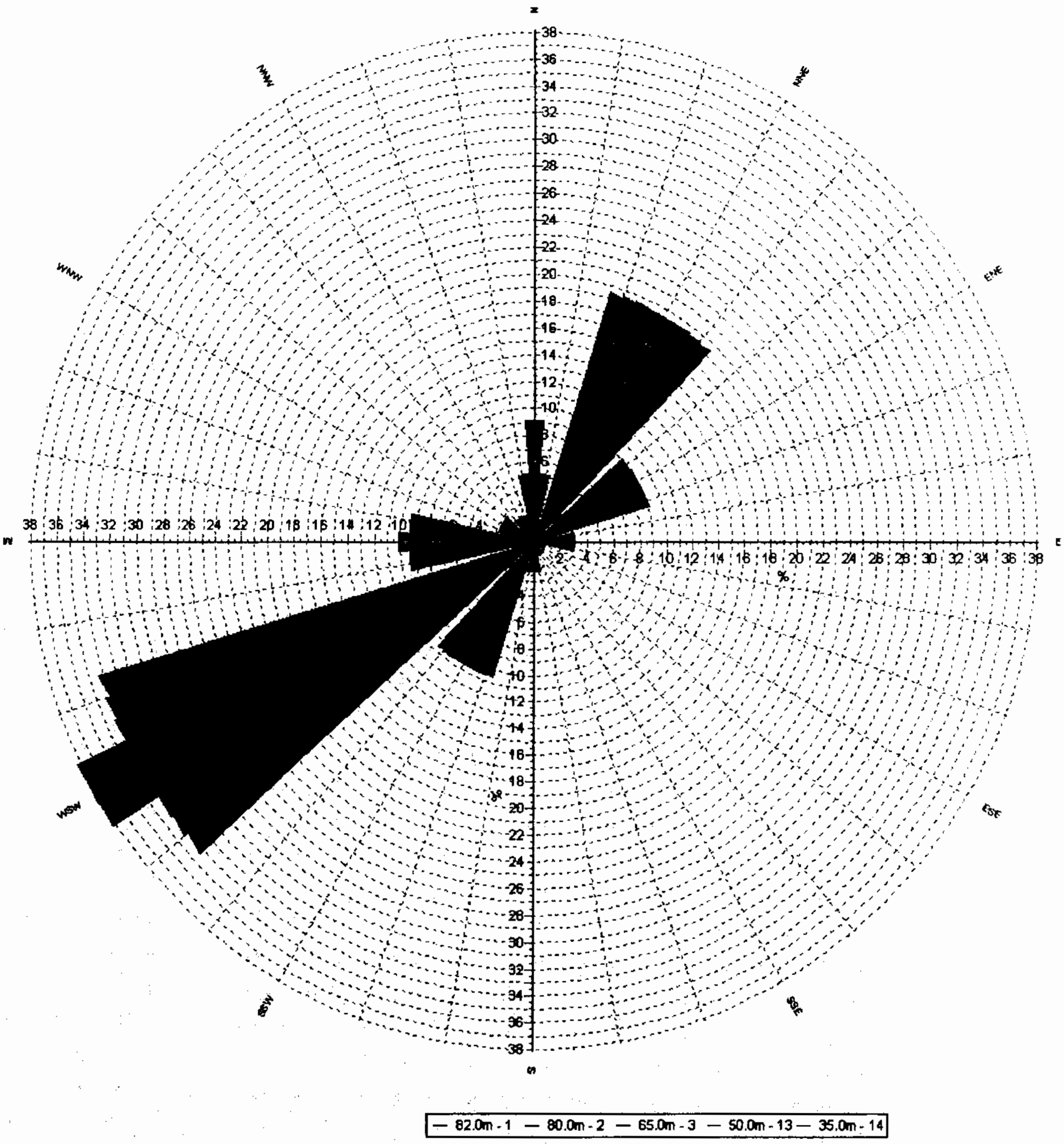



**Figure 4-8: Wind rose based on frequency of wind blows from any direction (in 12 sector) on wind mast No.2**

Every months wind speed and wind rose shows how wind speed and direction is changed month to month. This graphs contains some important information that helps manufacturers decide how to install the wind turbines and in which direction. These graphs are illustrated in appendices.

The direction from which the wind blows most often is the prevailing wind direction. Knowing the directional behavior of the wind is useful when considering where to install wind turbines. If the prevailing winds come from the west, for example, you would not want to install a turbine somewhere with an obstacle to the west. Therefore average wind direction by month, coupled with detailed site maps, can help show where the wind is coming from and how much production might be reduced from obstructions in the area as well as future development.

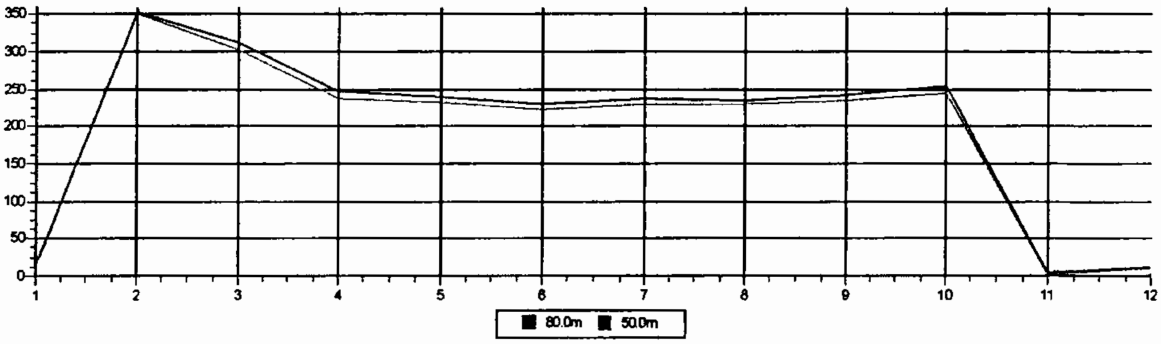



**Figure 4-9: Monthly mean wind direction of all current data in different heights of wind mast No. 1**

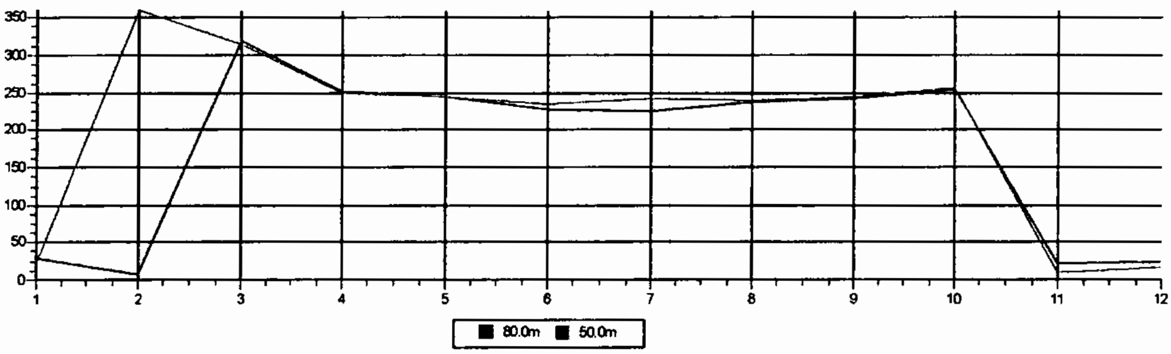



**Figure 4-10: Monthly mean wind direction of all current data in different heights of wind mast No. 2**

As it is repeated in pervious parts, figures (4-9) and (4-10) shows that the wind often blows from 240 degree (WSW).

## 4-2-6- Ambient Turbulence Intensity

Wind turbines are sited to take advantage of high average wind speeds. But knowing only wind speeds is insufficient - without also quantifying the degree of turbulence experienced at a location, the story is incomplete. In fact, when turbulence for a location is analyzed, a site that initially may have looked economically viable for wind turbines can become a site to immediately remove from the list.

A high degree of turbulence has several negative impacts on wind turbines. First, the turbine has to be designed to cope with the peak loads it will experience. If turbulence is high, the maximum loads on the blades, gearbox, generator and tower will also be higher. Typically, turbines designed to cope with high turbulence loads cost more and yield less energy.

Second, turbulent wind gusts occur at random frequencies and speeds. These rapidly changing loads have the potential to excite resonances (large vibrations) in the turbine and its supporting tower. Stiffer and stronger structures are needed to combat this.

Third, cyclically varying loads can cause fatigue problems in turbine structures. For example, if the blades are constantly flexed by turbulent wind gusts, they will need to be designed to safely withstand a greater number of these movements before failure.

Finally, rotor blades moving through turbulent air meet constantly varying conditions. In turbulent conditions the local wind environment is randomly changing in a way for which each blade cannot compensate. For example, a change of apparent wind direction or speed may cause localized stalling of the blade, so reducing the amount of energy being yielded by the generator.

Ambient turbulence intensity is a measure of the "gustiness" of the wind and is calculated as the standard deviation (over a short interval, e. g. 10 minutes) of the wind speed divided by the mean wind speed. Lower turbulence results in less required maintenance and better performance from a wind turbine. Average turbulence intensities are used to compare different sites.

Predicting turbulence at potential wind turbine locations is a critical element in finding economically viable locations. Using cutting-edge technology and sophisticated modeling, removes much of the uncertainty that previously surrounded the impact of turbulence on locating the best sites for wind turbines.

This graph shows the gustiness of the wind at different wind speeds. Together with the Wind Speed distribution, this graph can be used to determine the level of turbulence present under typical operating conditions. A turbine manufacturer will use this graph to predict maintenance scheduling. Figures (4-11) and (4-12) are show ambient turbulence intensity in different heights wind masts No. 1 and No.2. Ambient turbulence intensity of Iran - Pak wind farm is illustrated in figure 4-15 and figure 4-16. As it be can seen in those two graphs, the turbulence intensities are less than 0.15 in both meteo masts at 80 m and 65 m and 50 m above the ground.

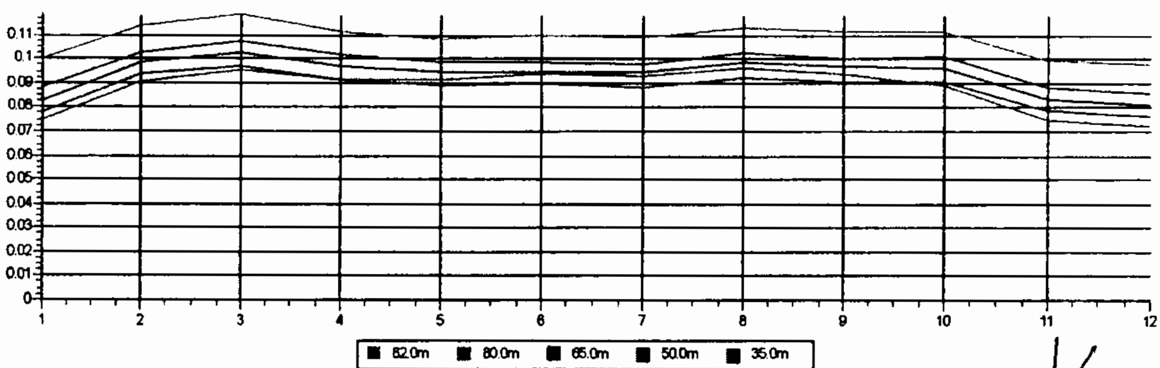



**Figure 4-11: Monthly mean ambient turbulence intensity of all current data in different heights of wind mast No.**

1

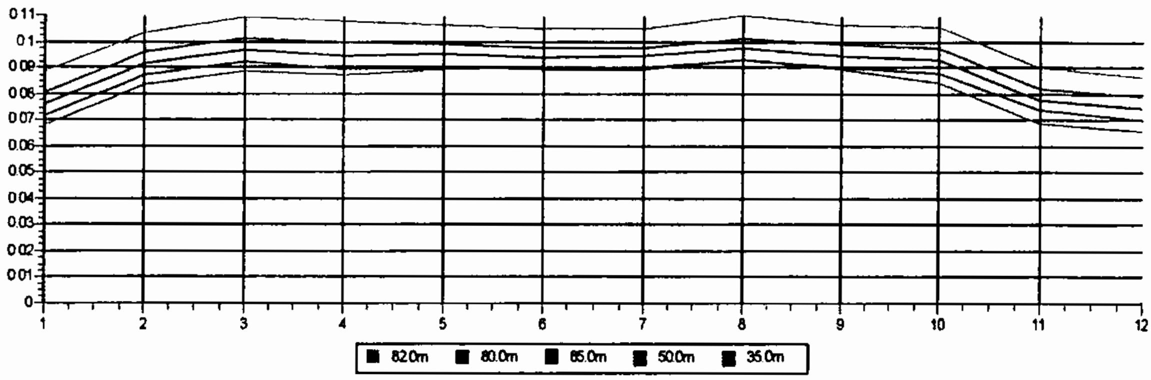



**Figure 4-12: Monthly mean ambient turbulence intensity of all current data in different heights of wind mast No. 2**

## 4-3- Wind Turbine Classes

The external conditions to be considered in design are dependent on the intended site or site type for a SWT installation. SWT classes are defined in terms of wind speed and turbulence parameters. The intention of the classes is to cover most applications. The values of wind speed and turbulence parameters are intended to represent the characteristic values of many different sites and do not give a precise representation of any specific site. The goal is to achieve SWT classification with clearly varying robustness governed by the wind. Table below specifies the basic parameters, which define the SWT classes.

Turbine wind class is just one of the factors which need to be considered during the complex process of planning a wind power plant. Wind classes determine which turbine is suitable for the normal wind conditions of a particular site. They're mainly defined by the average annual wind speed (measured at the turbine's hub height), the speed of extreme gusts that could occur over 50 years, and how much turbulence there is at the wind site.

The standard defines what wind conditions the wind turbines must endure. The three wind classes for wind turbines are defined by an International Electrotechnical Commission standard (IEC), and correspond to high, medium and low winds.

**Table 4-3: Wind turbine classification in International Electrotechnical Commission standard (IEC 61400-2)**

| Turbine Class | | I | II | III | S |
|---|---|---|---|---|---|
| Wind speed (m/s) | | 10 | 8.5 | 7 | Value *specified* by the designer |
| $V_{ref}$ (m/s) | | 50 | 42.5 | 37.5 | |
| $IT_{15}$ | **A** | 0.18 | | | |
| | **B** | 0.16 | | | |

The values apply at hub height Where:

A, designates the category for higher turbulence characteristics,

B, designates the category for lower turbulence characteristics,

$IT_{15}$ is the characteristic value of the turbulence intensity at 15 m/s,

In addition to these basic parameters, several important further parameters are required to specify completely the external conditions used in WTGs design. In the case of the WTGs classes IA through IIIB, later referred to as standard WTGs classes, the values of these additional parameters will affect the turbine design. The design lifetime is to be at least 20 years.

IEC Class "I" is for the windiest sites, those with an average annual wind speed of 10 m/s. Class "II" is for less windy sites with an average wind speed of 8.5 m/s at hub height. Class "III" is for even lower wind sites with an average wind speed not to exceed 7 m/s (Table 4.3).

For the WTGs class S the manufacturer shall in the design documentation describe the models used and values of essential design parameters. In cases where a special design (for example special wind conditions, severe environment or other external conditions or a special safety class) is necessary, a further SWT class, class S, is defined.

Based on previous part (4-2), site condition is suitable for using the class II B. In addition sub class of II A Turbines can be used because of low turbulence intensity.

## 4-4- Long-Term Validation of Data & Correlation

This stage compares data at the site to long term weather data over the course of ten years or more. This will help determine whether the data represents a low, medium, or high wind year and allow adjustments to your long-term production estimates.

Once both short-term and long-term data have been collected from the site and from other sources, a comparison can be done between historical data and that collected at your site. If there is an airport or a weather station within several miles of site with similar topography to site, with the help of meteorological consultant you can determine if the on-site data was collected during a year that was windier or less windy than the historical average. This will help to ensure that your production estimates are descriptive of the site and not inflated due to an abnormally windy year. These data were derived from the publically-available data compiled by FFC wind farm in North-East of Iran–Pak site with about 20 km distance. Values were accessed through WindPRO for reproduction of the primary wind regime of Iran–Pak wind maps on Wind Energy Site Production Tool. The FFC meteo data contained four years data from May 2007 until May 2010.

Correlation is a spatial analysis technique that can determine the degree to which the two variables are related. The process of correlation can be defined as the linear correlation between a time series and the time series at a later interval of time.

Figure 4-13 illustrated the level of correlation between the two wind masts data sets (FFC and Iran-Pak wind masts).

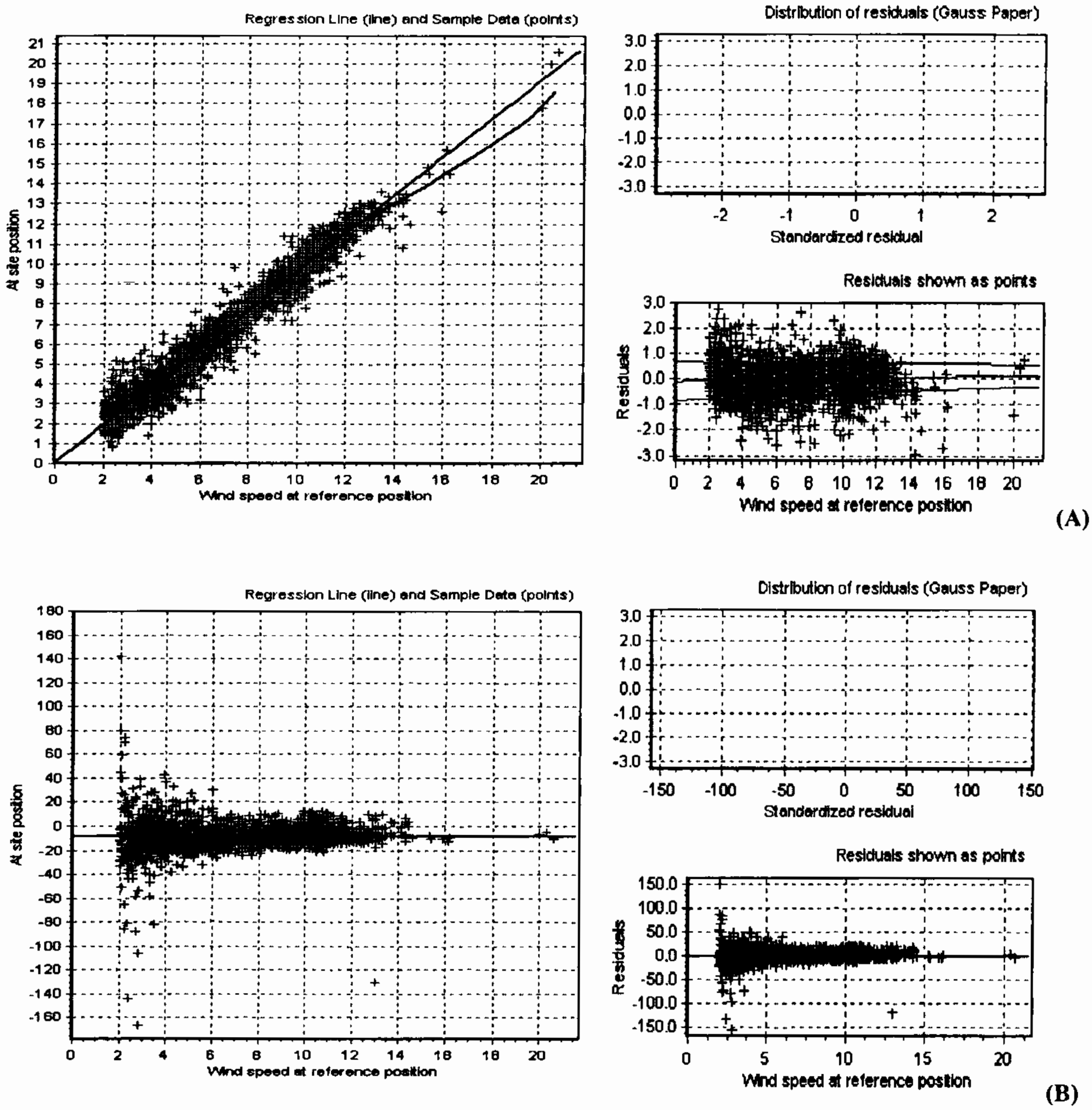



**Figure 4-13: (A) Daily Wind Speed Correlation (B) Daily Wind Direction Correlation**

## 4-5- Weibull Distribution

It is very important for the wind industry to be able to describe the variation of wind speeds. Turbine designers need the information to optimize the design of their turbines, so as to minimize generating costs. Turbine investors need the information to estimate their income from electricity generation.

In measuring wind speeds throughout a year, it should be noticed that in most areas strong gale force winds are rare, while moderate and fresh winds are quite common. The wind variation for a typical site is usually described using the so-called Weibull distribution, as shown in the image.

People who are familiar with statistics will realize that the graph shows a probability density distribution. The area under the curve is always exactly 1, since the probability that the wind will be blowing at some wind speed including zero must be 100 per cent.

Half of the area under black line in figures 4-14 and 4-15 are to the left of the vertical black lines at 8.9 and 9.1 meters per second respectively. The 8.9 and 9.1 m/s are called the median of the distribution. These mean that half the time it will be blowing less than 8.9 meters per second (In figure 4-14) and 9.1 meters per second (In figure 4-15), the other half it will be blowing faster than 8.9 meters per second (In figure 4-14) or 9.1 meters per second (In figure 4-15).

You may wonder then, why we say that the mean wind speed is 7.9 meters per second for meteo mast No.1 and 8.1 meters per second for meteo mast No.2. The mean wind speed is actually the average of the wind speed observations we will get at this site.

As you can see, the distribution of wind speeds is skewed, i.e. it is not symmetrical. Sometimes you will have very high wind speeds, but they are very rare. For Example for meteo mast No.1 wind speeds of 7.9 meters per second, on the other hand, are the most common ones. 7.9 meters is called the modal value of the distribution. If we multiply each tiny wind speed interval by the probability of getting that particular wind speed, and add it all up, we get the mean wind speed.

The statistical distribution of wind speeds varies from place to place around the globe, depending upon local climate conditions, the landscape, and its surface. The Weibull distribution may thus vary, both in its shape, and in its mean value.

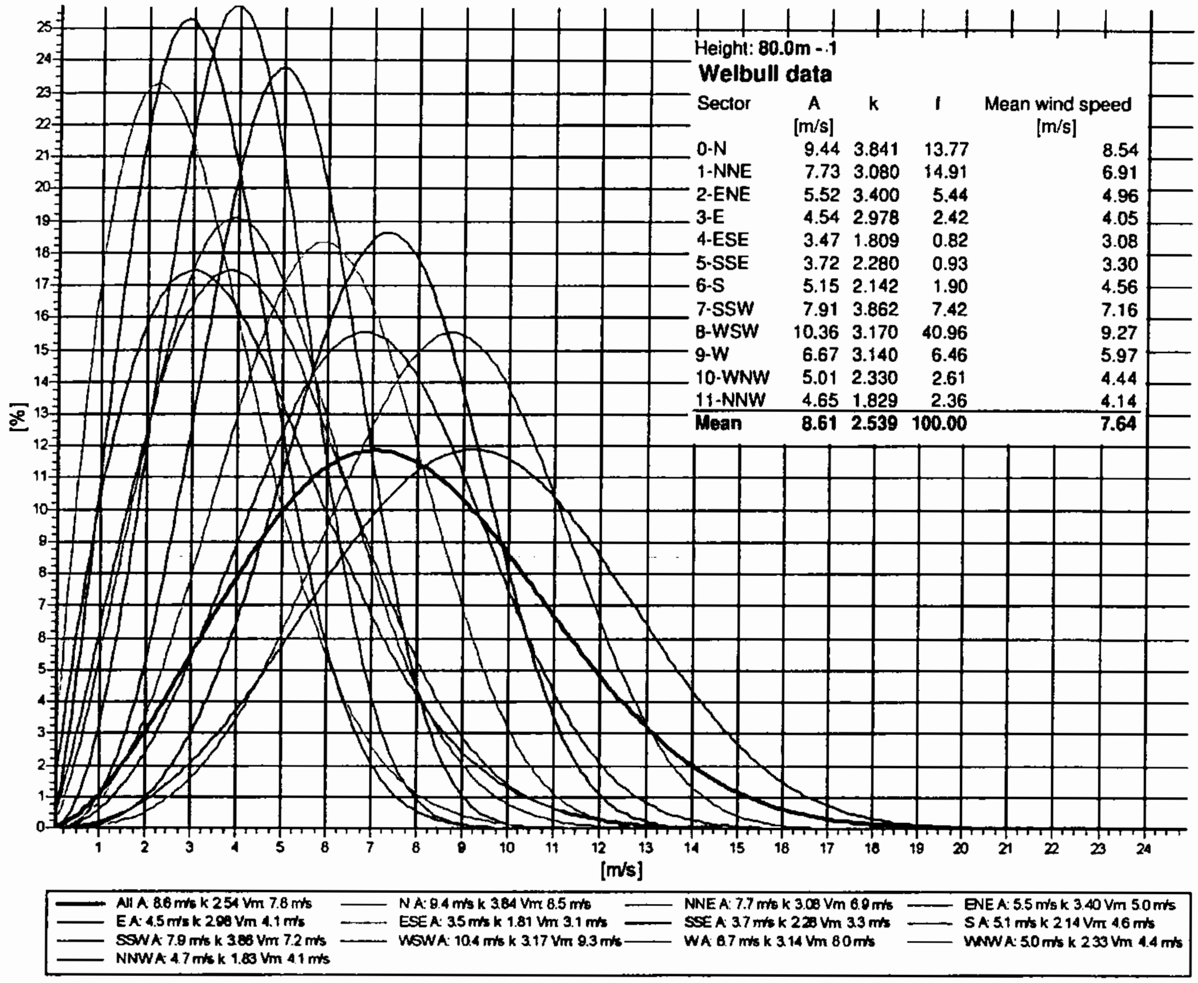



**Figure 4-14: The Weibull Distribution of Wind Mast No. 1 at 80 m Altitude**

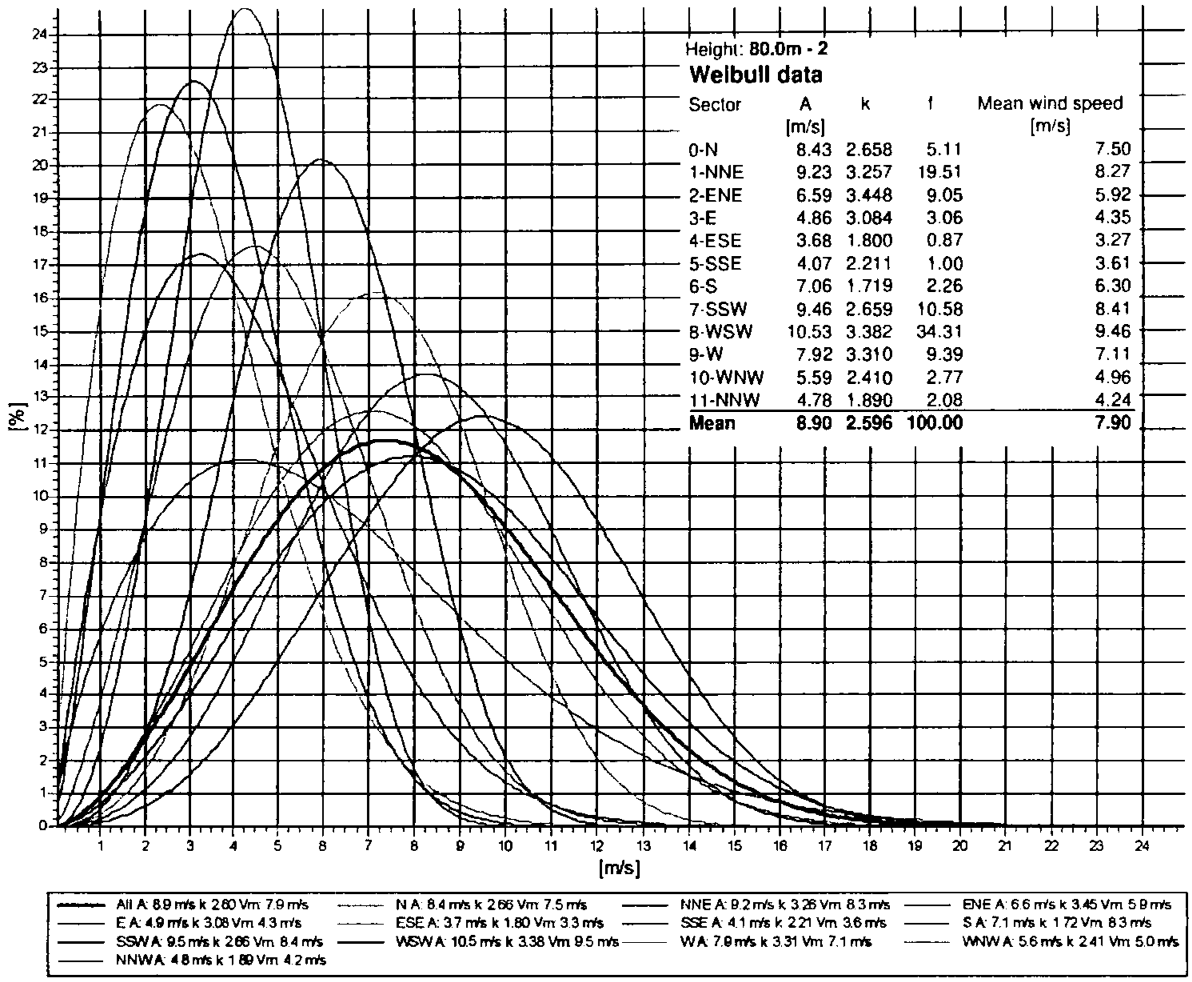



**Figure 4-15: The Weibull Distribution of Wind Mast No. 2 at 80 m Altitude**

# CHAPTER V:

## Turbine Selection and Layout

## 5-1- Introduction

The technological development of recent years, bringing more efficient and more reliable wind turbines, is making wind power more cost-effective. In general, the specific energy costs per annual kWh decrease with the size of the turbine notwithstanding existing supply difficulties.

At the end of 2013, the wind farms installed in more than 85 countries had a combined generating capacity of 318,000 megawatts, which would be enough to meet the residential electricity needs of the European Union's 506 million people. New data from the Global Wind Energy Council show that wind developers built 35,000 megawatts of new generating capacity worldwide in 2013. This was down from 45,000 megawatts installed in 2012—marking only the second time in 25 years that installed capacity increased by less than it did the year before [9].

In addition a wind turbine is a device that converts kinetic energy from the wind into electrical power. The result of over a millennium of windmill development and modern engineering, today's wind turbines are manufactured in a wide range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs. Slightly larger turbines can be used for making small contributions to a domestic power supply while selling unused power back to the utility supplier via the electrical grid. Arrays of large turbines, known as wind farms, are becoming an increasingly important source of renewable energy and are used by many countries as part of a strategy to reduce their reliance on fossil fuels.

Not all the energy of blowing wind can be harvested, since conservation of mass requires that as much mass of air exits the turbine as enters it. Betz's law gives the maximal achievable extraction of wind power by a wind turbine as 59% of the total kinetic energy of the air flowing through the turbine.

Further inefficiencies, such as rotor blade friction and drag, gearbox losses, generator and converter losses, reduce the power delivered by a wind turbine. Commercial utility-connected turbines deliver about 75% of the Betz limit of power extractable from the wind, at rated operating speed.This shows the importance of turbine selection for wind farms.

The establishment and development of a wind farm is a complex task involving a wide range of engineering and scientific skills. The analysis and design aspects of a wind farm may be divided into two separate parts: the resource and the constraints. The challenge for the wind farm designer is to maximize the energy captured within the bounds placed on it by the environmental and financial constraints.

The design process for a wind farm is inevitably an iterative one. It is necessary to establish at an early stage that there is a sufficient resource to make the project viable. In parallel with this it is necessary to assess (a) planning issues including: landscape designations, ecology, visual influence, sound, electromagnetic interference and (b) technical issues: grid connection, ground conditions and access which may affect the development.

For the purpose of defining the preliminary layout, it is necessary to define approximately what sizes of turbine are under consideration. The selection of a specific turbine model is often best left to the more detailed design phase, when the commercial terms of potential turbine suppliers are known. Therefore, at this stage it is either necessary to use a 'generic' turbine design, defined in terms of a range of rotor diameters and a range of hub heights, or to proceed with several layouts, each based on specific wind turbines.

## 5-2- WindPro and WAsP methodology

The software used to simulate the energy yield of the wind farm is WindPRO[1] created by the Danish company EMD. This software bases all the analyses related to wind resource assessment on WAsP[2], which was introduced in 1987 by the Wind Energy and Atmospheric Physics Department at Riso National Laboratory. WAsP is a powerful tool for wind data analysis, wind atlas generation, wind climate estimation and siting of wind climate estimation and siting of wind turbines. The program is based on the European Wind Atlas, describing theory and data sets selected to represent the European wind climate. Over the years, the program has become the industry standard for wind resource assessment and siting of wind turbines and wind farms and it has been employed in more than 90 countries around the world. [10, 11]

WAsP is a software package for the vertical and horizontal extrapolation of wind climate statistics. It contains several models to describe the wind flow over different terrains and close to sheltering obstacles. WindPro, based on the main structure of WAsP, consists of five main calculation blocks:

### 5-2-1- Analysis of raw data

This option enables an analysis of any time-series of wind measurements to provide a statistical summary of the observed wind climate.

### 5-2-2- Generation of wind atlas data

Analyzed wind data can be converted into a regional wind climate or wind atlas data set. In a wind atlas data set the wind observations have been 'cleaned' with respect to site-specific

[1] Version 2.7
[2] Version 10

conditions. The wind atlas data sets are site-independent and the wind distributions have been reduced to some standard conditions.

### 5-2-3- Wind climate estimation

Using a wind atlas data set calculated by WAsP or one obtained from another source the program can estimate the wind climate at any specific point by performing the inverse calculation as is used to generate a wind atlas. By introducing descriptions of the terrain around the predicted site, the models can predict the actual and expected wind climate at this site. There is also the possibility to set the stability of the atmosphere in this part.

### 5-2-4- Estimation of wind power potential

The total energy content of the mean wind is calculated by WAsP. Furthermore, an estimate of the actual, annual mean energy production of a wind turbine can be obtained by providing WAsP with the power curve of the wind turbine in question.

### 5-2-5- Calculation of wind farm production

Given the thrust coefficient curve of the wind turbine and the wind farm layout, WAsP can finally estimate the wake losses for each turbine in a farm and thereby the net annual energy production of each wind turbine and of the entire farm, i.e. the gross production minus the wake losses.

## 5-3- Turbine Selection

Wind turbines are available in various sizes from a number of wind turbine manufacturers, agents and developers. Size however is not the only aspect of the wind turbine that should be thoroughly investigated by developers when deciding which turbine to use with their project.

The wind profile and wind speeds at each specific site need to be evaluated to identify which turbine is suitable for the particular site conditions. As the wind turbine itself may be as much as 70% of the total project cost it is vital that it produces optimal electricity for the given site. To assist the decision, manufacturers are required to classify their turbines in accordance with International standards (IEC 61400-1&2). There are different classifications for operation of a turbine with respect to maximum wind speeds and average wind speeds.

In the selection of wind turbines, several parameters are considered, such as:

- Transportation to the foreseen wind park site
- Available space on site

- Orographical conditions on site which may prevent the installation of larger turbines in the Megawatt - range
- Local experiences with regular operation and maintenance with wind turbines
- Distances between site and turbine manufacturer who will perform the maintenance within the warranty period
- Wind turbine types installed in the county
- Energy Yield
- Turbine types available at the regional market
- Turbine Wind Class

In summary of this part, after studying suitable wind turbines that can satisfy the Iran-Pak aims, different wind turbines (from WindPRO library) were selected from among top turbine manufactures in the world. More detail will be given in following parts.

The capacity factors were calculated based on the chosen wind turbine. In this study, the yearly wind speed probability, density and wind power density (for different ground levels) are calculated to assess the wind power potential of Iran - Pak wind farm. The site weather condition that was used in this part is listed in table 5-1.

**Table 5-1: the site weather condition ***

| | |
|---|---|
| Air density calculation mode | Individual per WTG |
| Result for WTG at hub altitude | 1.159 kg/m$^3$ to 1.163 kg/m$^3$ |
| Air density relative to standard | 94.7 % |
| Annual mean temperature at hub alt. | 26.2 °C to 26.5 °C |
| Pressure at WTGs | 995.5 hPa to 1000.6 hPa |

* Calculation was based on "Wind Mast No. 1" with given Weibull distribution for the wind speed on the site.

The results of the wind speed distribution and wind power density are related to the preferred heights, so that the height, being one important factor, must be established, but which is neglected in most studies. Here, the power generated by a particular wind turbine and its capacity factors are investigated for different hub heights.

### 5-3-1- Suitable Tower Heights

Typically, wind speed increases with increasing height above the ground. For that reason higher towers can exploit higher wind speeds so that the annual energy production can be increased correspondingly. The counteracting effect is the respective additional investment cost for the tower and the foundation. In some countries available crane capacities could be a further limiting factor.

The tower heights for wind turbines are chosen to find a good combination of energy yield which is increasing with tower height, and costs for tower and foundation, which are also increasing with tower heights. Furthermore; for larger turbines, the tower heights are also increasing in general. Especially in lower wind speed areas the tendency towards higher hub heights can be found [12].

The use of larger hub heights, above 60 m and up to 100 m will cause higher costs for towers, foundations and the erection period, as well as higher crane costs.

It should be noticed that besides wind speed characteristics the choice of hub height depends on the terrain. Therefore the extrapolation of the wind speed at higher hub heights compared to the height of the measuring mast is associated with comparatively high uncertainties. These uncertainties could be reduced using higher measuring masts or higher models for the flow calculations like mesoscale models e.g. WAsP.

If these advanced options are not available, it will be necessary to choose a hub height, which does not exceed the height for qualified wind regime predictions for the specific site characteristics. At the Iran-Pak site meaningful prediction of the wind regime was considered possible up to hub heights of 75 to 100 m. Thus the costs related to these hub heights have been considered in the feasibility study for the Iran-Pak wind park. Beside the economic criteria, the wind shear also helps to choose a suitable hub height. The wind shear of site location is illustrated in figure 5-1.

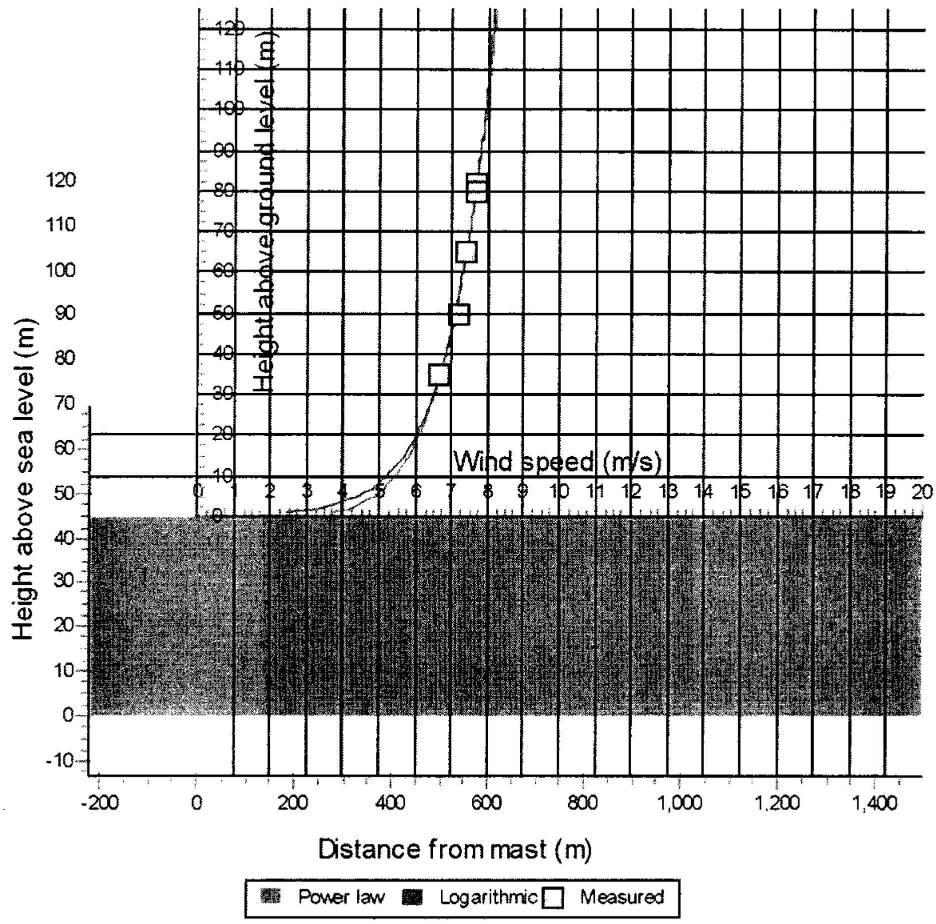



**Figure 5-1: Iran - Pak wind farm wind shear**

After considering the suitable hub height, the first step of turbine selection (by WindPRO) is study of the available wind data on site location (Meteo Calculation). In this step, the selection will be done on the base of wind parameters in hub height such as wind profile, wind shear, Weibull distribution parameters, wind rose, turbulence intensity, etc. The result of this step is illustrated in table 5-2.

**Table 5-2: Result of first step of turbine selection in WindPRO (Meteo Calculation)**

| WTG | Type | Rotor Diameter (m) | Hub Height (m) | Annual Energy (MWh) | | Mean Wind Speed (m/s) | Capacity Factor (%) |
|---|---|---|---|---|---|---|---|
| | | | | Result | Result -10% | | |
| VESTAS | V126 - 3.3 MW | 126 | 137 | 8975.6 | 8078 | 7.87 | 51.2 |

The second step in turbine selection is considering the terrain specifications (to find out more about data in this area, please see section 6-2). The result of this step is illustrated in table 5-3.

**Table 5-3: Result of first step of turbine selection in WindPRO (Atlas Calculation)**

| WTG | Type | Rotor Diameter (m) | Hub Height (m) | Annual Energy (MWh) | | Mean Wind Speed (m/s) | Capacity Factor (%) |
|---|---|---|---|---|---|---|---|
| | | | | Result | Result -10% | | |
| VESTAS | V126 - 3.3 MW | 126 | 137 | 7768.6 | 6992 | 7.18 | 44.3 |

The final step in turbine selection is considering the terrain specifications with the CFD model (WAsP). In this step the wind velocity perturbations induced by complex terrain and roughness changes are calculated. The result of this step is illustrated in table 5-4.

**Table 5-4: Result of first step of turbine selection in WindPRO (WAsP Calculation)**

| WTG | Type | Rotor Diameter (m) | Hub Height (m) | Annual Energy (MWh) | | Mean Wind Speed (m/s) | Capacity Factor (%) |
|---|---|---|---|---|---|---|---|
| | | | | Result | Result -10% | | |
| VESTAS | V126 - 3.3 MW | 126 | 137 | 9194.3 | 8275 | 7.96 | 52.4 |

After all, the suitable wind turbine for Iran - Pak proposed wind farm is VESTAS V126 - 3.3 MW. This turbine belongs to the class III A.

**Table 5-5: Selected wind turbines IEC wind classes**

| Turbine | Capacity (MW) | IEC IIA | IEC IIB | IEC IIIA |
|---|---|---|---|---|
| VESTAS V126 - 3300 kW | 3.3 | | | X |

## 5-4- Turbine Layout

For multi-turbine projects, siting becomes a bit more complicated. The prevailing wind in relation to the point of interconnection is a strong factor in determining the final configuration of project. Developers use different rules for laying out projects to achieve a balance between low installed cost and higher production. Some consulting firms begin laying out a project using the following rule-of-thumb: "*In the direction of the prevailing wind, the turbines should be spaced more than 7 rotor diameters apart. In the direction perpendicular to the prevailing wind, the machines should be more than 4 rotor diameters apart.*"

This means that a four-generator project that uses 82 meter diameter rotors may be expected to require a little over 200 acres of land. Taking into account the space requirements of the turbines as well as required setbacks from easement and property lines, a project this size will need more than a quarter part of land. This is a simplified example and should be used only as a place to begin understanding how to lay out project. The final project layout including the total space required in terms of land and turbine spacing is determined based on maximizing project economics. This is described in more detail in following parts.

## 5-4-1- Turbine Distances / Micro-siting

For the micro-siting certain minimum distances between the individual wind turbines have to be observed. A common rule of thumb specifies three to five rotor diameters in cross wind directions (less than four is possible under some circumstances) and six to eight rotor diameters in main wind direction as a minimum spacing between the individual turbines (in some cases it is recommended 10 D). The minimum distance of four times or less the rotor diameter in cross wind direction is only feasible in case the wind direction is strictly perpendicular to the row of wind turbines. The smallest distances in cross wind direction are determined by a layout development iteration process, carried out under the condition that the wake losses do not fall below a chosen average level for the individual turbines, which is considered as necessary for the economical operation of the wind farm (e.g. the wake losses do not cause decrease in energy output below 85 % for the following wind turbines). Depending on the location of the individual wind turbine and the ambient conditions (topography, location of nearby wind turbines, number of wind turbines towards the main wind direction) the distance between two adjacent turbines can be larger.

For the Iran - Pak wind project the minimal distances are summarized in the following table (table 5-6).

**Table 5-6: Minimal turbine distances for Iran - Pak Wind Park**

| Turbine type | Minimal Distance Between Turbines | | | |
|---|---|---|---|---|
| | In Cross Wind Direction | | In Main Wind Direction | |
| | [m] | [rotor diameter] | [m] | [rotor diameter] |
| VESTAS V126 - 3300 | 480 | 4.8 | 770 | 7.7 |

**Table 5-7: VESTAS V126 3.3 MW Turbine Layout Coordinates**

| UTM WGS84 Zone 42 | East | North | Z (m) |
|---|---|---|---|
| 1 | 387,967 | 2,576,535 | 50.0 |
| 2 | 388,150 | 2,756.091 | 44.5 |
| 3 | 388,333 | 2,755,647 | 43.3 |
| 4 | 387,310 | 2,756,131 | 50.0 |
| 5 | 387,493 | 2,755,687 | 45.0 |
| 6 | 387,073 | 2,755,707 | 47.2 |
| 7 | 387,858 | 2,754,800 | 45.2 |
| 8 | 387,913 | 2,755,667 | 45.0 |
| 9 | 388,224 | 2,753,912 | 75.0 |
| 10 | 386,653 | 2,755,728 | 47.4 |
| 11 | 386,836 | 2,755,284 | 45.0 |
| 12 | 387,019 | 2,754,840 | 45.0 |
| 13 | 387,201 | 2,754,396 | 45.0 |
| 14 | 387,384 | 2,753,952 | 51.0 |
| 15 | 387,566 | 2,753,508 | 58.2 |


**Figure 5-2: Layout of VESTAS V126 3.3 MW wind turbines for the Iran - Pak Wind Park in Pakistan**

## 5-5- Park Turbulence

To ensure the close spacing of the wind turbines will not affect (decrease) the lifetime of the turbine and its components, a turbulence calculation is necessary. The turbulence of the wind flow is a factor which causes stress and fatigue to several components of a wind turbine including blades, bearing and gearbox. It consists of the so called ambient turbulence applied to the wind flow by the coarseness of the earth (vegetation, buildings, rocks etc.) and the turbulence added by the other wind turbines of a wind park.

The impact of the turbulence to each individual wind turbine can be calculated and analyzed by means of the WindPRO software package using for example the Frandsen Turbulence Model (as recommended in IEC 61400 1, Rev 2) for GFK-Materials[3] of blades.

Turbines operating in wakes are subjected to significant higher structural loading than turbines operating in the free wind. Appropriate turbulence calculations should be made before selecting the proper turbine design class when having clusters of turbines. In this study, the wake added turbulence has been calculated using three different wake models and seven different turbulence models. These models are typically very different in detailing level – and possible also in accuracy. The models range is from simple engineering models to the more advanced computational fluid dynamic (CFD) models. The CFD-models are typically also very demanding in terms of calculation time [13, 14].

In the analysis the following wake added turbulence models have been implemented and tested: Danish Recommendation: 1992, Eddy Viscosity: 2003 (B. Lange), Quarton:1996 (D.C. Quarton & J.F. Ainslie), G.C.Larsen: 1998, Dutch TNO Laboratory (EWTS II), S. Frandsen: 1999 (Efficient turbulence model) and the DIBt Richtlinie: 2004. The turbulence model must be used in connection with a wake (wind field) model: In the analysis, the following wake models are included: PARK model: 1996 (N.O. Jensen), Eddy viscosity model: 1988 (J.F. Ainslie), G.C. Larsen: 1998 (European Wind Turbine Standards II).

Finally the wake model of G.C. Larsen: 2008 European Wind Turbine Standards II (EWTS) was suitable for Iran -Pak wind farm use and for the turbulence model, the DIBt Richtlinie: 2004 was used. The result of this part is illustrated in figure 5-3. As it can be seen in the mentioned figure; the park turbulence is acceptable through the IEC 61400 -1 (Ed 2) standard [15].

[3] Other common names for fiberglass are glass-reinforced plastic (GRP) or glass-fiber reinforced plastic (GFRP) ***Fiberglass is also known as GFK, for German: Glasfaserverstärkter Kunststoff***

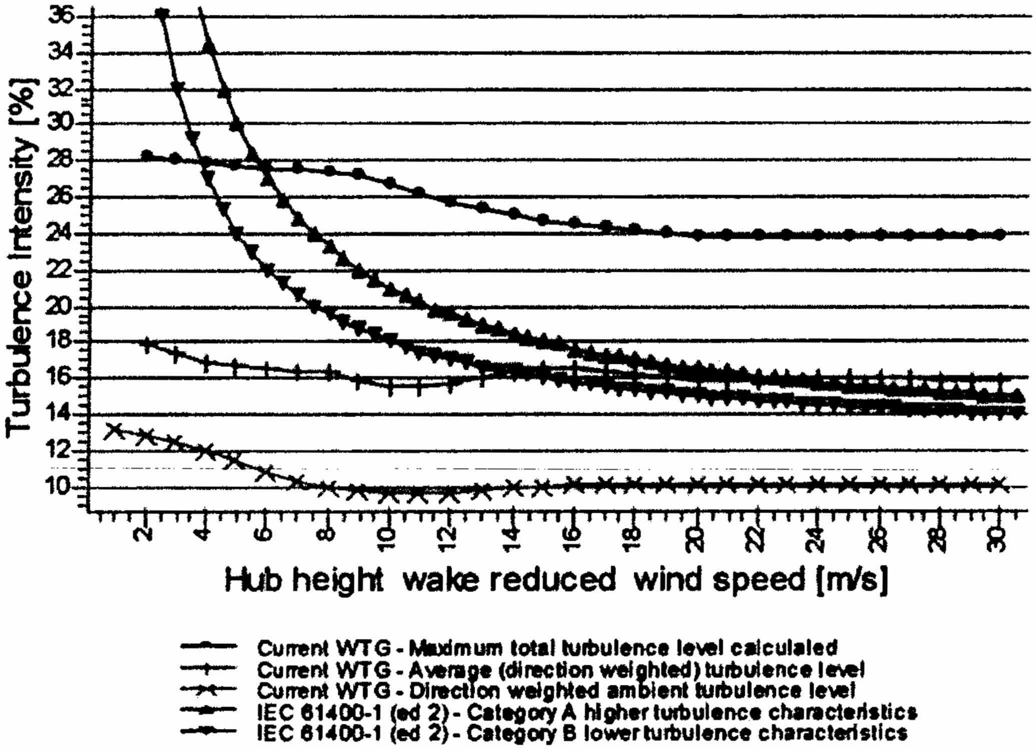



Figure 5-3: The VESTUS V126 - 2000 kW Layout's Turbulence

## 5-6- Noise Impact

The target of the noise assessment is to investigate the potential noise impact of the wind turbine operation on sensitive areas in the vicinity of the wind farm. The advisable distances between residences and the proposed wind turbine sites depend on a variety of factors including local topography, eventually background noise and the size of wind farm development. Official demands with regard to noise limit values for the operation of a wind park in Pakistan are not specified. Therefore a prediction of the sound produced by the proposed wind farm in the surrounding area and an optimization of the micrositing was made in accordance to the strict German noise limit regulations [16].

The calculation method is specified in German ISO 9613-2 and implemented in the WindPRO software used for the estimation of the noise effects. The sound emission data used in the calculation and the sound power level of the turbine bases on information given by the turbine manufacturers. Correspondingly the following standard values for noise emission can be considered depending on the utilization of the area:

**Table 5-11: Noise Standard according to German standards**

| Noise standards | Noise emission [dB(A)] | |
|---|---|---|
| Utilization | Day time 6:00-22:00 | Night time 22:00 - 6:00 |
| Regimen and hospital areas | 45 | 35 |
| Exclusive residential areas | 50 | 35 |
| General residential areas | 55 | 40 |
| Village centers, mixed utilization with small trades | 60 | 45 |
| Working areas | 65 | 50 |
| Industrial areas | 70 | 70 |

Considering that identified noise sensitive areas can be assigned to the Village centers with mixed utilization, the limiting noise standard for the operation of the wind farm in the example of Iran - Pak is an impact level of 45 dB (A) at night time (See figure 5-4).

## 5-7- Shadow Impact

When the sun is just above the horizon, the shadows of the wind turbine generators can be very long and can move across houses (windows) for short periods of time. If this happens for longer period, it causes stress to the inhabitants. The exact position and time period of shadow can be calculated very accurately for each location, taking into account the structure of topography and the movements of the sun. Official Boundary levels do not exist for the shadow flicker effect. In Germany, a commonly accepted value is the maximum of 30 hours shadow caused by the wind turbines per year, and 30 minutes shadow per day and we will apply this standard in Pakistan too.

The estimations are carried out for the worst case that the sun is always shining, 365 days per year. An additional calculation can be performed using the real sunshine probability. However the Iran - Pak wind farm is surrounded by barren and infertile land and there is no residential area in distance of 5 km of site district, consequently the shadow flicker has no considerable effect.

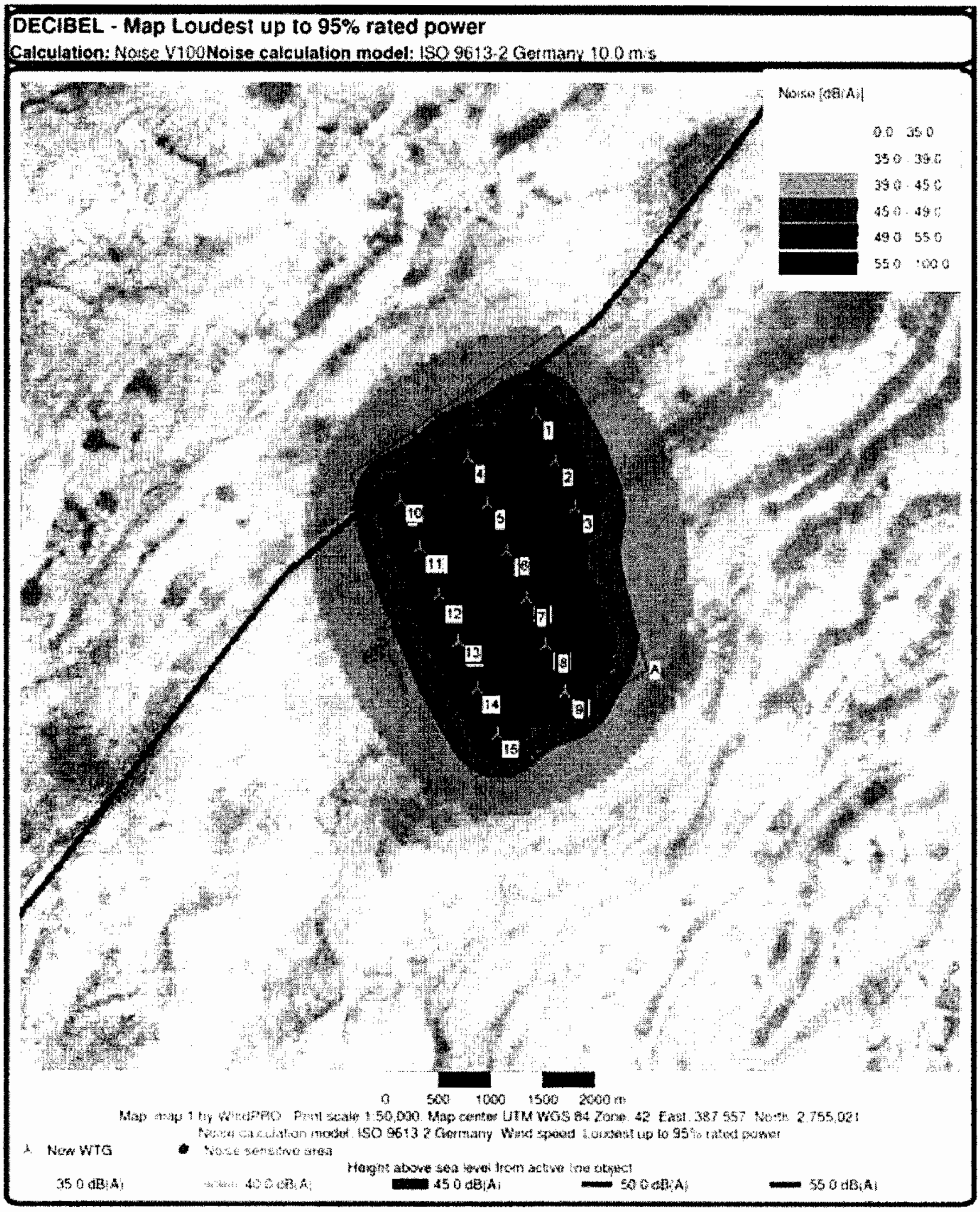



**Figure 5-4: VESTAS V126 Sample Noise Model**

# CHAPTER VI:

## Energy Estimation

## 6-1- Energy Estimation

The calculation of the wind resources on-site and the corresponding energy production are based on the assessment of wind potentials by anemometric measurement. The wind data is processed by software packages to calculate the expected wind energy yield for the proposed site.

This calculation by software packages like WindPro and WAsP combines a great number of characteristics (site conditions and wind speed distribution) [17]:

- Orographic description and roughness values as a quantitative description for the friction of the surface causing a slowdown of the near-surface air flow
- Valleys and similar terrain structures as an influence on wind speed differences within the proposed wind park area. For instance valleys can act as a blast pipe, concentrating the air flow.
- Wind shear as determined by measurement of wind speed in different heights and mathematic extrapolation
- Wind turbine parameters and the corresponding power curves of all proposed turbine types; scenario analysis for the different turbine types are worked-out
- Air density

In a reverse process, the generalized regional wind climate is then applied to topography, surface description and obstacles at the vicinity of each individual wind turbine, providing the wind flow at this point even if the wind data has measured in some distance which can be, depending on the terrain, up to several kilometers.

A very important aspect of estimation of energy production for use within a feasibility study is the determination of potential losses and uncertainties caused by uncertainties in variables and parameters of the used model. Meteorological phenomena can only be predicted to a certain limited degree. As a consequence it is not possible to make an exact forecast of the wind conditions even if long-term reference data is used.

Description of uncertainties includes [18]:

- Turbine Availability - describes the percentage of a year (i.e. 8760 hours) where the turbine is able to generate electrical energy while being connected to the grid.
- Electrical Losses - the electrical losses depend on the resistance of the conductors and on the current intensity.
- Wind Speed related Uncertainties

- Uncertainties of the Wind Data

The uncertainties are summarized to calculate a value for the complete uncertainties in energy yield estimation, which can be used for the calculation of financial returns of the project. The estimation of energy yield as well as the corresponding uncertainties is calculated for several scenarios to allow extensive comparison before a layout is implemented.

For providing this selection as well as possible; all the following parts (6-2) were considered.

## 6-2- Model Input Parameters

Besides the processed wind data, important input parameters for the energy yield calculation model are the terrain description, comprising of the topographical (Orographical) model and the description of the earth's surface (roughness description).

### 6-2-1- Topography

A method to gather data describing the topographical terrain is the analysis of data collected by site survey. The topography data base was provided by the US Geological Survey.

The data in between these lines can be interpolated using the WindPRO software to gain the topographical model of the proposed site, with a height contour density of 5 meters, as shown in Figures 6-1 till 6-3 (these figures show the orographic maps of the Iran - Pak in Pakistan, where a feasibility study for a wind park has been conducted by Ghods-Niroo (GNEC).

Besides this advanced method of gathering topographical data, national or regional institutions can be asked for topographical maps of the area. The developers have to take care, whether the maps are available in an appropriate scale. Sources should be compared regarding accuracy and potential failures.

The height data is than processed to a three-dimensional digital elevation model of the wind farm site. An example for the Iran - Pak site is shown in figure 6-4.

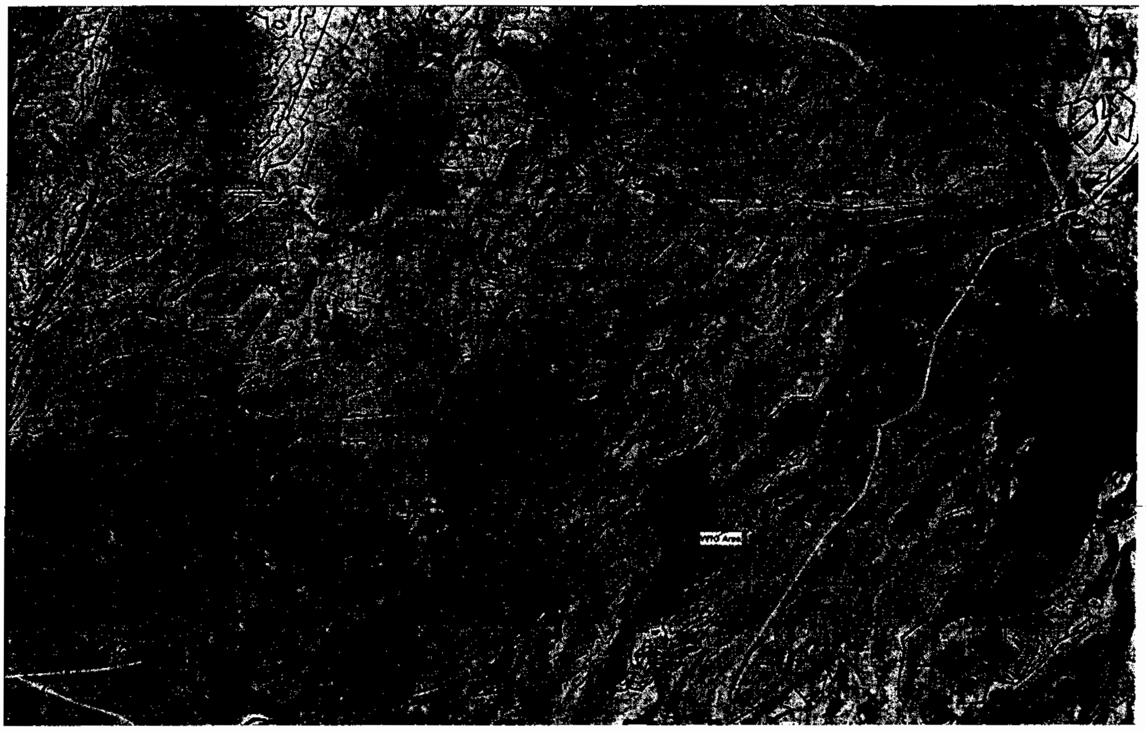


**Figure 6-1: Height Contours Map of Iran - Pak Wind Park Site In Pakistan**

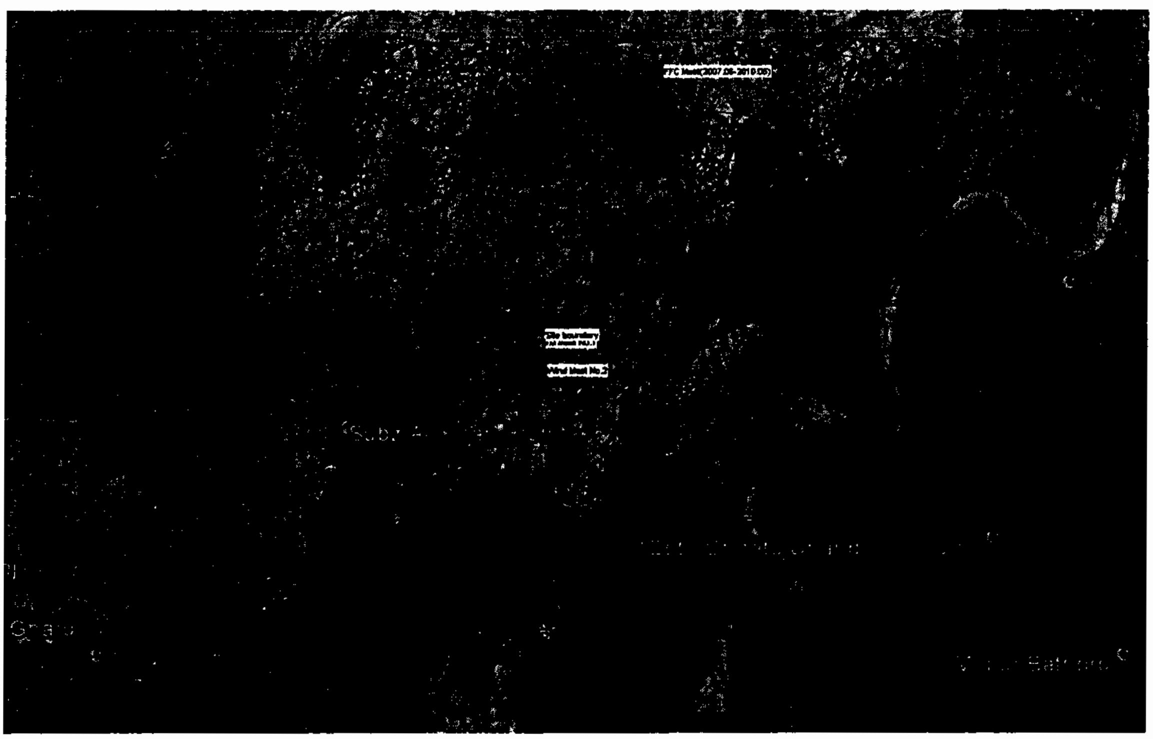


**Figure 6-2: Triangulation Map of height contour (TIN) of Iran - Pak Wind Park Site In Pakistan**

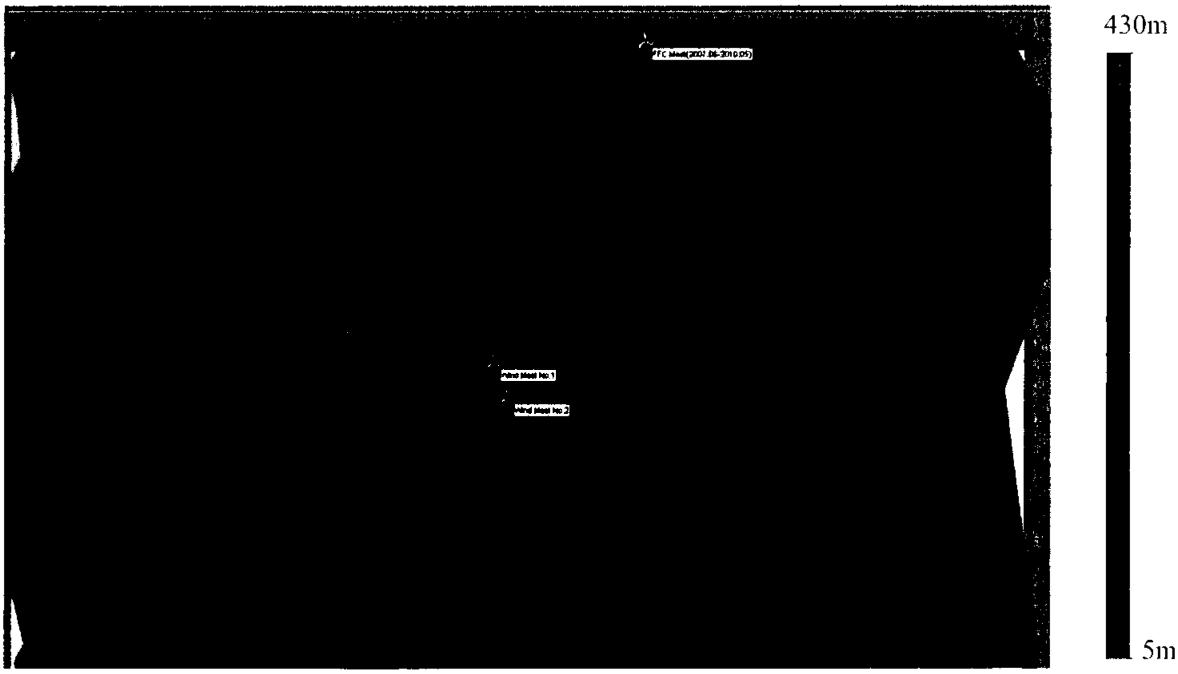



**Figure 6-3: Optimization of height contour map of Iran - Pak wind park site in Pakistan**

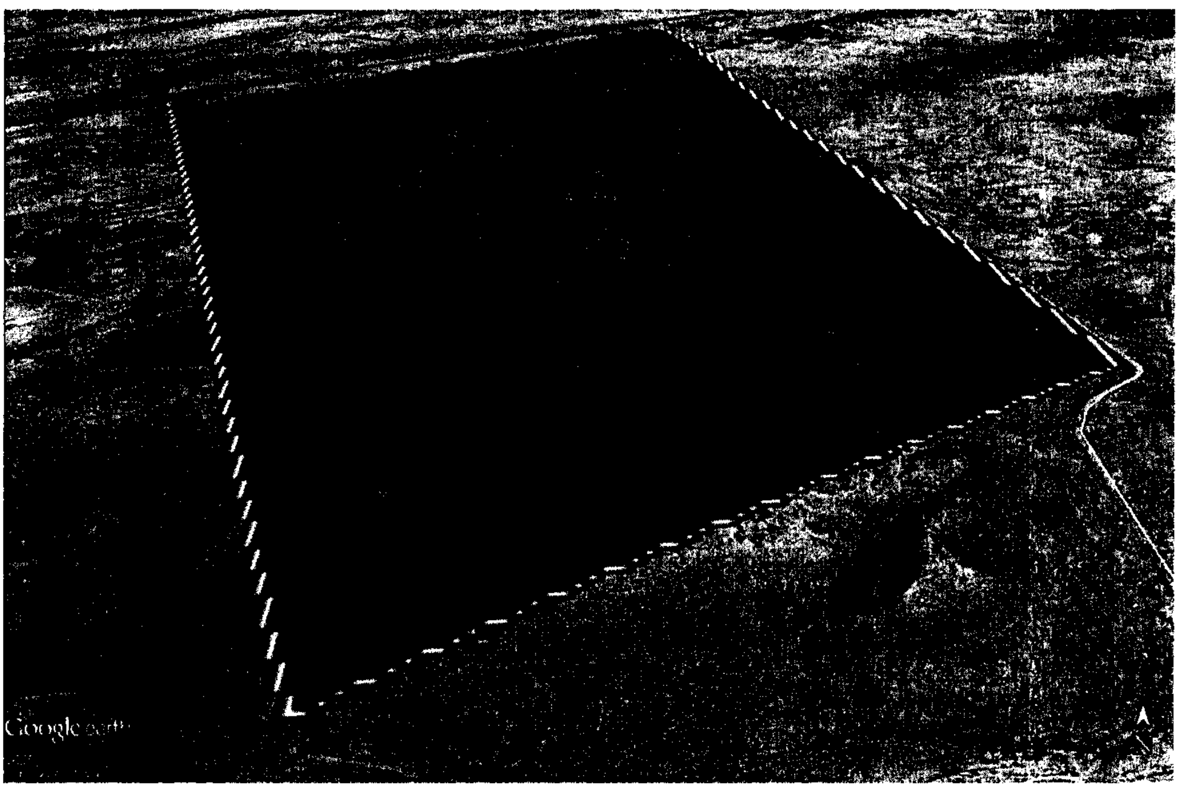


**Figure 6-4: Three-dimensional view of turbine layout in Iran - Pak site**

## 6-2-2- Roughness

For the model simulations the roughness classification for the surface in close proximity to the wind farm site is derived from topographical maps, data obtained during site visits as well as aerial photos of the region. A basic description of the roughness classes is given in the following (roughness length is a second roughness description unit), it has to be noted that the roughness class is a defined value which cannot be measured directly. The roughness length describes the height where the wind speed in a logarithmic wind profile is becoming zero; the coarser the surface, the higher the roughness length [16].

**Table 6-1: roughness classes by RISO**

| Description of surface | Roughness length | Relative energy | Roughness class |
|---|---|---|---|
| Water areas | 0,0002 | 100 | 0 |
| Mixed Water and land area of very smooth land | 0,0024 | 73 | 0,5 |
| Open farmland with no crossing hedges and with scattered buildings. Only smooth hills | 0,03 | 52 | 1 |
| Farmland with some buildings and crossing hedges of 8m height and about 1250 m apart. | 0,055 | 45 | 1,5 |
| Farmland with some buildings and crossing hedges of 8m height and about 800 m apart. | 0,10 | 39 | 2 |
| Farmland with some buildings and crossing hedges of 8m height and about 250 m apart. | 0,20 | 31 | 2,5 |
| Villages, small towns, very closed farmland with many or high hedges, Forrest, many abrupt orographic changes. | 0,40 | 24 | 3 |
| Large towns, cities with extended build-up areas | 0,80 | 18 | 3,5 |
| Large cities with build-up areas and high buildings | 1,6 | 13 | 4 |

As an example for a roughness description of Iran - Pak site is presented in the Figure 6-5 and table 6-2.

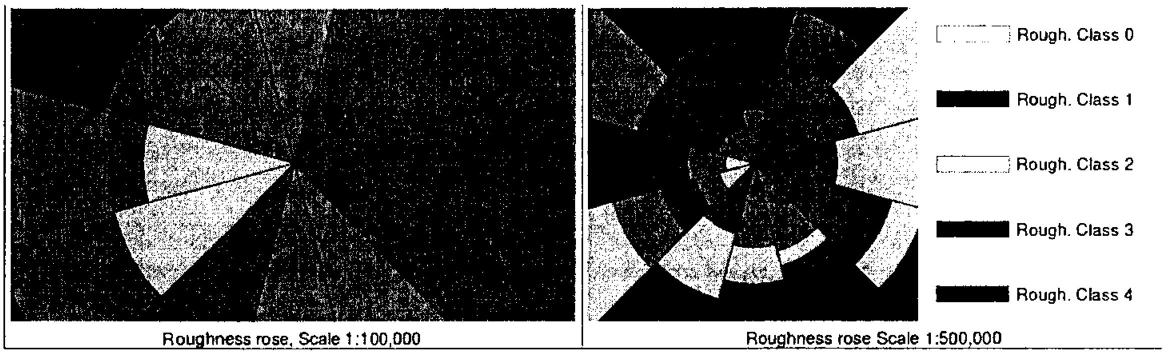



**Figure 6-5: Roughness rose for Iran - Pak wind park site in Pakistan in two scales**

**Table 6-2: Roughness rose classification table for Iran - Pak wind park site in Pakistan**

**Terrain classification**

**Roughness classification (Roughness length)**

| Sector | Roughness at WTG | Distance to 1. change [m] | Roughness after 1. change [m] | Distance to 2. change [m] | Roughness after 2. change [m] | Distance to 3. change [m] | Roughness after 3. change [m] | D 4 [m] | R 4 [m] |
|---|---|---|---|---|---|---|---|---|---|
| 0 N | 0.0015 | 4,275 | 0.0040 | 9,675 | 0.0110 | 17,050 | 0.0040 | | |
| 1 NNE | 0.0024 | 12,475 | 0.0300 | | | | | | |
| 2 ENE | 0.0024 | 8,525 | 0.0005 | | | | | | |
| 3 E | 0.0024 | 6,550 | 0.0005 | | | | | | |
| 4 ESE | 0.0024 | 8,850 | 0.0040 | 11,225 | 0.0005 | 13,900 | 0.4000 | | |
| 5 SSE | 0.0015 | 7,050 | 0.0005 | 8,250 | 0.0040 | 9,500 | 0.4000 | | |
| 6 S | 0.0015 | 6,575 | 0.0005 | 9,450 | 0.4000 | | | | |
| 7 SSW | 0.0024 | 5,650 | 0.0005 | 10,925 | 0.4000 | | | | |
| 8 WSW | 0.0005 | 2,950 | 0.0015 | 4,925 | 0.0040 | 7,575 | 0.0015 | 11,500 | 0.0005 |
| 9 W | 0.0005 | 2,375 | 0.0015 | 5,350 | 0.0040 | 13,875 | 0.0015 | | |
| 10 WNW | 0.0015 | 3,100 | 0.0040 | 9,475 | 0.0015 | | | | |
| 11 NNW | 0.0015 | 2,975 | 0.0040 | 10,325 | 0.0110 | 15,750 | 0.0040 | | |

## 6-2-3- Wind Shear

In many assessments of the wind potential the upper anemometers of the wind measurement are installed at a height of 40 m above ground while the hub height of modern wind turbines today often reaches heights between 70 m and 100 m above ground level. To estimate the wind regime at hub height of the wind turbines (the WAsP model simplifies the wind speed distribution over the rotor as concentrated to the hub height) the wind speed is extrapolated.

In Iran - Pak wind farm, two 80 meters wind mast were installed that really reduce the error of extrapolation of wind shear by height due to the real measured wind data in 80 m. An example for a calculated wind profile (increase of the wind speed with height) for the main wind direction of this site (sector south-southwest) for the selected wind turbine (VESTAS V126 - 3.3 MW) is displayed in Figure 6-6.

**Site Coordinates** UTM WGS 84 Zone: 42 East: 388,017 North: 2,754,680

| | |
|---|---|
| **Air density calculation mode** | Individual per WTG |
| Result for WTG at hub altitude | 1.161 kg/m³ to 1.162 kg/m³ |
| Air density relative to standard | 94.8 % |
| **Hub altitude above sea level (asl)** | 123.7 m to 130.7 m |
| **Annual mean temperature at hub alt.** | 26.3 °C to 26.4 °C |
| **Pressure at WTGs** | 998.3 hPa to 999.1 hPa |

**Wind data**

| Wind statistics | Distance [km] | Weight [%] |
|---|---|---|
| PK Wind Mast No.1 - 2 80.00 m.lib | 1 | 36 |
| PK Wind Mast No.2 - 2 80.00 m.lib | 1 | 64 |

**All sectors**

| Height | Mean wind speed [m/s] | A-parameter [m/s] | k parameter | Wind energy [kWh/m²] | Yield [MWh] | Yield change [MWh] | Orography [%] |
|---|---|---|---|---|---|---|---|
| 5 | 4.79 | 5.4 | 1.94 | 1,114 | 3,415 | -5,779 | 6.1 |
| 10 | 5.41 | 6.1 | 2.09 | 1,488 | 4,454 | -4,740 | 4.9 |
| 15 | 5.77 | 6.5 | 2.18 | 1,736 | 5,104 | -4,091 | 4.2 |
| 20 | 6.03 | 6.8 | 2.24 | 1,930 | 5,578 | -3,617 | 3.8 |
| 25 | 6.22 | 7.0 | 2.28 | 2,085 | 5,946 | -3,248 | 3.5 |
| 30 | 6.45 | 7.3 | 2.36 | 2,256 | 6,372 | -2,823 | 3.3 |
| 35 | 6.64 | 7.5 | 2.43 | 2,407 | 6,737 | -2,458 | 3.1 |
| 40 | 6.80 | 7.7 | 2.49 | 2,541 | 7,054 | -2,141 | 2.9 |
| 45 | 6.94 | 7.8 | 2.54 | 2,663 | 7,335 | -1,860 | 2.8 |
| 50 | 7.07 | 8.0 | 2.58 | 2,775 | 7,587 | -1,607 | 2.7 |
| 55 | 7.25 | 8.2 | 2.58 | 2,993 | 7,932 | -1,263 | 2.5 |
| 60 | 7.41 | 8.3 | 2.58 | 3,202 | 8,238 | -956 | 2.3 |
| 65 | 7.56 | 8.5 | 2.58 | 3,401 | 8,513 | -681 | 2.2 |
| 70 | 7.70 | 8.7 | 2.57 | 3,595 | 8,760 | -434 | 2.1 |
| 75 | 7.83 | 8.8 | 2.57 | 3,785 | 8,988 | -207 | 2.0 |
| 80 | 7.96 | 9.0 | 2.56 | 3,970 | 9,194 | 0 | 1.9 |
| 85 | 8.07 | 9.1 | 2.56 | 4,149 | 9,385 | 190 | 1.8 |
| 90 | 8.18 | 9.2 | 2.56 | 4,317 | 9,560 | 365 | 1.7 |
| 95 | 8.28 | 9.3 | 2.56 | 4,485 | 9,719 | 524 | 1.7 |
| 100 | 8.38 | 9.4 | 2.56 | 4,643 | 9,866 | 672 | 1.6 |
| 105 | 8.54 | 9.6 | 2.54 | 4,915 | 10,090 | 896 | 1.5 |
| 110 | 8.68 | 9.8 | 2.54 | 5,181 | 10,293 | 1,098 | 1.4 |
| 115 | 8.82 | 9.9 | 2.53 | 5,444 | 10,480 | 1,286 | 1.4 |
| 120 | 8.96 | 10.1 | 2.52 | 5,704 | 10,654 | 1,460 | 1.3 |
| 125 | 9.09 | 10.2 | 2.51 | 5,964 | 10,814 | 1,620 | 1.2 |
| 130 | 9.21 | 10.4 | 2.51 | 6,215 | 10,963 | 1,768 | 1.2 |
| 135 | 9.33 | 10.5 | 2.50 | 6,469 | 11,100 | 1,906 | 1.1 |
| 140 | 9.45 | 10.6 | 2.49 | 6,719 | 11,227 | 2,032 | 1.1 |
| 145 | 9.56 | 10.8 | 2.49 | 6,959 | 11,344 | 2,149 | 1.0 |
| 150 | 9.67 | 10.9 | 2.49 | 7,194 | 11,451 | 2,257 | 1.0 |
| 155 | 9.77 | 11.0 | 2.48 | 7,433 | 11,551 | 2,356 | 0.9 |
| 160 | 9.87 | 11.1 | 2.47 | 7,661 | 11,644 | 2,450 | 0.9 |
| 165 | 9.97 | 11.2 | 2.47 | 7,884 | 11,730 | 2,535 | 0.8 |
| 170 | 10.06 | 11.3 | 2.47 | 8,103 | 11,811 | 2,617 | 0.8 |
| 175 | 10.15 | 11.4 | 2.46 | 8,319 | 11,886 | 2,692 | 0.8 |
| 180 | 10.24 | 11.5 | 2.46 | 8,529 | 11,953 | 2,758 | 0.7 |
| 185 | 10.33 | 11.6 | 2.46 | 8,733 | 12,017 | 2,823 | 0.7 |
| 190 | 10.41 | 11.7 | 2.45 | 8,934 | 12,077 | 2,882 | 0.6 |
| 195 | 10.49 | 11.8 | 2.45 | 9,131 | 12,132 | 2,938 | 0.6 |
| 200 | 10.57 | 11.9 | 2.44 | 9,323 | 12,184 | 2,989 | 0.6 |

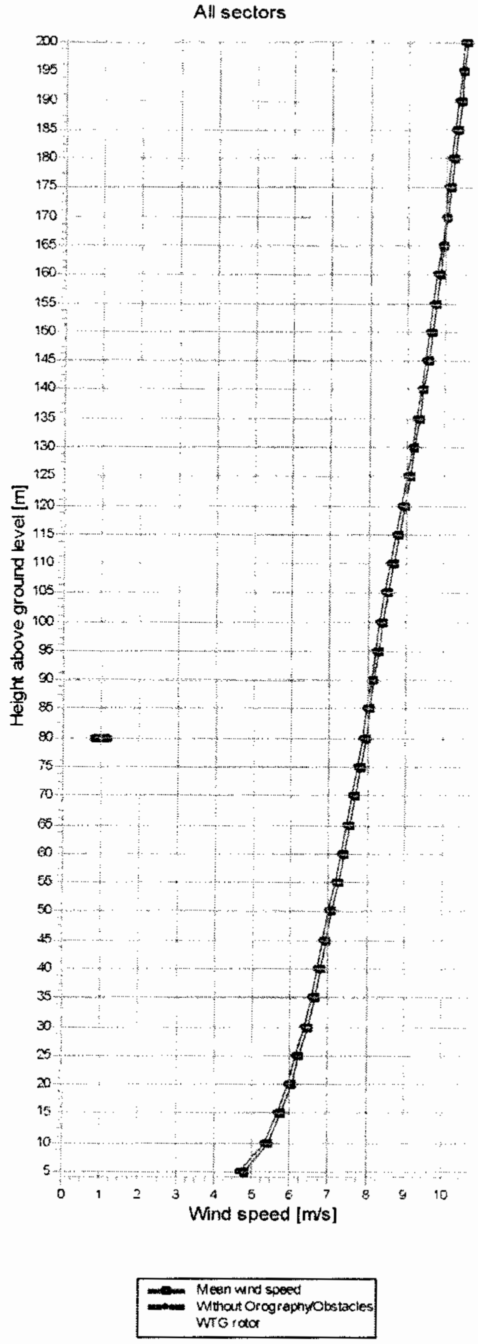



**Figure 6-6: WAsP Interface - Wind Profile Detailed - WTG: VESTAS V126 - 3.3 MW**

Combining considerations of terrain and roughness, the wind profile for the area of each individual wind turbine is then calculated by WAsP and Wind Park modules of WindPRO software. The extrapolation from all measuring heights power law or logarithmic law to 80 m hub height can be compared with wind speed at 137 m height measured in this site.

## 6-2-4- Wind Turbine Parameters

To estimate the performance of different turbine types for the development of a new project usually several scenarios using different turbine types are calculated. Important turbine parameters, which should be included, are hub height, nominal power, rotor diameter, WTG class and etc.

## 6-2-5- Power Curve and Air Density

The Power curve of a wind turbine is an important parameter, describing the relation between the wind speed on site and the respective electrical energy output. Power curves and ct-values (a parameter for the calculation of the wake effect) of the turbines under consideration are applied for the energy calculation. Power curves which had been measured by independent institutions are of higher quality than calculated ones. Due to the fluctuations of both the characteristics of the wind turbine components, and the measuring conditions; power curves of different measurements differ slightly between each other.

Several manufacturers are thus providing power curves which are calculated from the results of several measured ones; the performance of this calculated power curves might be contractually guaranteed by the manufacturers.

During the calculation of the energy yield, the power curves, given for the standard conditions of air density = 1.225 kg/m$^3$ are adapted to the air density of each individual turbine location at hub height, with the transformed power curve for the average air density. The air density can be calculated by WindPRO for each individual wind turbine according to the site conditions, height above sea level plus the hub height of the turbines (e.g. 60m+80m) and an annual average temperature level (e.g. 26.8°C / 27°C). As verification, the calculated adaptations for air density at the turbine sites should be compared to information provided by two wind masts in site location. Figure 6-7 shows the power curve of VESTAS V126 - 3.3 MW wind turbine at an air density of $\rho$ = 1,225kg/ m$^3$.

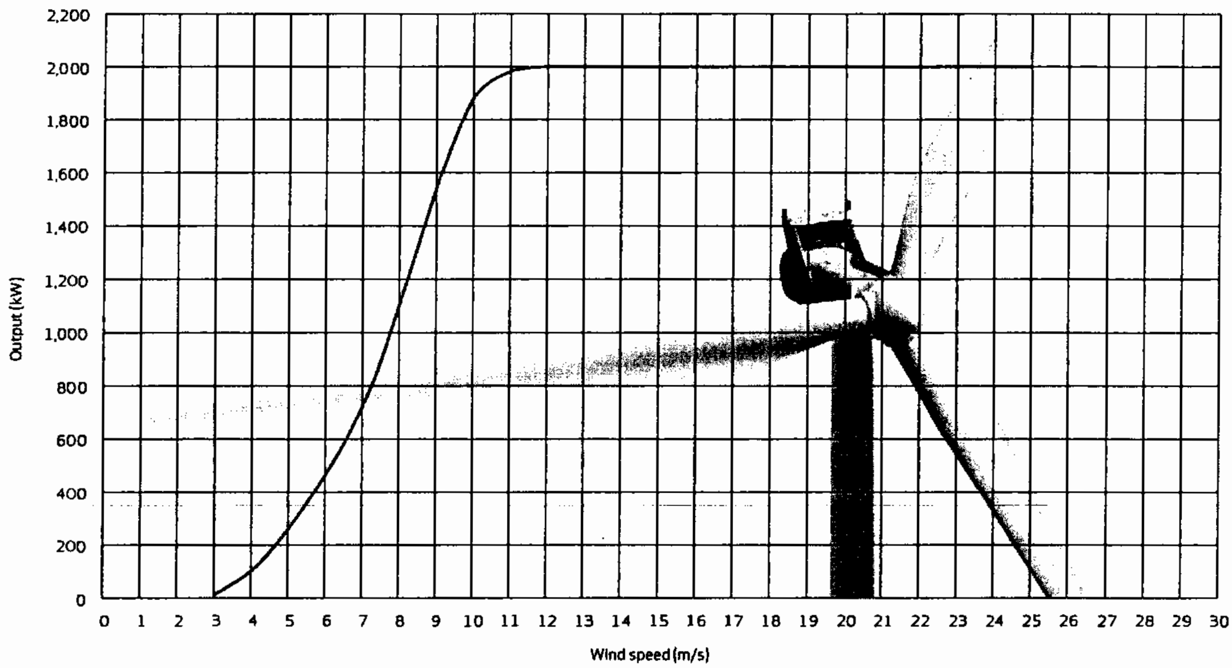



**Figure 6-7: Power curves for VESTAS V126 - 3.3 MW wind turbine**

## 6-2-6- Losses and Uncertainties

Meteorological phenomena can only be predicted to a certain limited degree. As a consequence it is not possible to make an exact forecast of the wind conditions even if long-term reference data (which can only represent the past) is used. Furthermore, data collection and processing is always afflicted with errors and inaccuracies as is every mathematical or physical model used to describe or predict real procedures. To compensate the inaccuracies in modeling approach and basic input data, it is advisable to use factors of safety to adjust, or discount the final output. Two blocks determine the factors of safety: losses and uncertainties.

Losses are found on the whole energetic transformation chain from the rotor (kinetic energy) to the substation (electrical energy). The losses are simple add-ups to the total reduction of the calculated energy yield. In detail:

### 6-2-6-1- Losses Due to Park Efficiency

After passing the rotor of a wind turbine, the wind has a decreased speed due to the kinetic energy taken away by the rotor and increased turbulence caused by the rotating rotor and the difference in speed compared to the undisturbed flow. Until the speed difference to undisturbed flow is not equalized, the result is a lower energy yield for the wind turbine following in the direction of the flow. These losses are called array or wake losses. The park efficiency for VESTAS V126 - 3.3 MW wind turbine is mentioned and illustrated in table 6-3

**Table 6-3: The Wind Park Efficiency for Selected Wind Turbines**

| Wind Turbines | Park Efficiency |
|---|---|
| VESTAS V126 - 3.3 MW | 92.2 |

### 6-2-6-2- Losses Due to Turbine Availability

The turbine availability is the percentage of a year (i.e. 8760 hours) where the turbine is able to generate electrical energy while being connected to the grid. Reasons for the non-availability of a wind turbine are various, and include downtimes for regular maintenance and servicing, component failures (including defect sensors), overheating of components, repairs or exchange of components, as well as errors and downtimes of the superior electrical grid. The turbine availability can be set to a value by taking into account the experience in the operation of wind turbines in the region and skills of local staff. For a country without experiences and a high need for capacity building during the first years of a project a standard value of 95% can be applied. Later on and after the first years of sufficient turbine availability averages, the aim should be to raise the level up to 97% which could be seen as a good value for the first wind parks in a country with few experiences in wind turbine operation. A common value for countries with a very established wind energy industry, an availability of 98% is assumed.

### 6-2-6-3- Electrical Losses

The electrical losses depend on the resistance of the conductors and on the current intensity. To assess the current intensity of the wind park the following methodology is used: the duration curve of the wind park for one year is approximated by a two stage approach. For 10% of the year (876 hours) full power is assumed and for the rest of the year (7,884 hours) the load is estimated to 25% of full load.

For this power pattern of the wind park, the losses of the internal wind park cabling and connection to the substation of the wind farm are calculated relative to the total energy output.

For the Iran - Pak wind park in Pakistan the following values have been calculated:

- internal park cabling: 0.2%
- internal park transmission lines: 0.5%
- turbine transformers: 1.1%
- transmission line: 0.7%
- substation transformer 0.5%

The total electrical losses of the park are estimated at 3% of that amount of electricity which is produced by the wind turbines.

### 6-2-6-4- Miscellaneous Losses

In addition to the transmission losses and lost production due to reduced availability a number of other losses should be taken into account. The aerodynamic turbine performance described by the power curve is strongly depending on the profile and surface of the wind rotor blades. Blade fouling from dirt or insects on the surface of it can lead to non-expected change of airfoil characteristics and to lower energy yield. Whether a change of blade characteristics has to be expected, depends on climatic conditions like humidity. For example; an average air density of a temperature of 27° in 80 m above sea level in Pakistan may provide thermal problems for the wind turbines

High wind control losses are caused by the turbine cut-in and cut-out strategy. The turbines will cut-off when cut-out wind speed is reached and will not re-cut-in until wind speed is below a defined wind speed level, lower than the cut-out level.

A reduction factor of 0.5% to the gross energy output was applied to take these effects into account.

### 6-2-6-5- Wind Speed related Uncertainties

Uncertainties cover the inaccuracy of the data processing from the measurement, the internal data processing and the long-term prediction. A percentage value describes the standard deviation of scattering results around the expected true value. For the energy calculation, these wind speed-related uncertainty values have to be transformed to the energy production level. Additional uncertainties have to be determined for modeling and mathematical algorithms.

### 6-2-6-6- Uncertainties of the WAsP-Model

The WAsP (Wind Atlas Analysis and Application Program) software is a proven tool used in the wind industry for more than 15 years. As every model; it has limitations and uncertainties mainly due to the simplifications behind it which had been done to handle the calculations on desktop computers in an acceptable time frame. Mesoscale meteorological models require powerful computers and a calculation time of several days. However, WAsP has been used for a considerable time worldwide and the uncertainties have been evaluated over the years.

In case of Iran - Pak, the existence of modestly shaped hills and ridges lead to a sufficient quality of the calculation.

- Transfer Wind to Energy

  The discrete wind flow from discrete wind directions is simplified to 10-minute average values for 12 direction sectors and statistically preprocessed before being applied to the power curve.

- Site modeling

  Basically consists of two input parameters: the topographical model and the surface description (roughness surface).

- Flow modeling

  WAsP has been developed for use in areas with only modestly shaped hills which is the case at Iran - Pak site. The uncertainty of the flow modeling is set to the medium value of 3.0%.

- Wake modeling

  The uncertainty of the selected wake model will be low, if the area of the wind farm itself is nearly plain (no additional uncertainties due to the influence of the terrain). In case a high roughness length is found for the terrain, the uncertainty in wake modeling can be much higher.

To calculate the total uncertainty all single uncertainties can be considered as stochastically independent and the commonly used way of estimating the joint uncertainty of independent (un-correlated) uncertainties is to calculate the RMS (Root Mean Square) value.

### 6-2-6-7- Uncertainties of the wind data

The reliability of the WAsP calculation is highly dependent on the quality of the input parameters of which wind data is the most important one. The collection and processing of wind data is subject to several uncertainties.

- Anemometer calibration

  Anemometers should be calibrated in order to secure that the measured wind speed equals the actual wind speed.

- Anemometer characteristics

  Describes the uncertainty of the quality by which the anemometer detects the wind flow and processes the values to digital data.

- Mounting error

  The anemometer has to be vertically mounted. The uncertainty describes the effect if this is not done properly.

- Data recording

  Describes the uncertainties related to processing and storage of the data provided by the anemometer and the wind vane in the data logger.

- Terrain description

  It describes the uncertainty of the influence of the terrain to the measurement. Inclined wind flow and strong turbulence cannot be measured accurately by a cup anemometer.

- Long term correlation (wind speed and wind direction)

  The data used for the long term correlation as well as the MCP-Process includes uncertainties; MCP reduction was 0.4%. (See figure 4-13)

To calculate the total uncertainty all single uncertainties can be considered as stochastically independent and the commonly used way of estimating the joint uncertainty of independent (un-correlated) uncertainties is to calculate the RMS value.

**6-2-6-8- Uncertainties of the Power Curve**

It has to be considered that the power curve used for the gross energy calculation is also subject to uncertainties which had been described in the part 'Power curve and air density'. Due to the non linear relation of mean wind speed and energy these uncertainties cannot be integrated into the uncertainties of wind conditions but have to be dealt with separately. In the following part an example for the calculation of the uncertainties of the energy yield for one wind turbine type is given.

The uncertainty of the power curve is, assuming the power performance of the turbine as independent of the energy deviation due to wind uncertainties, connected to the uncertainties of the energy yield by the following equation:

The turbine supplier usually gives a guarantee of 95% of the energy values, which leads to an uncertainty to the predicted figures of 5%; the actual guarantee value has to be negotiated with the manufacturer, the uncertainty can be adapted accordingly. This figure has been taken for every wind turbine type as it is sufficiently conservative for both calculated and measured power curves.

**6-2-6-9- Uncertainties energy yield**

The interpretation of uncertainty in energy yield from the total uncertainty in wind speed is not straightforward. The theoretical cubic relation of wind speed and energy does not give a correct description of the phenomena.

For the long term mean wind speed averaged over all turbine locations at hub height the average wind speed value is derived from the wind data processing. The uncertainty is equivalent to a reduction of the mean wind speed when considering the worst case. To translate this reduced mean wind speed into energy yield, the parameters of a Weibull distribution are modified and this new Weibull distribution is then applied to the individual turbine power curves. The results for the considered wind park layout can be found in the examinations in the following table deviation of energy due to wind uncertainties, indicating an energy deviation due to the uncertainty in wind speed assessment.

The analysis of uncertainties is an important step for the risk assessment of the project. From the predicted annual energy and from the total uncertainty on the energy level the probability of exceeding of certain energy yields can be calculated by statistical methods. Applying a Gauss process for the statistic analysis, the calculated gross annual energy can be understood as the mean annual energy yield having the highest rate of probability of all single results. The uncertainty shall be understood as standard deviation of the expected results around the most probable event.

Gross annual energy describes the energy yield as calculated and net annual energy the energy yield considering the losses and uncertainties (e.g. 7%).

Besides the uncertainties for wind conditions and power curve, the losses for electricity transmission (e.g. 3%) and reduced availability of the turbines (e.g. 95%) have also to be considered as constant factors (e.g. 8%), reducing the estimated energy yield. Finally the total energy reduction by all losses and uncertainly is considered as 15% in park calculations.

## 6-3- From Wind to Electricity

The amount of electricity produced by a specific wind turbine is primarily a function of the wind speed at the hub of the turbine. A key variable of this function is the height of the turbine tower, as wind speeds are almost invariably greater at higher elevations.

The net capacity factor listed in Table 6-4 is the estimated electricity produced as a percentage of the turbine at full capacity over a static period of time - a standard measurement of how effective a turbine installation is. Capacity factor calculated is: 39.9% which is very good for Iran - Pak site. The table 6-4 contains the annual energy production of selected turbine.

| Result PARK [MWh/y] | Result-15.0% [MWh] | GROSS (no loss) Free WTGs [MWh/y] | Park efficiency [%] | Capacity factor [%] | Mean WTG result [MWh/y] | Full load hours [Hours/year] | Mean wind speed @hub height [m/s] |
|---|---|---|---|---|---|---|---|
| 205,824.3 | 174,950.7 | 223,290.5 | 92.2 | 39.9 | 6,998.0 | 3,499 | 7.8 |

**Table 6-4: Estimated Electricity Produced by VESTAS V126 - 3.3 MW Wind Turbine**

| Name | VESTAS V126/ 2000 kW |
|---|---|
| Wind Farm Capacity (MW) | 50 |
| Total Gross Annual Electricity (MWh/y) | 223290.5 |
| Park Efficiency (%) | 92.2 |

| | |
|---|---|
| Result Annual Electricity Generated (MWh/y) | 205824.3 |
| Full load hours (hour/year) | 3499 |
| Mean WTG result (MWh/y) | 6998.5 |
| **Net Annual Energy (considering all losses & uncertainties) (MWh/y)** | **174762** |
| **Park Capacity Factor (%)** | **39.9** |

## 6-4- Wind Farm Monthly Production

The banker will likely be more interested in monthly power production estimates (which take into consideration wind resource frequency distribution), as the amount of electricity produced is directly proportional to the revenue of the project. Power production projections, as shown in figure 6-8, demonstrate to the bank whether or not the project will perform well enough to cover the debt service on a loan from the bank. In the monthly power production figures that are illustrated in figure 6-8, the result includes wake losses and a reduction of 15.0 % for both Wind Masts ( No.1 and No.2 at 80.00 m 10 minutes data for **518 days) (09/01/2013 - 01/31/2015)**. As it can be seen, the month with the highest power production on average is September with an average of 15.2%. The month with the lowest power production on average is February with an average of 3.8 %. The average amount of power production for the year in site is 8.4 %.

WindPRO version 2.7.490

Project:
**50 MW IPWPPL**

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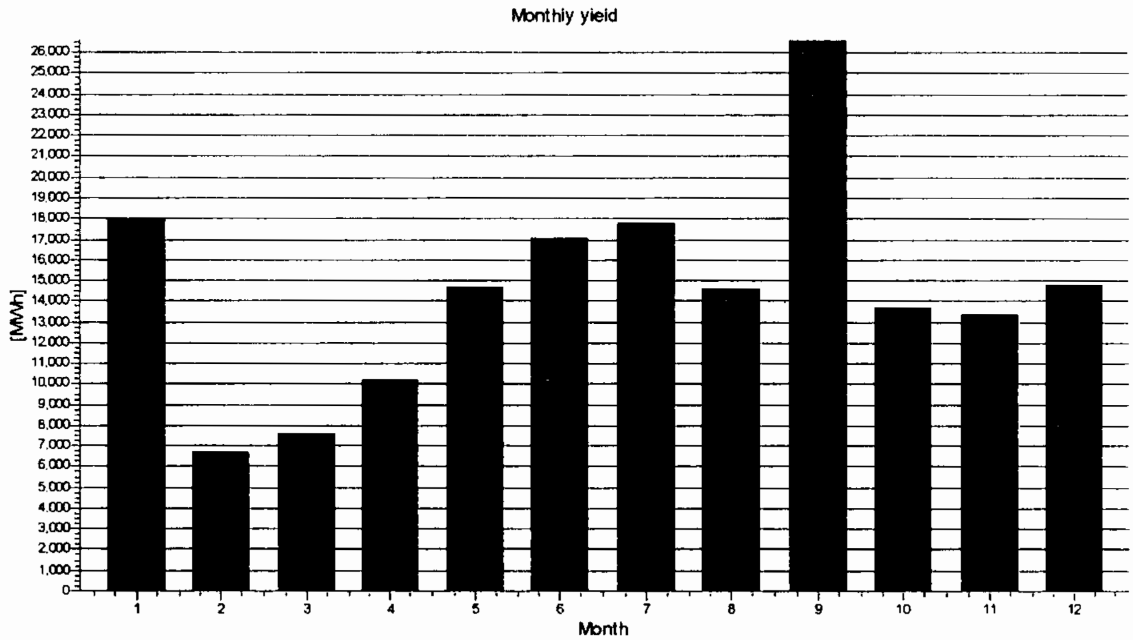
**PARK - Time varying AEP**

**Calculation:** ED 03 EWTS II 2008 (V100)**WTG:** 1 - VESTAS V100 2000 100.0 !O! Mode 0, Hub height: 80.0 m

Windfarm: 50.0 MW based on 25 turbines of type VESTAS V100 2000 100.0 !O!.
Calculated mean yield per month and hour [MWh]. The result includes wake losses and a reduction of 15.0 %
Used wind distribution: Wind Mast No.1 - 2 80.00 m. 2013/09/01 - 2015/01/31 (518 days), 10 minutes, 100%




*WindPRO is developed by EMD International A/S, Niels Jernesvej 10, DK-9220 Aalborg ?, Tlf. +45 96 35 44 44, Fax +45 96 35 44 46, e-mail: windpro@emd.dk*

**Figure 6-8: Calculated Annual Electricity Production Variation for VESTAS V126 - 2000 kW Wind Turbine**

The project managers will likely be more interested in daily power production estimates, as the hours of electricity produced is directly proportional to the staff management in the project and in the site. Power production projections, as shown in Figure 6-9, demonstrate whether or not the project will perform well enough to cover the maintenance service.

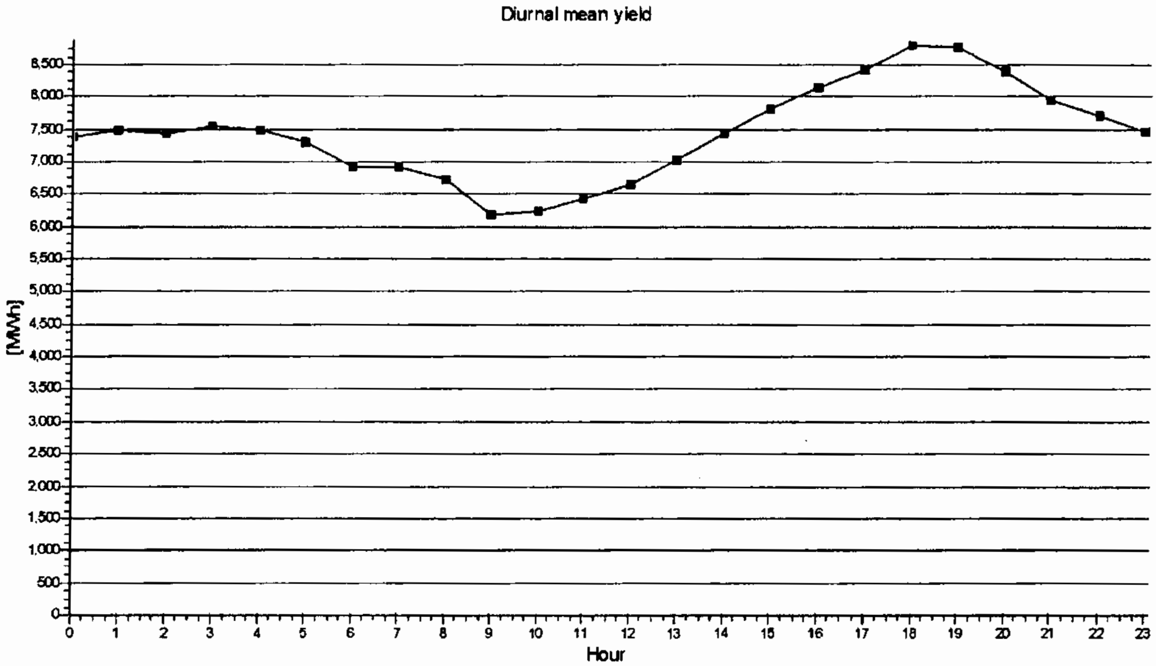



**Figure 6-9: Calculated Diurnal Electricity Production Variation for VESTAS V126 - 2000 kW Wind Turbine**

In Summary, in technical analyses of 50 MW wind farm study in Pakistan, after perusing suitable wind turbines that can satisfy the Iran-Pak aims, top turbine manufacturer in the world, VESTAS V126 – 3.3 MW wind turbine was selected. This turbine passed the technical parameters for Iran - Pak proposed wind farm (see this section in detail). The capacity factor estimate 39.9 % to 40 % is very good for Pakistan spatial conditions. For more analyses and selecting suitable wind turbine manufacturer and starting contraction phase and installing suitable wind turbine; more financial analyses is necessary which comes in (next section) section seven.

It should be noted that the above amount of capacity factor is calculated considering P50, and in order to have a more realistic and safe result for bankable studies it is a typical approach to consider P90, P84 or P75. Based on this, the calculated capacity factor for P90 is 36.23. (table 6-5)

**Table 6-5: Estimated Capacity Factor for Different Probabilities**

| Probability of Exceedance [%] | Net AEP [GWh/y] | Capacity Factor |
|---|---|---|
| 50 | 174.9 | 39.93 |
| 75 | 166.4 | 37.99 |
| 84 | 162.3 | 37.05 |
| 90 | 158.7 | 36.23 |
| 95 | 154.1 | 35.18 |

# CHAPTER VII

## Grid Interconnection Study

(Attached As Annexure AL)

# Executive Summary

## Grid Interconnection Study :

The IPWPPL gird connection study is being carried out by the M/s Power Planners International (Pvt.) Ltd., who is the leading consultant in this sector.

### (i) Grid Interconnection Point:

The proposed Grid Interconnection point will be the Jhimpir –New 220/132 kV grid station to be connected to Hyderabad (T. M. Khan Rod 220 kV)through double circuit of 220 kVand a double circuit of 132 kV line to be connected with T. M. Khan grid station of 132 kV. The double circuit of 132 will emanate from the Wind Farm substation which will have a dimension of 100 by 80 meter.

Alternatively; If the 220 kV and 132 kV lines from Jhimpir-New grid station cannot take overload of 50 MW power plant then the second optionis to take a new 220 kV double circuit line from Jhimpir-New grid to Matiari. The existing grid at Matiari is 500 kV and in this regard it will be required to add 220 kV voltage level by adding 500/220 kV transformers and a bus bar of 220 kV in the same grid station.

# CHAPTER VIII

## Environmental Study

# Executive Summary :

Iran-Pak Wind Power Pvt. Ltd (IPWPPL) intends to undertake a 50 MW wind power project at Thatta in Sindh Province of Pakistan. The prevailing legislation in the country requires that an environmental assessment be carried out, and its report submitted to the relevant Environmental Protection Agency (EPA), before embarking upon any project. In line with this requirement IPWPPL has commissioned an environmental assessment through Tekcellent Private Limited (TPL).

In line with the guidelines provided in PEPA 1997, an EIA needs to be carried out for projects situated within a radius of 1.0 km from the main transport network (in this case the main railway line parallel to the northern boundary of the project). However, keeping in view the lack of any major settlements and endangered flora and fauna species in the project vicinity, TPL has proposed that an IEE is sufficient for this project. A letter was sent to SEPA, on which their decision was that the project can carry out an IEE Study [ Letter is attached in Appendix]

## 8- 1 Introduction :

The project site is located in Jhimpir, District Thatta. TPL has commenced baseline Social and Environmental assessment and TPL personnel have conducted four field visits in and around the site location. TPL has surveyed four points that enclose the project boundary, two wind mast stations, the three major lakes; namelyHaleji, Keenjhar and Hadero, and five villages; Haji Jan Muhammad Brohi Goth, Haji Dil Murad Brohi Goth, Umar Deen Brohi Goth, Saleh Muhammad Burfat Goth and Khameeso Brohi Goth.

## 8-2 Objectives :

TPL's objectives for these comprehensive field visits were primary data collection of key baseline environmental parameters to determine the impacts of the project on the environment. The information will be further refined to propose mitigations for the impacts.One of the main issue that maybe encountered during such projects during operation phase is collision threat to avifauna (resident and migratory birds) caused by the wind turbines. Other issues include the ambient noise levels, and shadow flicker impacts. These are under study to determine what further assessments or sturdies for these are required or not?

Furthermore, TPL Team has carried out stakeholder engagement with NGOs, environmental organizations and other relevant departments and agencies in Karachi and Thatta,which include:

1. National Rural Support Programme (NRSP), Thatta
2. Sindh Radiant Organization (SRO), Thatta / Badin
3. Additional Deputy Commissioner – I Thatta, Sindh

4. Sindh Environmental Protection Agency (SEPA), Karachi
5. Worldwide Fund for Nature (WWF), Karachi
6. Sindh Forest Department, Karachi
7. International Union for Conservation of Nature (IUCN), Karachi

## 8-3 Conclusion :

The stakeholders were provided with information regarding project boundary, project vicinity and findings from the site visit. In a nutshell, no critical concerns were raised by the stakeholders.

Table 9-1 below, presents a summary of the findings from the site visits.

**Table 8- 1: Summary of Field Visits**

| S. No. | Date | Consultants | TPL Personnel | IPWPPLPersonnel | Purpose of Visit | Scope /Areas covered |
|---|---|---|---|---|---|---|
| 1 | January 3, 2015 | Ms.TasneemBhatti (Sociologist)<br>Dr. Syed Ali Ghalib (Avifauna expert)<br>Dr. Atiq-ur-Rehman (Flora expert)<br>Mr. Abdul Razzaq (Fauna expert) | Mr. Basim Z. Khan<br>Mr. FaizanSiddiqui<br>Mr. M. Waqas Younus | Mr. Mehboob Ali Brohi (Local Guide) | To gain an understanding of the local area and identify key environmental issues. | This visit mainly covered the areas near the two wind masts, project boundaries, Braudabad railway station and banks of theHadero Lake. Ms Tasneem covered the socio-economic aspects. The consultants studied the flora, fauna and avifauna of the area and took observations. |
| 2 | January 11, 2015 | Dr. Syed Ali Ghalib (Avifauna expert)<br>Mr. Abdul Razzaq (Fauna expert) | Mr. Basim Z. Khan<br>Mr. M. Waqas Younus<br>Ms. Yashfeen Z. Ansari | – | To conduct the ecological study of fauna near the wetlands in the site vicinity and identify key environmental issues. | This visit covered three major wetlands in the site vicinity namely Haleji Wildlife sanctuary, Hadero Lake and Keenjhar Lake. Dr. Ghalib and Mr. Razzaq conducted a detailed study for the fauna and avifauna of the area. |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | January 15, 2015 | Ms.TasneemBhatti (Sociologist) | Mr. Basim Z. Khan<br>Mr. Faizan Siddiqui<br>Ms. Yashfeen Z. Ansari | Mr. Mehboob Ali Brohi (Local Guide)<br>Mr. RahatMajeed | To conduct a socio-economic study of any settlements near the project area and identify key social issues. | This visit entirely covered the socio-economic aspects of the area. TPL team alongwith Ms. Tasneem visited 2 villages in the project vicinity and engaged some local womenfolk into a discussion about their living conditions and current issues. After that TPL team proceeded to meet some social officials from 2 local NGOs and Additional Deputy Commissioner - 1 of Thatta District. |
| 4 | January 17, 2015 | Dr. Atiq-ur-Rehman (Flora expert)<br>Mr. Abdul Razzaq (Fauna expert) | Mr. M. Waqas Younus<br>Ms. Yashfeen Z. Ansari | Mr. Mehboob Ali Brohi (Local Guide)<br>Mr. RahatMajeed | To conduct the socio-economic and ecological study of the flora, fauna and avifauna of the local area and identify key EIA's environmental issues. | This visit was the most comprehensive in terms of area coverage and the team covered all four points of the project area, Braudabad Railway Crossing, a few villages, two out of use poultry farms, and several graveyards and shrines in the project vicinity. Socio-economic aspects were also covered by interviewing the local village people. |

# CHAPTER IX

## Conclusion

## 9- 1 Conclusion

In 2006, the government reported that the Pakistan economic growth reached 8.4 percent and will most likely grow for the foreseeable future. It is quite normal for power outages to happen on a daily basis in the country, but this cannot continue if the Pakistan economy is to grow. In March 2007, President Musharraf stated that renewable energy should be part of the push to increase energy supplies by 10 to 12 percent every year. The present government has also set a target of 10 percent of energy to come from renewable by 2015. If it does follow through with aggressive capacity enhancements, Pakistan could be an Asian leader in renewable energy given its strategic endowments.

Pakistan meteorological department has conducted a detailed wind power potential survey of coastal areas of Pakistan and ministry of science and technology has provided the required funding for this purpose. This study has enabled us to identify the potential areas where economically feasible wind farms can be established. One interesting aspect of this study is that contrary to the general impression, Sindh coastal areas have greater wind power potential than Baluchistan coastal areas. Potential areas cover 9700 $km^2$ in Sindh. The gross wind power potential of this area is 43000 MW and keeping in view the area utilization constrains etc. the exploitable electric power generation potential of this area is estimated to be about 11000 MW.

The Iran - Pak Wind Power Pvt Limited (IPWPPL) company is seeking investment in 50 MW wind power project in the Sindh province, in Pakistan. IPWPPL appointed Ghods-Niroo Engineering Company (GNEC) for providing consultancy for the wind power feasibility study. GNEC then prepared the detailed feasibility study for the 50 MW wind power project in the selected Sindh province, Pakistan. Detailed comparative study of the central and state governments wind power policies were presented in the report along with the description of wind power technology, selection of wind turbine and wind farmable sites. The proposed wind farm site of Iran - Pak is 18 km north of Thatta city, in the Sindh province of Pakistan.

In addition IPWPPL proposed wind farm has a land leased for a period of 30 years from Thatta District Administration, and after that two 80m wind masts were installed. Met masts are the primary tool for wind data gathering and specification of wind regime and wind directions.10 minutes interval data from wind masts for a period of 518 days has been gathered so far and used in this feasibility study (09/01/2013 - 01/31/2015). According to their data, the annual average wind speeds are 7.9 m/s, 8.1 m/s respectively (see table 10-1).

**Table 9-1: Summary of processed data on sites**

| Site | Time Series | Record Interval | Recovery Rate (%) | W.S. (80m) | W.D. (80m) | Power Low (α) | Power Density ($W/M^2$) |
|---|---|---|---|---|---|---|---|
| **No.1** | 09/01/2013 to 01/31/2015 | 10 Minute | 100 | 7.9 | WSW | 0.167 | 430.7 |
| **No.2** | | | 100 | 8.1 | WSW | 0.150 | 481.5 |

This feasibility study includes the review of central government and state government's policies on wind power in Pakistan. Feasibility study also includes cost estimates of the wind power project, financial assessment including determination of IRR and payback period for the Iran–Pak site and the selected wind turbines, sensitivity analysis and the recommendation on the selection of wind turbine. The study is carried out by WindPRO and WAsP software and the result of this study shows that selected wind turbine based on its ratings, performance power curve, and other characteristics had the best performance in Iran - Pak site location. The selected wind turbine is VESTAS V126 3.3 MW. Total wind energy of proposed Iran–Pak Wind Power Plant with mentioned wind turbine is estimated and illustrated in table 10-2.

**Table 9-2: Estimated Electricity Produced of VESTAS V126 – 3.3 MW wind Turbine**

| Name | VESTAS V126/ 3.3 MW |
|---|---|
| Wind Farm Capacity (MW) | 49.5 |
| **net annual energy (considering all losses & uncertainties) (MWh/y)** | **174762** |
| Park Efficiency (%) | 92.2 |
| **Park Capacity Factor (%)** | **39.9** |

Based on the estimated energy generation and cost of wind power project, the financial analysis has been carried out. The results of IRR and payback period for sale to utility for both the cases.

In summary, the key information of economic and financial analyses is shown in table 9-3.

**Table 9-3: project summary**

| Item | Subject | Description |
|---|---|---|
| 1 | Type of the project | Wind (farm) power plant |
| 2 | Company | IRAN - PAK WIND POWER (Pvt.) LIMITED (IPWPPL) |
| 3 | Farm capacity | 49.5 MW |
| 4 | Land area | 1250 acres |
| 5 | Construction period | 2 years |
| 6 | Production period | 20 years |
| 7 | Turbine type | 3.3 MW (Based on manufacturer) |
| 8 | Project location | Near "Janabad" Jhimpir, District Thatta, Sindh, Pakistan |
| 9 | Estimated generation energy | 174762 MW/Year |
| 10 | Fixed investment cost | 112.8 Million Dollar |
| 11 | Financing structure | Debt 75% /Equity 25% |

K