Annex - I

HARAPPA SOLAR (PRIVATE) LIMITED

1485/C-2A, Asad Jan Road, Lahore Cantt. Ph: 042 36687823-24, Fax: 042 36687825

The Registrar
National Electric Power Regulatory Authority
Islamabad

Subject: **Application for a Generation Licencefor an 18.0 MW_p Solar PV Power Generation Project by Harappa Solar (Private) Limited**

Dear Sir,

I, Musaddiq Rahim, Company Secretary, being the duly authorized representative of Harappa Solar (Private) Limited, by virtue of Board Resolution dated October 13, 2014, hereby apply to the National Electric Power Regulatory Authority for the grant of a Generation Licence, pursuant to Section 15 of the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997, in the name of:

HARAPPA SOLAR (PRIVATE) LIMITED
Incorporated under the Companies Ordinance, 1984
Corporate Universal Identification No. 0090005, dated September 24, 2014

For itsSolar Generation Facility / Solar Power Plant / Solar Farm located at Jinnah Town and Chak 4/10-L near Harappa Bypass, Tehsil & District Sahiwal, Punjab
(Installed Capacity: 18.0 MW_p Gross ISO)

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 in sum of Rs. 206,364 (Rupees Two Lac Six Thousand Three Hundred and Sixty Four Only), being the nonrefundable licence application fee calculated in accordance with Schedule II to the National Electric Power Regulatory Authority Licensing (Application and Modification Procedure) Regulations, 1999, is also attached herewith.

Date: May 20, 2015

Musaddiq Rahim
COMPANY SECRETARY

HARAPPA SOLAR (PVT) LTD. LAHORE

ANNEX - 2

HARAPPA SOLAR (PRIVATE) LIMITED

1485/C-2A, Asad Jan Road, Lahore Cantt. Ph: 042 36687823-24, Fax: 042 36687825

CERTIFIED TRUE COPY OF THE RESOLUTION PASSED

BY THE BOARD OF DIRECTORS OF

HARAPPA SOLAR (PRIVATE) LIMITED

IN MEETING HELD ON OCTOBER 13, 2014

"RESOLVED that in addition to the Chief Executive Officer of Harappa Solar (Private) Limited (hereinafter referred to as the "Company"), Mr. Musaddiq Rahim as Company Secretary of the Company, is hereby also authorized to sign, verify, execute, institute and commence, on behalf of the Company, any applications, petitions, affidavits, guarantees or any other oral or written representations or statements, in order to obtain the necessary approvals, permits, licenses and determinations from the following bodies and companies:

- Alternative Energy Development Board
- Central Power Purchasing Agency
- Multan Electric Power Company Limited
- National Electric Power Regulatory Authority
- National Transmission and Despatch Company Limited
- Punjab Environmental Protection Agency

FURTHER RESOLVED that certified copies of this resolution be communicated and supplied to the concerned quarters as and when so demanded and shall remain in force until notice in writing to the contrary be given."

CERTIFIED TRUE COPY
For HARAPPA SOLAR (PRIVATE) LIMITED,

MUSADDIQ RAHIM
COMPANY SECRETARY

HARAPPA SOLAR (PVT) LTD. LAHORE

ANNEX - 5

(PVT) LTD

A004387

SECURITIES AND EXCHANGE COMMISSION OF PAKISTAN

SECP

COMPANY REGISTRATION OFFICE, LAHORE

CERTIFICATE OF INCORPORATION

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

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

Corporate Universal Identification No. 0090005

I hereby certify that **HARAPPA SOLAR (PRIVATE) LIMITED** is this day incorporated under the Companies Ordinance, 1984 (XLVII of 1984) and that the company is **Limited by Shares.**

Given under my hand at **Lahore** this **Twenty Fourth** day of **September,** Two **Thousand** and **Fourteen**.

Fee Rs. 5,000/-

(LIAQAT ALI DOLLA)
Additional Registrar of Companies

No.ARL/ 5935 DATED: 24/9/2014

CERTIFIED TO BE TRUE COPY

13/5/15

DEPUTY REGISTRAR OF COMPANIES
COMPANY REGISTRATION OFFICE
LAHORE

ANNEX-6

(PVT) LTD ہڑپہ سولر

THE COMPANIES ORDINA

--: o: --

(PRIVATE COMPANY LIMITED B

(PVT) LTD ہڑپہ سولر

--: o: --

Memorandum of Associa

Of

HARAPPA SOLAR (PRIVATE) LIMITED

I. The name of the Company is **"HARAPPA SOLAR (PRIVATE) LIMITED"**.

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

III. The sole object of the Company is:-

1. To set up, own, manage, operate, and maintain power generation plants anywhere in Pakistan and to carry on the business of electric power generation subject to permission from NEPRA/other regulatory authorities.

2. To achieve the above object, the Company shall be entitled:

   a) To design, construct or acquire by way of outright purchase or financial or other lease(s) plant, machinery, equipment and services for setting up the said power plant on turnkey basis or otherwise, under such arrangements, guarantees or warranties as may be considered appropriate.

   b) To engage in transmission, distribution and sale of electric power to any entity in the public or private sector to perform all acts directly or indirectly related or incidental to the business of the Company permitted under law.

   c) To self-consume or store the electricity generated by the Company.

   d) To engage in activities required for compliance with environmental or other laws

e) To purchase, acquire or lease land and or buildings for the purpose of the Company or for other work considered necessary under relevant laws.

f) To borrow or raise money by means of loans or other financing arrangements from banks, or other financial institutions or from Directors, in such manner as the Company may think fit and in particular by issue of debentures, debenture-stock, perpetual or otherwise, convertible into shares and to mortgage, assign or charge the whole or any part of the property, rights, assets or revenue of the Company, present or future, by special assignment or to transfer or convey the same absolutely or in trust as may seem expedient and to purchase, redeem or pay off any such financing or securities.

g) To arrange local and foreign currency loans or financing from scheduled banks, industrial banks and other financial institution for the purpose of purchase and import of machinery, construction of plant, building, raw material and for working capital or for any other purpose of the Company.

h) To draw, accept, make, endorse, discount and negotiate promissory notes, bills of exchange, bills of lading and other negotiable instruments connected with the business of the Company.

i) To open, maintain and operate banking accounts of the Company with one or more banks and to deposit or withdraw money there from.

j) To distribute any of the properties of the Company amongst the members in specie or kind at the time of winding up.

k) To enter into contracts and arrangements of all kinds permitted by law including, without prejudice to the forgoing, contracts with suppliers and manufacturers of machinery, construction, procurement and engineering contractors, turnkey contractors, contractors for operation and maintenance of plant and machinery.

l) To approve and enter into schemes for joint venture agreements or amalgamation, merger and reorganization with such companies or other entities as may be considered appropriate or beneficial.

m) To support and subscribe to any charitable or public object 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 carries 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 and benevolent funds for the benefit of any such persons, or of their wives, children or other relatives or dependents.

n) To establish, purchase, maintain and contribute to any pension, provident, gratuity, superannuation, retirement, redundancy, injury, death benefit or insurance funds, trusts, schemes, entities, or policies for the benefit of, and to give or procure the giving of pension, annuities, allowances, gratuities, donation, emoluments, benefits, of any description (whether in kind or otherwise), incentives, bonuses, assistance (whether financial or otherwise) and accommodation in such manner and on such terms as it thinks fit to, and to make payments for or towards the insurance of, any individuals who are or were at any time in the employment of, or directors or officers of (or held comparable or equivalent office in), or acted as consultants or advisers to or agents for, the Company or any company which is its holding company or is a subsidiary of the company or any such holding company

o) To deal with the surplus monies of the Company not immediately required in such lawful form as may be thought expedient.

p) To enter into contracts or arrangements with any Government or Authority, Federal, Provincial, Municipal, Local or otherwise public bodies or any corporations, companies or persons that may seem conducive to the Company's objects, or any of them and to obtain any licenses, permits, authorisations as may be required in this regard.

q) To advance money to staff members, customers and others having dealing with the Company, with or without security, upon such terms as may deem expedient not to act banking company.

r) To pay for any property or rights acquired by the Company, either in cash or fully paid shares or by the issue of securities, or partly in one mode and partly in another and generally on such terms as may be determined.

3. It is declared that notwithstanding anything contained in the foregoing object clause of this Memorandum of Association nothing contained therein shall be construed as empowering the Company to undertake or to indulge in the business of banking leasing managing agency or insurance business directly or indirectly as restricted under law or to indulge in any other unlawful operations.

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

IV. The liability of the members is limited.

V. The Authorized Capital of the Company is Rs. 100,000/- (Rupees One hundred thousand only) divided into 10,000 ordinary shares of Rs. 10/- (Rupees Ten each), with powers 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.

Company Registration Office Lahore
Securities and Exchange Commission of Pakistan
SECP

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

Name and Surname (present & Former) in Full (in Block Letters) and C.N.I.C	Father's/ Husband's Name (in Full)	Nationality with any former nationality	Occupation	Residential Address (in Full)	Number of Shares Taken by each subscriber	Signatures
RANA NASIM AHMED (35202-0464547-7)	Fakir Muhammad Khan	Pakistani	Business	76-B, Street 4, Phase V, DHA, Lahore.	750 Seven Hundred Fifty	
RANA UZAIR NASIM (35201-8925121-7)	Rana Nasim Ahmed	Pakistani	Business	76-B, Street 4, Phase V, DHA, Lahore.	250 Two Hundred Fifty	
				Total Number of Shares Taken	1,000 One Thousand	

Company Registration Office Lahore
Securities and Exchange Commission of Pakistan
SECP

Dated this Monday the 14th day of September, 2014

Witness to the above signatures:

Full Name: NATIONAL INSTITUTIONAL FACILITATION TECHNOLOGIES (PVT) LTD

Full Address: 5TH FLOOR AWT PLAZA I. I. CHUNDRIGAR ROAD, KARACHI

CERTIFIED TO BE TRUE COPY
13/5/15
DEPUTY REGISTRAR OF COMPANIES
COMPANY REGISTRATION OFFICE
LAHORE

THE COMPANIES ORDINANCE, 1984

(Private Company Limited by Shares)

ARTICLES OF ASSOCIATION

OF

HARAPPA SOLAR (PRIVATE) LIMITED

1. The Regulations contained in Table 'A' to the First Schedule to the Companies Ordinance, 1984 (the "Ordinance") shall be the regulations of **HARAPPA SOLAR (PRIVATE) LIMITED** (the "Company") so far as these are applicable to a private company.

PRIVATE COMPANY

2. The Company is a "Private Company" within the meaning of Section 2(1)(28) of the Ordinance and accordingly:

(1) No invitation shall be made to the public to subscribe for the shares or debentures of the Company.

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

(3) The right to transfer shares of the Company is restricted in the manner and to the extent herein appearing.

TRANSFER OF SHARES

3. A member desirous to transfer any of his shares shall first offer such shares for sale or gift to the existing members and in case of their refusal to accept the offer, such shares may be transferred to any other person, as proposed by the transferor member, with the approval of the Board of Directors.

DIRECTORS

4. The number of directors shall not be less than two or a higher number as fixed under the provisions of Section 178 of the Ordinance. The following persons shall be the first directors of the Company and shall hold the office upto the date of First Annual General Meeting:

1. MR. RANA NASIM AHMED
2. MR. RANA UZAIR NASIM

(PVT) LTD (PVT) LTD

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

Name and Surname (present & Former) in Full (in Block Letters) and C.N.I.C	Father's/ Husband's Name (in Full)	Nationality with any former nationality	Occupation	Residential Address (in Full)	Number of Shares Taken by each subscriber	Signatures
RANA NASIM AHMED (35202-0464547-7)	Fakir Muhammad Khan	Pakistani	Business	76-B, Street 4, Phase V, DHA, Lahore.	750 Seven Hundred Fifty	
RANA UZAIR NASIM (35201-8925121-7)	Rana Nasim Ahmed	Pakistani	Business	76-B, Street 4, Phase V, DHA, Lahore.	250 Two Hundred Fifty	
				Total Number of Shares Taken	1,000 One Thousand	

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

Dated this Monday the 14th day of September, 2014

Witness to the above signatures:

Full Name: NATIONAL INSTITUTIONAL FACILITATION TECHNOLOGIES (PVT) LTD

Full Address: 5TH FLOOR AWT PLAZA I. I. CHUNDRIGAR ROAD, KARACHI

CERTIFIED TO BE TRUE COPY

13/5/15

DEPUTY REGISTRAR OF COMPANIES
COMPANY REGISTRATION OFFICE
LAHORE

ANNEX-7

"THIRD SCHEDULE

(See section 156)

FORM A- ANNUAL RETURN OF COMPANY HAVING SHARE CAPITAL

1	**Registration No.**	0090005
2	**Name of the Company**	Harappa Solar (Private) Limited

3	**Form A made upto (Day/Month/Year)**	19	05	2015
4	**Date of AGM (Day/Month/Year)**			

PART-A

5	**Registered office address:**	1485/C-2A, Asad Jan Road, Lahore Cantt.
6	**Email Address:**	binyameen@harappasolar.com, musaddiq@jdw-group.com
7	**Office Tel. No.:**	042 36687823-24, 042 36680141
8	**Office Fax No.:**	042 36687825
9	**Nature of Business:**	Power Generation

10

Authorized Share Capital			
Type of Shares	No. of Shares	Amount	Face Value
Ordinary Shares	10,000	Rs.100,000	Rs.10

11

Paid up Share Capital			
Type of Shares	No. of Shares	Amount	Issue Price
Ordinary Shares	1,000	Rs.10,000	Rs.10

12	**Amount of indebtedness on the date upto which form A is made in respect of all**				
	Mortgages/Charges	N/A			
13	**Particulars of the holding company**				
	Name	N/A			
	Registration No.		% Shares Held		
14	**Chief Executive**				
	Name	Rana Uzair Nasim	NIC	35201-8925121-7	
	Address	76-B Street 4, Phase V, DHA, Lahore			
15	**Chief Accountant**				
	Name	Binyameen	NIC	31101-9180387-1	
	Address	76/B Street#02 Model Colony Gulberg-III Lahore			
16	**Secretary**				
	Name	Musaddiq Rahim	NIC	35202-1915617-5	
	Address	House#8 Gali #2 Mohala Abu			

	Qasim Street Jia Mosa Shahdera Lahore		

17 **Legal Adviser**

Name	RIAALAW
Address	191-A, Cavalry Ground, Shami Road, Lahore Cantt.

18 **Auditors**

Name Riaz Ahmad, Saqib, Gohar & Company
Address 35-D/E, Ali Block, New Garden Town, Lahore

19 **List of Directors on the date of Form-A**

Name of Director	Address	Nationality	NIC (Passport No. if foreigner)												
Rana Nasim Ahmed	76-B Street 4, Phase V, DHA, Lahore	Pakistani	3	5	2	0	2	0	4	6	4	5	4	7	7
Rana Uzair Nasim	76-B Street 4, Phase V, DHA, Lahore	Pakistani	3	5	2	0	1	8	9	2	5	1	2	1	7

PART-B

20. List of members & debenture holders on the date upto which this Form A is made

Folio	Name	Address	Nation-ality	No. of shares	NIC (Passport No. if foreigner)												
	Members																
1	Rana Nasim Ahmed	76-B Street 4, Phase V, DHA, Lahore	Pakistani	750	3	5	2	0	2	0	4	6	4	5	4	7	7
2	Rana Uzair Nasim	76-B Street 4, Phase V, DHA, Lahore	Pakistani	250	3	5	2	0	1	8	9	2	5	1	2	1	7
	Debenture holders	N/A															

Use separate sheet, if necessary

21. Transfer of shares (debentures) since last Form A was made

	Name of Transferor	Name of Transferee	Number of shares transferred	Date of registration of transfer
	Members	N/A		
	Debenture holders	N/A		

22. **I certify that this return and the accompanying statements state the facts correctly and completely as on the date upto which this Form-A is made**

Date		19	05	2015		Signature	
					Designation (Please tick)		Chief Executive/Secretary

HARAPPA SOLAR (PVT.) LTD. LAHORE

FORM 21

THE COMPANIES ORDINANCE, 1984
[SECTION 142]

NOTICE OF SITUATION OF REGISTERED OFFICE OR ANY CHANGE THEREIN

1	Incorporation Number		
2	Name of the Company	HARAPPA SOLAR (PVT.) LIMITED	
3	Fee Paid (Rs.)	600.00	Name & Branch of the Bank LAHORE, MCB - Model Town [0967]
4	Receipt No.	E-2014-257666	
5	The situation of registered office of the company was changed from (previous address)		
6	The Registered Office of the company is now situated at	1485/C-2A Asad Jan Road, Lahore Cantt. Lahore Punjab 54000	
6.1	Telephone Nos	042-36680141	
6.2	Fax No. if any		
6.3	Email Address	musaddiq@jdw-group.com	
7	With Effect from (date)	Since Incorporation	
8	Signature of Chief Executive/Secretary		
9	Name of Signatory	Rana Uzair Nasim	
10	Designation	Director	
11	NIC Number of Signatory	35201-8925121-7	
12	Date (DD/MM/YYYY)	19/09/2014	

Company Registration Office Lahore
Securities and Exchange Commission of Pakistan
SECP

CERTIFIED TO BE TRUE COPY

13/5/15

DEPUTY REGISTRAR OF COMPANIES
COMPANY REGISTRATION OFFICE
LAHORE.

PARTICULARS OF DIRECTORS AND OFFICERS, INCLUDING THE CHIEF EXECUTIVE, MANAGING AGENT, SECRETARY, CHIEF ACCOUNTANT, AUDITORS AND LEGAL ADVISERS, OR OF ANY CHANGE THEREIN

THE COMPANIES ORDINANCE, 1984

[SECTION 205]

FORM 29

1 Incorporation Number			
2 Name of Company	HARAPPA SOLAR (PVT) LIMITED		
3 Fee Paid (Rs.)	600 0	Name and Branch of Bank	LAHORE MCB - Model Town [0967]
4 Receipt No	E-2014-257666		19/09/2014
5 Mode of Payment (Indicate)	Bank Challan		

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

(PVT) LTD

6. Particulars*:

6 1 New Appointment/Election

Present Name in Full (a)	NIC No. or Passport No in case of Foreign National (b)	Father / Husband Name (c)	Usual Residential Address (d)	Designation (e)	Nationality** (f)	Business Occupation*** (if any) (g)	Date of Present Appointment or Change (h)
Rana Uzair Nasim	35201-8925121-7	S/O Rana Nasim Ahmed	76-B, Street 4, Phase 5, DHA Lahore Punjab Pakistan 54000	Director	Pakistan	Businessman	Since Incorporation
Rana Nasim Ahmed	35202-0464547-7	S/O Fakir Muhammad Khan	76-B Street 4, Phase 5, DHA Lahore Punjab Pakistan 54000	Director	Pakistan	Businessman	Since Incorporation

6.2. Ceasing of Officer/Retirement/Resignation

Present Name in Full (a)	NIC No or Passport No in case of Foreign National (b)	Father / Husband Name (c)	Usual Residential Address (d)	Designation (e)	Nationality** (f)	Business Occupation*** (if any) (g)	Date of Present Appointment or Change (h)	Mode of Appointement / change / any other remarks (i)

6.3 Any other change in particulars relating to columns (a) to (g) above

Present Name in Full (a)	NIC No. or Passport No in case of Foreign National (b)	Father / Husband Name (c)	Usual Residential Address (d)	Designation (e)	Nationality** (f)	Business Occupation*** (if any) (g)	Date of Present Appointment or Change (h)	Mode of Appointement / change / any other remarks (i)

Name of Signatory	Rana Uzair Nasim	Designation	Director
Signature of Chief Executive/Secretary		Date (DD/MM/YYYY)	19/09/2014

CERTIFIED TO BE TRUE COPY

13/5/15

DEPUTY REGISTRAR OF COMPANIES
COMPANY REGISTRATION OFFICE
LAHORE

PARTICULARS OF DIRECTORS AND OFFICERS, INCLUDING THE CHIEF EXECUTIVE, MANAGING AGENT, SECRETARY, CHIEF ACCOUNTANT, AUDITORS AND LEGAL ADVISERS, OR OF ANY CHANGE THEREIN

THE COMPANIES ORDINANCE, 1984

[SECTION 205]

FORM 29

1 Incorporation Number	0090005		
2 Name of Company	HARAPPA SOLAR (PVT) LIMITED		
3 Fee Paid (Rs.)	600.0	Name and Branch of Bank	LAHORE, MCB - Model Town [0967]
4 Receipt No	E-2014-258957		25/09/2014
5. Mode of Payment (Indicate)	Bank Challan		

Company Registration Office Lahore
Securities and Exchange Commission of Pakistan
SECP

6. Particulars*:

6.1. New Appointment/Election

Present Name in Full (a)	NIC No. or Passport No. in case of Foreign National (b)	Father / Husband Name (c)	Usual Residential Address (d)	Designation (e)	Nationality** (f)	Business Occupation*** (if any) (g)	Date of Present Appointment or Change (h)	
Rana Uzair Nasim	35201-8925121-7	Rana Nasim Ahmed	76 B, Street 4, Phase 5, Dha Lahore Cantt	Chief Executive	Pakistan	Businessman	25/09/2014	Appointed
Musaddiq Rahim	352002-1915617-5	Abdul Rahim	House # 8, Gali #2, Mohala Abu qasim, Street Jia Mosa, Shahdera, Lahore	Secretary	Pakistan	Employee	25/09/2014	Appointed
Riaz Ahmad Saqib Gohar and Company Chartered Accountants			35-D/E, Ali block, New Garden Town, Lahore	Auditor	Pakistan		25/09/2014	Appointed

6.2 Ceasing of Officer/Retirement/Resignation

Present Name in Full (a)	NIC No. or Passport No. in case of Foreign National (b)	Father / Husband Name (c)	Usual Residential Address (d)	Designation (e)	Nationality** (f)	Business Occupation*** (if any) (g)	Date of Present Appointment or Change (h)	Mode of Appointement / change / any other remarks (i)

6.3 Any other change in particulars relating to columns (a) to (g) above

Present Name in Full (a)	NIC No. or Passport No. in case of Foreign National (b)	Father / Husband Name (c)	Usual Residential Address (d)	Designation (e)	Nationality** (f)	Business Occupation*** (if any) (g)	Date of Present Appointment or Change (h)	Mode of Appointement / change / any other remarks (i)

Name of Signatory	Rana Uzair Nasim	Designation	Director
Signature of Chief Executive/Secretary		Date (DD/MM/YYYY)	25/09/2014

CERTIFIED TO BE TRUE COPY

13/5/15

DEPUTY REGISTRAR OF COMPANIES
COMPANY REGISTRATION OFFICE
LAHORE.

Company Profile

Project Company

The project is being developed by Harappa Solar (Pvt.) Limited ("HSPL"), a private limited company incorporated under the Companies Ordinance, 1984 for the purpose of setting up, owning and operating the planned 18 MW_p solar PV project as an independent power producer (IPP). The registered office of the company is located at 1485/C-2A, Asad Jan Road, Lahore Cantt., Pakistan.

Project Sponsors

The project sponsors include Mr. Rana Nasim Ahmed and Mr. Rana Uzair Nasim (collectively the "Sponsors"). The Sponsors plan to add additional investors as the project develops further; however, Mr. Rana Nasim Ahmed shall remain the key sponsor and shareholder of HSPL. He is the Chief Operating Officer / Resident Director of JDW Sugar Mills Limited ("JDW") since 2001 and is also one of JDW's largest shareholders.

The Sponsors have extensive and first-hand power sector experience. They have pioneered high-pressure cogeneration in the sugar industry by developing, constructing, commissioning and operating the approximately 2 x 26.5 MW (53 MW total) bagasse-based power projects at JDW Unit-II and Unit-III. The projects are the first to materialize under NEPRA's upfront bagasse tariff regime. The power plants are also unique in that they were set up through direct procurement from various tier 1 manufacturers / vendors under close supervision of the Sponsors and owner's engineer without an EPC contractor.

The first power plant at JDW Unit-II was commissioned in June 2014 whereas the second at JDW Unit-III was commissioned in October 2014. Both projects are selling electricity to the Central Power Purchasing Agency ("CPPA") under thirty year Energy Purchase Agreements. The plants are running at full capacity with operations and maintenance ("O&M") and invoicing supervised by the Sponsors.

In addition, the sponsors also have many years of experience of managing commercial matters and O&M related to JDW's low-pressure captive power plants of approximately 70 MW cumulative capacity. Two of these plants also export surplus capacity during the sugarcane crushing season to Multan Electric Power Company ("MEPCO") and Sukkur Electric Power Company ("SEPCO") respectively.

The Sponsors have thus built up hands-on expertise in power project development (e.g. design, financing, licensing, tariff development, grid studies, and security documents) as well as project tendering, construction, installation and operation. As such, the Sponsors are uniquely positioned to leverage their experience towards the successful commissioning and operation of the proposed 18.0 MW_p solar PV project.

CVs of Key Personnel

Rana Nasim Ahmed - Director

Rana Nasim Ahmed is a Director and key shareholder of HSPL and provides top supervision and guidance for the successful implementation and operation of the proposed project. He has a distinguished public as well as corporate sector track record with unique knowledge of power project development, tendering, project management and operations & maintenance.

Mr. Ahmed has served as the Chief Operating Officer / Resident Director of JDW Sugar Mills Limited since 2001. He is responsible for operations spanning corporate farming, sugarcane milling and power generation. He has helped transform JDW over this period from a single sugar mill with 7,000 tonnes per day (TCD) capacity to one of the largest and most efficient sugar sector enterprises in Pakistan. JDW Group now comprises four sugar mills with a total crushing capacity of nearly 65,000 TCD and accounts for 12-15% of the total sugar output of Pakistan. JDW also operates 20,000 acres of highly mechanized sugarcane farms, which represent the largest corporate farming operations in the country.

Mr. Ahmed has directly overseen JDW's diversification into the power sector over the last several years by successfully developing first of their kind 2 x 26.5 MW (53 MW total) high-pressure cogeneration IPPs at JDW Unit-II and Unit-III. Set up at a total cost of approximately US$ 60 million, these pioneering projects are the only ones in recent times to have been set up through direct procurement and supervision without an EPC contractor. Both plants are fully operational since 2014 and have already sold 245 million units to the grid with gross revenue of $28.3 million as of end April 2015. Besides managing various aspects related to the projects' conceptualization, development, regulatory affairs, tendering, construction and commissioning, Mr. Ahmed now also supervises their operations & maintenance.

Before joining JDW in 2001, Mr. Ahmed served as a civil servant in the highly selective District Management Group. He worked at progressively senior positions in his public sector career including Assistant Commissioner, Deputy Commissioner, Deputy Secretary, Additional Secretary and Secretary to the Government of Punjab. His postings included various key provincial departments and major cities. He last served as Secretary, Agriculture Department, Punjab from 1999 to 2001.

Mr. Ahmed holds an MBA from Saint Louis University, USA and MA and BA degrees in Economics from the University of Punjab, Pakistan.

Rana Uzair Nasim - Chief Executive Officer

Rana Uzair Nasim is the CEO of HSPL. His responsibilities center on achieving various development milestones leading to financial close and subsequently leading project management through the construction, installation and operational phases. He serves as the primary point of contact on behalf of HSPL with other project stakeholders including concerned public sector agencies, project lenders, insurers, the EPC contractor, power purchaser, etc. In performing his role, he also leverages input as required from the project's legal, technical and financial advisors.

Uzair has first-hand power sector experience across development and operations including project design, policy and tariff development, financing, insurance, licensing, negotiation of project security documents, invoicing and regulatory affairs. He has been employed as Business Development Manager at JDW Sugar Mills Limited since 2010, with primary focus on assisting the company's executive management with the development and operation of the company's pioneering 2 x 26.5 MW high-pressure cogeneration power projects. He is also responsible for providing expert input on tariff and contract negotiations and regulatory issues relating to the company's low pressure captive power plants.

Uzair has contributed significantly to several important developments in the broader renewable energy sector in Pakistan. He provided extensive input on the country's policy framework for high-pressure cogeneration by the sugar industry and the first-ever upfront tariff for bagasse-based power projects. He contributed important commentary over the course of two years to NEPRA in its development of the first-ever upfront tariff for small hydropower projects. He along with other sponsors also suggested and commented on breakthrough guidelines recently issued by NEPRA to address long-standing issues relating to power purchase and evacuation from small hydro and other smaller renewable projects.

Uzair previously worked as a management consultant in New York with Oliver Wyman and Dalberg Global Development Advisors where he advised clients in the financial services, corporate and development sectors on new market and product strategy and operational optimization.

At Dalberg, his key projects included developing a business, supply chain and financing plan for an export-focused beverage company based out of a small Pacific island country; and supporting a large foundation in creating a long-term strategy for transferring technical knowledge and training to small agribusinesses in Sub-Saharan Africa and South Asia. At Oliver Wyman, some of Uzair's major projects included strategizing and prioritizing growth strategy initiatives for one of the largest capital markets data, news and trading technology providers in the world; recommending comprehensive budgeting and process improvements to a major Turkish commercial bank; and developing default and loss models for a start-up mortgage provider based in Saudi Arabia.

He holds a BA degree in Economics and an MS degree in Management Science & Engineering, both from Stanford University, California, USA.

ANNEX- 9

HBL

HABIB BANK
حبیب بینک

May 09, 2015

TO WHOM IT MAY CONCERN

THIS IS TO CERTIFY THAT M/S HARAPPA SOLAR (PRIVATE) LIMITED IS MAINTAINING A/C NUMBER 1242-79480798-03 AT OUR CENTRE SINCE 04-10-2014.THE CONDUCT OF ACCOUNT IS SATISFACTORY.

THIS CERTIFICATE IS BEING ISSUED AT THE REQUEST OF CUSTOMER, WITHOUT ANY RISK OR RESPONSIBILITY ON PART OF BANK OR ITS OFFICERS.

MANAGER,

GHULAM MOHY UDDIN
MANAGER
P.A. # 11817

Habib Bank Limited, Corporate Centre, 102-103, Upper Mall Lahore
Ph: 042-36281655,, 036281820-3613 Fax 042-36281661

ANNEX - 11

ECO Trade and Development Bank

Rana Uzair Nasim
Chief Executive Officer
Harappa Solar (Private) Limited

CPF-12-2015-184

May 5, 2015

Subject: **<u>Expression of Interest – 18 MW_p Harappa Solar Power Project located near Harappa Bypass, District Sahiwal, Punjab, Pakistan (the "Project")</u>**

Dear Sir,

Reference is made to our meetings and ongoing discussions on the Project being set up by Harappa Solar (Private) Limited (the "**Company**").

We understand that the total cost of the Project is expected to be around USD 30.0 million, which shall likely be funded on a debt to equity ratio of 75:25. Based on a review of the preliminary information and documents submitted by the Company in relation to the Project, we are pleased to provide you this Expression of Interest for providing finance to the project by ECO Trade and Development Bank (the "**Bank**").

Please note, however, that this Expression of Interest does not constitute a legally binding commitment and the Bank's final decision shall be based on satisfactory detailed due diligence and internal credit approvals, procurement of all necessary consents and regulatory approvals, and the execution of definitive agreements between the Bank and the Company.

For and on behalf of ECO Trade and Development Bank

Shahzad Cheema
Corporate & Project Finance, Director

Yeşim Çevik
Corporate& Project Finance, Manager

Bomonti Business Center Cumhuriyet Mah. Silahşör Cad. Yeniyol Sk. No: 8 Kat: 14 - 16 34380 Bomonti Şişli Istanbul / Turkey
Tel: (+90) (212) 393 6300 (pbx) Fax: (+90) (212) 393 6301
info@etdb.org www.etdb.org

Financial Statement (Net Worth of Sponsors)

As Harappa Solar (Private) Limited ("HSPL") is a newly incorporated special purpose company, it currently does not hold meaningful assets in its own name. Therefore, the net worth statement of Mr. Rana Nasim Ahmed, who is the main sponsor of HSPL, is being provided instead. While other investors shall be added and finalized in due course, Mr. Ahmed on his own has sufficient financial resources for funding the required equity commitment for the project. In this regard, copy of certification of net wealth from chartered accountants Riaz Ahmad, Saqib, Gohar & Company is enclosed, which was also submitted earlier to the Alternative Energy Development Board.

RASG

RIAZ AHMAD, SAQIB, GOHAR & COMPANY

Chartered Accountants

786 RASG/2014-15/438

March 31, 2015

The Company Secretary
Harappa Solar (Private) Limited
1485/C 2A, Asad Jan Road, Lahore Cantt.

Dear Sir

NET WEALTH OF MR. RANA NASIM AHMED AS ON JUNE 30, 2014

We have reviewed the computation of net wealth of **Mr. Rana Nasim Ahmed having CNIC number 35202-0464547-7** along with relevant documentary evidence i.e. wealth statement for the tax year 2014 and report that:

Description	As on June 30, 2014
Assets (Rs.)	1,248,549,912
Liabilities (Rs.)	(60,000,000)
Net Assets (Rs.)	1,188,549,912
PKR/US$ Exchange Rate	99.4
Net Assets (US$)	11,957,243

We have used the open market currency rate for conversion to US$ and market share price of Rs. 202.5 for valuation of shareholding of 7.42% (4,437,381 shares) in JDW Sugar Mills Limited.

Yours truly

(Chartered Accountants)

Building No. 35 - D-1, Ali Block, New Garden Town, Lahore Tel: (92-42) 35940246-7, Fax: (92-42) 35940248
www.rasgco.com E-mail:rasglhr@rasgco.com
Corporate Office at Karachi & Regional Office at Islamabad

Employment Record of Engineering and Technical Staff

Avant-Garde Engineers & Consultants FZC, Sharjah, UAE have been appointed as the Owner's Engineer for Harappa Solar (Private) Limited ("HSPL"). Their scope encompasses basic engineering services, EPC procurement and technical evaluation, vetting and approval of detailed engineering drawings, inspection services and supervision of erection and commissioning.

Avant-Garde has provided similar services for various solar PV power projects with cumulative capacity of over 400 MW. They have a multi-disciplinary in-house workforce of more than 200 including over 150 engineers with expertise spanning electrical & instrumentation, civil & structural, material handling, piping, process engineering, project management, quality inspection, site services, etc. Their solar power plant profile is enclosed for reference.

As the project is in pre-operating phase, HSPL has not yet hired dedicated plant staff. However, in addition to the services of Avant-Garde as Owner's Engineer, the company also benefits from the voluntary advisory services of Mr. Rana Saeed Ahmed, who is a very experienced civil engineer. His CV is also enclosed.

Profile and Experience of EPC Contractor

The Company has not yet finalized the EPC Contractor for the project. However, it is in advanced stages of negotiation with several reputable contractors, all of whom have various references as both EPC contractor and top tier module manufacturers. It is anticipated that the EPC contractor shall be finalized and selected out of the four shortlisted companies below.

a. ET Solar

- Tier 1 solar PV module manufacturer
- Annual production capacity of 1,000 MW
- 3,500 MW cumulative capacity of modules installed globally
- Diversified into solar IPP development and investment as well
- Strong project references in Europe along with countries in the Middle East

b. China Electric Equipment Group (CEEG)

- Parent company of China Sunergy, which is a Tier 1 module manufacturer
- Annual production capacity of 1,200 MW
- 2,500 MW cumulative capacity of modules installed globally
- Various project references in Europe, India and Japan

c. Chint Group

- Large and diversified electrical equipment conglomerate
- Parent company of Astronergy, which is a Tier 1 module manufacturer
- Annual production capacity of 1,300 MW
- Project references across Europe, China, India and Japan

d. SUMEC Group

- Diversified engineering, contracting and trading company
- Part of the SINOMACH group, which is a large-scale Fortune 500 enterprise
- Parent company of Phono Solar, which is a Tier 1 module manufacturer
- Annual production capacity of 450 MW, with another 150 MW under construction
- 1,800 MW cumulative capacity supplied to date, primarily in Europe and China
- Recently commissioned a 1.25 MW captive solar power plant in Pakistan

EXPERIENCE OF POWER PROJECTS (1/2)

JDW Sugar Mills Limited		
26.6 MW High-Pressure Cogeneration Plant at JDW Unit-II (Sadiqabad, Punjab)		
No.	**Item**	**Information**
1	**Name of Sponsor**	Rana Nasim Ahmed
2	**Sponsor's role in the project completed**	• Lead project developer • Lead operations manager
3	**Name of Project**	Bagasse-based, high-pressure cogeneration plant at JDW Sugar Mills Unit-II
4	**Sponsor's share in the equity of the completed project** (if applicable)	7.42%
5	**Location of plant**	JDW Unit-II, Machi Goth, Tehsil Sadiqabad, District Rahim Yar Khan, Punjab
6	**Name of Owner** (including contact person, his address and telephone, fax No.'s/email address)	JDW Sugar Mills Limited Contact: Group Director (Finance) 17-Abid Majeed Road, Lahore Cantt. PABX # 042-36664891-95 Fax # 042-36654490 Email: jdwho@jdw-group.com
7	**Name of power purchaser**	Central Power Purchasing Agency (CPPA)
8	**Capacity of plant**	26.60 MW (gross) 24.37 MW (net)
9	**Type of plant**	Cogeneration
10	**Fuel of plant**	Bagasse / biomass
11	**Number and rated capacity of units**	1 x 26.6 MW (gross)
12	**Status of plant**	Fully operational
13	**Number of Years of successful operation**	One year
14	**Principal manufacturers of major equipment**	Descon, Hangzhou Steam Turbine Company, Siemens, Truwater, ABB, Yokogawa, WEMS, KSB
15	**List of specific major tasks/services performed by Sponsor(s)**	Project development including design, tariff, licensing, various other permits approvals and consents; project tendering, contractor selection and finalization; supervision of construction and installation; supervision of operations & management
16	**Date of award of project**	Various packages. Set up without EPC contractor.
17	**Duration of construction period**	Approximately two years
18	**Commercial operations date of each unit**	June 12, 2014

19	**Total capital cost of project**	Rs. 2.92 billion
20	**Companies and institutions who financed the project**	MCB, UBL, ABL, Bank of Punjab, Askari Bank, Meezan Bank, JS Bank, Habib Metropolitan Bank
21	**Value of contract**	Various contracts, please see Sr. 19 above
22	**Any other details**	First project to be commissioned on NEPRA's upfront bagasse tariff

EXPERIENCE OF POWER PROJECTS (2/2)

JDW Sugar Mills Limited		
26.8 MW High-Pressure Cogeneration Plant at JDW Unit-III (Ghotki, Sindh)		
No.	**Item**	**Information**
1	**Name of Sponsor**	Rana Nasim Ahmed
2	**Sponsor's role in the project completed**	• Lead project developer • Lead operations manager
3	**Name of Project**	Bagasse-based, high-pressure cogeneration plant at JDW Sugar Mills Unit-III
4	**Sponsor's share in the equity of the completed project** (if applicable)	7.42%
5	**Location of plant**	JDW Unit-III, Goth Islamabad, District Ghotki, Sindh
6	**Name of Owner** (including contact person, his address and telephone, fax No.'s/email address)	JDW Sugar Mills Limited Contact: Group Director (Finance) 17-Abid Majeed Road, Lahore Cantt. PABX # 042-36664891-95 Fax # 042-36654490 Email: jdwho@jdw-group.com
7	**Name of power purchaser**	Central Power Purchasing Agency (CPPA)
8	**Capacity of plant**	26.83 MW (gross) 24.41 MW (net)
9	**Type of plant**	Cogeneration
10	**Fuel of plant**	Bagasse / biomass
11	**Number and rated capacity of units**	1 x 26.83 MW (gross)
12	**Status of plant**	Fully operational
13	**Number of Years of successful operation**	Less than one year
14	**Principal manufacturers of major equipment**	HMC, Hangzhou Steam Turbine Company, Siemens, Truwater, ABB, Yokogawa, WEMS, KSB
15	**List of specific major tasks/services performed by Sponsor(s)**	Project development including design, tariff, licensing, various other permits approvals and consents; project tendering, contractor selection and finalization; supervision of construction and installation; supervision of operations & management
16	**Date of award of project**	Various packages. Set up without EPC contractor.
17	**Duration of construction period**	Approximately two years
18	**Commercial operations date of each unit**	October 3, 2014

19	**Total capital cost of project**	Rs. 3.03 billion
20	**Companies and institutions who financed the project**	MCB, UBL, ABL, Bank of Punjab, Askari Bank, Meezan Bank, JS Bank, Habib Metropolitan Bank
21	**Value of contract**	Various contracts, please see Sr. 19 above
22	**Any other details**	Second project to be commissioned on NEPRA's upfront bagasse tariff

PROJECT TECHNICAL, FINANCIAL & OTHER INFORMATION

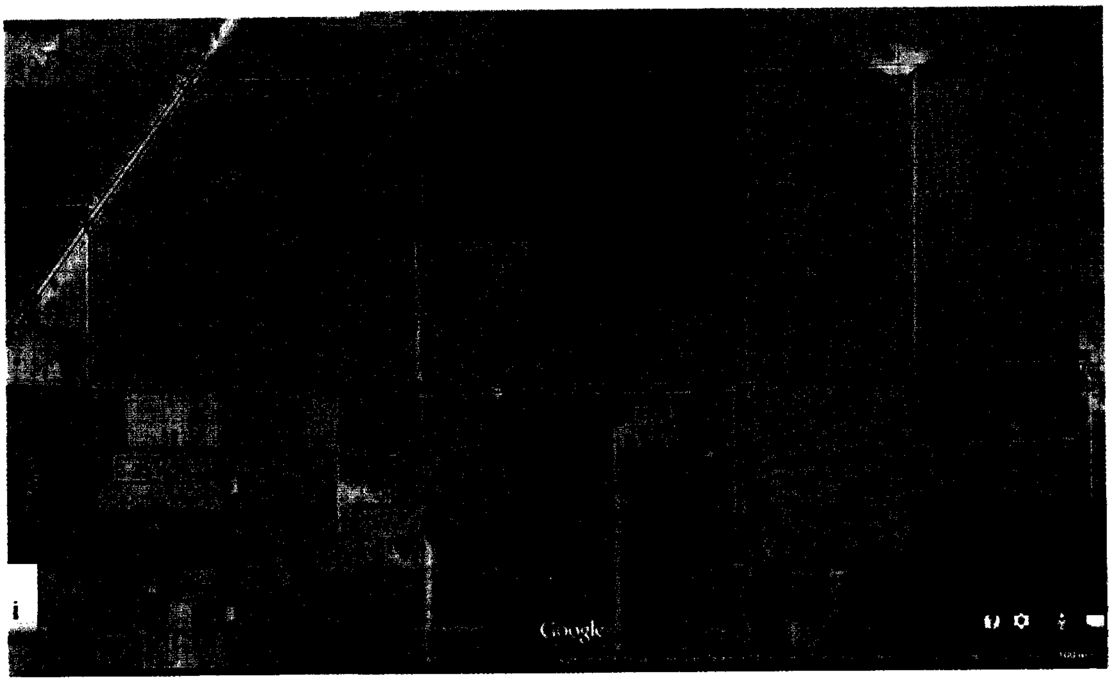
1) Location and Land Details

The project shall be located on approximately 66 acres. The land is located in both Jinnah Town and Chak 4/10-L about 1 km from the Harappa Bypass section of the Lahore-Multan highway in Tehsil & District Sahiwal, Punjab. The site is situated at a distance of approximately 175 km from Lahore and 145 km from Multan. The indicative coordinates of the project site are given below.

North	East
30°34'57.55"	72°53'35.66"
30°34'57.27"	72°53'44.14"
30°34'52.69"	72°53'44.14"
30°34'52.69"	72°53'56.60"
30°34'57.54"	72°53'56.98"
30°34'57.55"	72°54'03.11"
30°34'47.97"	72°54'03.24"
30°34'47.99"	72°54'09.60"
30°34'42.08"	72°54'09.59"
30°34'41.93"	72°53'57.02"
30°34'47.94"	72°53'57.00"
30°34'47.73"	72°53'36.90"
30°34'43.85"	72°53'36.94"
30°34'43.84"	72°53'31.91"
30°34'45.78"	72°53'31.99"
30°34'45.78"	72°53'33.32"
30°34'47.72"	72°53'33.12"
30°34'47.79"	72°53'32.01"
30°34'52.81"	72°53'32.02"

The selected project site has various advantages. It is located just off a main highway with existing road access. The 132/11 kV Harappa Grid Station is located at a short distance of approximately 2.5 km from the site and has significant demand of up to 40 MW. The site is located on the ancestral land of the sponsors who have long-standing local ties and broad community support for the project. The land comprises level soil with no water table or salinity issues, which shall facilitate construction.

Google image of the land with outline of boundaries is given below. The plant layout drawing is also enclosed.



2) Technology & Plant Details

a) Proposed Scheme

It is proposed to install an 18.0 MW_p capacity Solar PV power plant with polycrystalline solar PV modules in fixed tilt (23°) or seasonal tilt (10° & 35°) configuration and Central Grid Tied Inverters. Generated power shall be stepped-up to 11 kV through inverter transformers, as shown in the attached Single Line Diagram.

b) PV Modules

305 W_p polycrystalline modules from top tier Chinese PV module manufacturers are being considered for the project. The modules shall be protected by high transmission tempered glass covered with anodized aluminum alloy frames. Serially connected cells shall be terminated to IP66 junction boxes at bottom with 4 Sq.mm multi-strand copper cables. Positive & Negative terminals shall be terminated with MC4 connectors and Y-connectors, for making module interconnections.

Typical parameters of the modules:

	Solar Panels – PV Modules	
i.	Type of Module	Polycrystalline PV Module Type 305Wp
ii.	Type of Cell	Polycrystalline Silicon
iii.	Dimension of each Module	1956mmx992mmx40mm

iv.	Module Surface Area	1.94 m^2
v.	No. of Panel /Modules	59,136
vi.	Total Module Area	217240 m^2 (53.68 Acers)
vii.	Total Land Area Used	Approximately 66 acres
viii.	Panel's Frame	Anodised Aluminium
ix.	Weight of one Module	26.3kg (57.98lbs)
x.	Module Output Warranty	97% for the first year
		Not more than 0.7% per year between 2nd and 25th Year
xi.	Number of Solar Cells in each module	72
xii.	Efficiency of module	15.72%
xiii.	Environment Protection System	Encapsulation and sealing arrangement for protection from environment
xiv.	Maximum Power (P_{max})	305 W
xv.	Voltage @ (P_{max})	37.18 V
xvi.	Current @ P_{max}	8.21 A
xvii.	Open circuit voltage (V_{oc})	45.12 V
xviii.	Short circuit current (I_{sc})	8.78 A
xix.	Maximum system open Circuit Voltage	1000V DC
	PV Array	
i.	Nos. of Sub-array	176
ii.	Modules in a string	21
iii.	Total Nos. of Strings	2816
iv.	Modules in Sub-Array	3696 (176 strings with 21 modules)
v.	Total No. of Modules	59,136
	PV Capacity	
	Total	18.0 MW_p (DC)
	Junction Boxes Installed	
i.	Number of J/Box units	192
ii.	Input circuits in each box	16 Inputs
iii.	Max. input current for each circuit	10A
iv.	Max. input voltage	1000V
v.	Power at each box	104.16kWp
vi.	Protection Level	IP 66
vii.	Overcurrent protection	Fuse
viii.	Output switch	250A, 1000V Disconnector
ix.	Surge protection	1000V DC, Type II surge protection device with remote contact

c) Solar Inverters

Solar Inverters are the most critical equipment in the Solar PV plant, as the reliability & performance of the inverters have great influence on the plant overall performance & availability. It is proposed to use Central Inverters of sixteen (16) numbers, with 1200 kW_p PV modules per Inverter / Block.

Negative grounding in inverters shall be planned to counter Potential Induced Degradation ("PID") effect for the modules. Inverters shall be from ABB or equivalent.

Parameters of the proposed inverter:

<table>
<tr><th></th><th>Inverters</th><th colspan="2"></th></tr>
<tr><td>i.</td><td>Capacity of each unit</td><td colspan="2">1200 kW_p</td></tr>
<tr><td>ii.</td><td>Inverter Model</td><td colspan="2">PVS800-57-1000kW-C</td></tr>
<tr><td>iii.</td><td>Manufacturer</td><td colspan="2">ABB</td></tr>
<tr><td>iv.</td><td>Rated Input Voltage</td><td colspan="2">1100V DC</td></tr>
<tr><td>v.</td><td>Input Operating Voltage Range</td><td colspan="2">600 to 850 V DC</td></tr>
<tr><td>vi.</td><td>Number of Inverters</td><td colspan="2">16</td></tr>
<tr><td>vii.</td><td>Total Power</td><td colspan="2">16,000kW AC</td></tr>
<tr><td>viii.</td><td>Efficiency</td><td colspan="2">98.8%</td></tr>
<tr><td>ix.</td><td>Max. Allowable Input voltage</td><td colspan="2">1100V DC</td></tr>
<tr><td>x.</td><td>Max. Current</td><td colspan="2">1710A DC</td></tr>
<tr><td>xi.</td><td>Max. Power Point Tracking Range</td><td colspan="2">600 to 850 V DC</td></tr>
<tr><td>xii.</td><td>Output electrical system</td><td colspan="2">3 Phase, 3 wire</td></tr>
<tr><td>xiii.</td><td>Rated Output Voltage</td><td colspan="2">400 V</td></tr>
<tr><td>xiv.</td><td>Rated Frequency</td><td colspan="2">50 HZ</td></tr>
<tr><td>xv.</td><td>Power Factor</td><td colspan="2">Adjustable 0.95 Lag to UPF</td></tr>
<tr><td>xvi.</td><td>Power Control</td><td colspan="2">MPP Tracker</td></tr>
<tr><td rowspan="5">xvii.</td><td rowspan="5">Environmental Enclosures</td><td>Operating Temperature Range</td><td>-15 to +50 °C</td></tr>
<tr><td>Relative Humidity</td><td>15 to 95%</td></tr>
<tr><td>Audible Noise</td><td>75 dBA Max</td></tr>
<tr><td>Operating Elevation</td><td>Maximum Altitude 4000m</td></tr>
<tr><td>Warranty Period</td><td>5 Years</td></tr>
<tr><td rowspan="7">xviii.</td><td rowspan="7">Grid Operation Protection</td><td>(a).</td><td>Ground Fault monitoring</td></tr>
<tr><td>(b).</td><td>Grid monitoring</td></tr>
<tr><td>(c).</td><td>Anti-islanding</td></tr>
<tr><td>(d).</td><td>DC reverse polarity</td></tr>
<tr><td>(e).</td><td>AC & DC short circuit and over current</td></tr>
<tr><td>(f).</td><td>AC & DC overvoltage and temperature</td></tr>
<tr><td>(g).</td><td>Lightning Protection Level III</td></tr>
</table>

d) String Combiner Boxes & DC Cabling

The modules will be connected with DC cables, in series & parallel combinations and hooked-up to Inverters, through string Combiner Boxes. Total 2816 strings (21 modules per string) shall be connected in nine inverters each with 12 inputs. There shall be eight (8) inputs in String Combiner Boxes (SCBs) with string current monitoring arrangement.

All solar field cables upto SCBs shall be single core electron beam / UV resistant cables with multi-strand copper conductors.

Connection from SCB to inverters shall be with single core armored, multi-strand Aluminum cables with Cross-Linked Polyethylene ("XLPE") insulation.

e) Inverter Transformers

It is proposed to use twin, secondary oil filled transformers for stepping up the power generated from the PV system, by connecting one inverter per secondary. The transformers intended for connecting to the Solar Inverters shall confirm to IEC: 76. The transformers will be as per the following specification:

	Isolating Transformer	
i.	Rating	2.25 MVA Dual Secondary Transformers (8 NOs)
ii.	Type of Transformer	ONAN
iii.	Input voltage	400V-400V (LV1-LV2)
iv.	Output Voltage	11kV
v.	Purpose of Transformer	Step Up Voltage Transformer
vi.	Efficiency	98.94%

f) HT Panels:

It is proposed to provide 11 kV switchboards one at Plant Main Control building and One (1) more in Inverter Room. Also, Six (6) Nos of inverter rooms are planned. Proposed hook-up arrangement is shown in the attached single line diagram. Brief parameters of 11 kV switchboard is given below:

Rated Voltage	11 kV, 3 Phase, 50 Hz
Maximum Voltage	12 kV
Power frequency Voltage	28 kV rms
Impulse withstand Voltage	75 kV peak
Maximum bus bar temperature	85 Deg. C
Operating Duty	O-0.3sec-CO-3min-CO

g) Civil & Structural Works:

PV modules shall be fixed on the Module Mounting Structures (MMS) in two rows in portrait arrangement. Main columns of these steel panel tables will be with galvanized MS hot rolled sections / GI cold formed sections, while the rafters, cross bracing & purlins will be with GI cold formed sections / galvanized steel tubes. Structural materials foundation bolts, fastening bolts, screws, nuts, washers shall conform to the relevant International Standards. All mild steel members (inner & outer surface area) will be electro galvanizing/hot dip galvanizing to 85 microns.

The structures shall either be left embedded in short RCC piers or rammed into earth, depending on soil properties.

Main control building, inverter rooms and security buildings shall be single story buildings with brick work & insulated pre-painted galvanized corrugated sheets. Inverter & control rooms shall be envisaged with pressurized ventilation arrangement.

Internal roads, fencing & gates shall be planned as in layout drawings.

	Mounting Structure	
i.	Structure	Galvanised MS Hot Rolled Sections / GI Cold Formed Sections / Galvanised Steel Tubes
ii.	Tilt of Array Frame	23°
iii.	Array Specification	Certified for Wind and Seismic Requirements
	Foundation Pillars/Piling	
	No. of Foundations	9856
	Foundation Structure	Short Pile Foundation

h) Cables, Grounding and illumination system:

Power cables for 11 kV system will be with three core aluminum conductor, XLPE insulated, screened, armored and overall PVC sheathed confirming to IEC: 502. The power cables of 1.1 kV grade will be XLPE insulated, aluminum conductor with outer sheath of PVC compound conforming to latest version of IEC: 227. The control cables for control / protection / indication circuit of the various equipment will be of 1.1 kV grade, PVC insulated annealed high conductivity stranded copper conductor, inner sheath PVC taped, flat/round wire armored with outer sheath of PVC compound conforming to latest version of IEC: 227.

Non-current carrying parts of all electrical equipment viz. distribution boards, control panels, HT switchgears, and all lighting fittings shall also be grounded rigidly, to ensure safety. Building lightning protection system will be provided as per relevant IEC standards.

AC supplies of single / three phase, needed for internal use for several functions such as Illumination through lighting inverters, SCADA supply through UPS, Battery Chargers, Transformer tap-changer drives, Power supplies for communication equipment / surveillance system, Breakers / Disconnect switch motors, etc. Auxiliary transformer shall be planned in each inverter building for catering to the auxiliary loads.

Good lighting in the plant will be ensured for maintenance requirement in control buildings and security / surveillance of the boundaries. All lighting supplies shall be extended through lighting inverters. Fence lighting shall be envisaged with low wattage LED lamps.

i) Monitoring System & SCADA

Monitoring of system operation parameters will be monitored locally and also from remote locations through internet.

Weather monitoring station, for irradiance, wind velocity & ambient temperature, String currents, Inverter Parameters, Transformer protections and temperature, HT Panel parameters, Export & import (auxiliary) energy and Perimeter Security through CCTVs & alert systems are hooked-up to SCADA system.

	Data Collecting System		
i.	Weather Data	(i).	Pyranometer – Two Sets (Incline to record irradiation level)
		(ii).	Thermometer – Two Sets (to record ambient temp)
ii.	System Data	(i).	DC input voltage(V) & current (A) of each Inverter (Phase, Line)
		(ii).	Total DC power (kW) generated by PV array.
		(iii).	AC output voltage(V) and current (A) of each Inverter (Phase, Total)
		(iv).	AC output power (kW) and energy (kWh) of each Inverter
		(v).	Frequency (Hz)
		(vi).	Power Factor (PF)

j) Module Cleaning System

Module cleaning system shall be envisaged for spraying soft water over the modules manually, by providing storage tanks, water pumps, PVC piping network & valves. This cleaning process is to be carried out periodically depending upon the intensity of dust deposition over the PV modules.

3) Interconnection with National Grid Company, Distance & Name of nearest Grid, Voltage Level

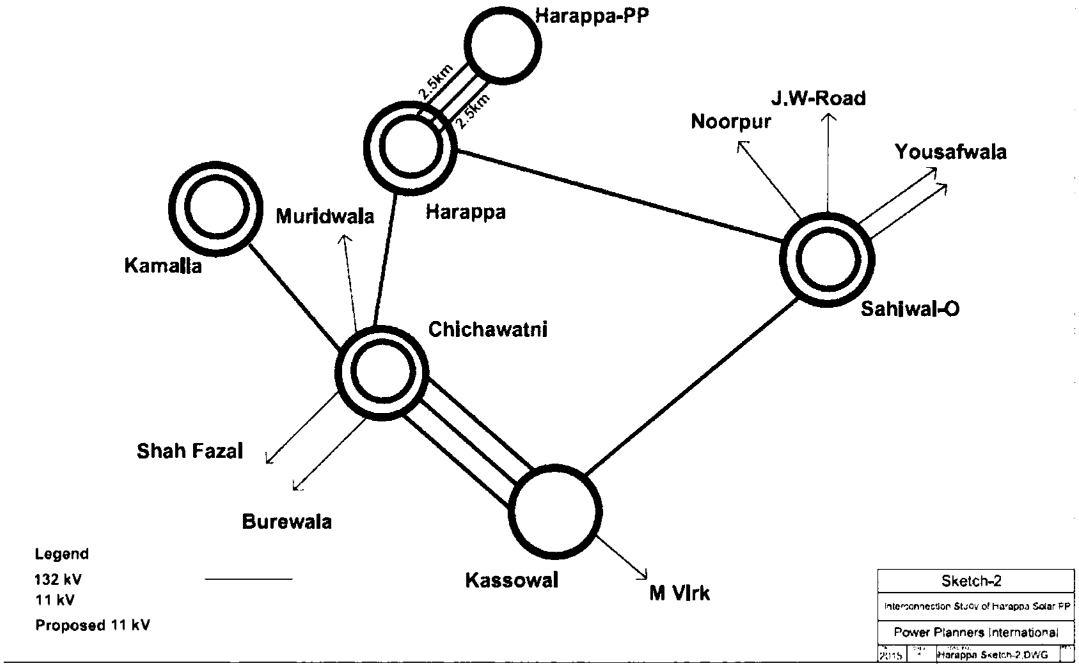
Harappa Solar (Private) Limited intends to sell electricity generated by the project to the Central Power Purchasing Agency (CPPA) pursuant to the NEPRA (Sale of Electric Power by Renewable Energy Companies) Guidelines, 2015.

The power generated from the Generation Facility / Power Plant / Solar Farm of Harappa Solar (Private) Limited shall be dispersed to the load center of MEPCO.

The proposed interconnection / dispersal arrangement for the project comprises a direct 11 kV triple circuit line of approximately 2.5 km length using Osprey conductor to be laid from the 11 kV bus bar of the project to the 132/11 kV Harappa Grid Station. Two circuits are to be connected to Harappa 132/11 kV T-1 and one circuit to be connected to Harappa 132/11 kV T-2.

Any change in the above interconnection arrangement shall be communicated to the Authority in due course. The sketch of the proposed scheme is provided below.

132 kV Network Near Harappa
With Harappa Solar Power Plant, June 2016



4) Project Cost, Sources and amounts of Equity and Debt

a) Project Cost

The total project cost is expected to be in the range of USD 28.38 million with Engineering, Procurement & Construction Cost of USD 25.40 million. The cost is budgetary at this stage and shall be firmed up in due course after conclusion of EPC contract negotiations and finalization of financing arrangements. The breakup of project cost is summarized as follows:

PROJECT COST	USD million
EPC Cost	25.40
Non-EPC Cost	0.86
Development Costs	0.73
Insurance During Construction	0.18
Financing Fees & Charges	0.75
Contingencies	-
Project Cost Before IDC	27.92
Interest During Construction	0.46
Total Project Cost	**28.38**

b) Financial Plan:

The total project cost of approximately USD 28.38 million is to be financed with a combination of debt and equity. Based on initial discussions with the financial institutions, the Company is likely to finance the project on the basis of a Debt: Equity ratio of 75:25. The debt amount is expected to be funded by foreign and local debt with interest payable quarterly on the basis of 3-Month prevailing LIBOR plus 450 basis points for foreign debt and 3-Month KIBOR plus 350 basis points for local debt. The term of the loan is expected to be 10 years plus grace period for construction. A summary of the financial plan is provided below:

		USD million
	Total Equity (25%)	7.10
	Foreign Debt (50% of Total Debt)	10.64
	Local Debt (50% of Total Debt)	10.64
	Total Debt (75%)	21.29
	Total Project Cost	28.38

5) Project Schedule with Milestones

The project is currently in an advanced stage of development prior to financial close. The following milestones have been achieved to date:

- Incorporation of Project Company
- Issuance of Letter of Intent by the Alternative Energy Development Board (AEDB)
- Arranging project land
- Topographic and soil investigation surveys
- Rigorous solar resource assessment and basic plant design
- Approval of grid interconnection study by MEPCO and submission to NTDC for further vetting
- Submission of environment study for approval

The following activities are currently being pursued on a fast track basis:

- Commercial and technical negotiations with shortlisted EPC contractors
- Finalization of project capital structure
- Drafting EPC, land and other project agreements for sharing with lenders
- Procurement of various other regulatory approvals and consents

Financial close for the project is targeted by November 2015 while commercial operations date is expected to be achieved by June 2016. However, the timelines shall be firmed up and divided into more detailed milestones in consultation with the EPC contractor, project lenders and other stakeholders.

6) ESSA (Environmental and Social Soundness Assessment)

The energy sector of Pakistan is relying heavily on imported fossil fuels for generation of electricity. The development of solar power generation projects could reduce dependence on fossil fuels for thermal power generation and increase diversity in Pakistan's electricity generation mix thereby reducing greenhouse gas (GHG) emissions. The electricity generated shall directly offset greenhouse gas emissions from the combustion of fossil fuels and displace an estimated 17,400 tonnes of CO_2 emissions in first year of operation. There are no endangered flora or fauna species occupying the land. It is proposed that the environmental impact of the proposed solar power plant shall be minimal and greatly outweighed by the environmental benefits of generating much-needed renewable and pollution free electricity. An Initial Environmental Examination (**IEE**) has been conducted for the HSPL project and has been submitted for approval.

7) Social Impact

The project will generate direct and indirect employment opportunities for the local population. The project will improve the basic infrastructure, which can be used by people of nearby villages. HSPL will give priority to skilled, un-skilled labor of the nearby villages. Overall, it is anticipated that there will be marginal impacts on the socio-economic conditions of the locality and the impact will be positive.

8) Safety Plans, Emergency Plans

a) Health, Safety & Environment (HSE) Protection

The Company will be committed to ensuring the highest standard when it comes to the health and safety of people and protection of the environment. This shall apply to all locations of the office space as well as the construction site. Commitment will remain in place to continuously improve HSE at the workplace, and contractors will be required to follow such an example by adopting the Company's policy or developing their own equivalent.

b) Health, Safety & Environment Policy

The Company is committed to comply with all applicable HSE legislations. Every person in the scope of the project will be obliged to comply with all legal requirements as well as all HSE policies. Any person who fails to comply with these requirements will be denied access to the project site. Emergency procedures will be regularly communicated and exercised with all employees, contractors/subcontractors and any other stakeholder in the project's permanent and temporary workspaces.

c) Environment

HSPL will actively encourage its employees and contractors/subcontractors to contribute to waste reduction. In the permanent workspaces, a predefined set of measures to reduce consumption of electricity, water and paper will be put in place. Employees and contractors/subcontractors shall ensure proper waste disposal and all employees and contractors/contractors shall be required to demonstrate a high level of care when handling solar modules, inverters and cables to minimise waste from breakage. Hazardous materials shall be identified before they enter the site and the proper disposal of any hazardous waste will be monitored and ensured.

9) System Studies: Load Flow, Short Circuit, Stability, Reliability

An interconnection study for the project has been conducted by Power Planners International and approval from MEPCO has already been received. The interconnection study has also been submitted to NTDC for their vetting as required under the upfront tariff and is under review by them.

Detail of Load Flow, Short Circuit, Stability and Reliability can be found in the interconnection connection study, which has been attached with this application.

10) Plant Characteristics: Generation Voltage, Frequency, Power Factor, Automatic Generation Control, Ramping Rate, Time(S) Required To Synchronize To Grid

Please refer to Plant Technical Details in Section 2 above

11) Control, Metering, Instrumentation And Protection

Please refer to Plant Technical Details in Section 2 above

12) Training And Development

Training is part of the scope of works to be conducted under the Engineering, Procurement and Construction ("EPC") Contractor. The EPC Contractor shall also carry out the training of the Employer's Personnel in the operation and maintenance of the Complex.

Harappa Solar (Private) Limited

18.0 MW_p Solar PV Power Project

Prospectus

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1 The Project

Harappa Solar (Private) Limited ("HSPL" or the "Company") is planning to set up an 18.0 MW_p solar photovoltaic ("PV") power generation plant (the "Project") near Harappa Bypass in District Sahiwal, Punjab. The Project is presently in an advanced stage of development prior to financial close.

2 Project Sponsors

The Project is being developed by an experienced group of industry professionals consisting of senior executives and key shareholders of JDW Sugar Mills Limited ("JDW"), including Mr. Rana Nasim Ahmed and Mr. Rana Uzair Nasim (collectively the "Sponsors").

The Sponsors have deep knowledge of the power sector and are the pioneers in recently developing and commissioning approximately 2 x 26.5 MW (53 MW Total) high-pressure cogeneration projects at JDW Unit-II and Unit-III. These power projects are one of the few to have been set up through direct procurement and supervision of various vendors without an EPC contractor. The first project at JDW Unit-II was commissioned in June 2014 whereas the second at JDW Unit-III was commissioned in October 2014. Both are running at full capacity with O&M supervised by the Sponsors.

The Sponsors have thus built up first-hand experience in power project development (e.g. design, financing, licensing, tariff development, grid studies, and security documents) as well as project tendering, construction, installation and operation. As such, the Sponsors are uniquely positioned to leverage their expertise towards the successful commissioning and operation of the Project.

3 Project Site

The Project shall be located in Jinnah Town and Chak 4/10-L approximately 1 km from the Harappa Bypass section of the Lahore-Multan highway in Tehsil & District Sahiwal. The site is situated at a distance of about 175 km from Lahore and 145 km from Multan.

The Project is expected to be set up over an area of approximately 66 acres on land currently owned by the Sponsors. The land shall be leased to HSPL under a 25-year agreement by the land owners at the prevailing market rates.

Access to the site is available via a road emanating from Harappa Bypass Road. A satellite view of the Project site is provided in the figure on the next page. A detailed soil investigation and topographic survey at the Project Site has been carried out; the land available is almost flat with no water table intervention.

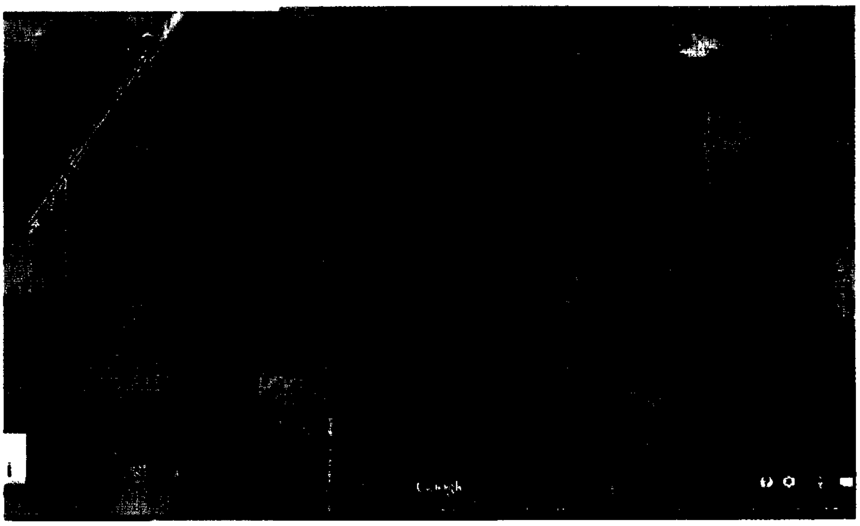

Figure 3-1

4 Applicable Policy

The Project is being set up pursuant to the Policy for Development of Renewable Energy for Power Generation 2006 (the "Policy") being administered by the Alternative Energy Development Board ("AEDB"). Under the terms of the Policy, electricity purchase by the power purchaser from qualifying renewable energy-based generation projects has been made mandatory.

HSPL holds Letter of Intent ("LOI") No. B/3/2/SPV/LOI-44 issued on December 31, 2014 by AEDB, which was subsequently modified to 18 MW. Copies of the same are enclosed for reference. The Company intends to opt for the upfront tariff recently determined by the National Electric Power Regulatory Authority ("NEPRA") for solar PV power projects. Following the tariff approval/determination, the Company shall approach AEDB for a Letter of Support ("LOS"), pursuant to which the Company shall be required to achieve financial close within the period determined by NEPRA for the tariff validity.

5 Power Purchaser

The Company intends to sell all energy generated from the Project to the Central Power Purchasing Agency ("CPPA") under a 25-year Energy Purchase Agreement pursuant to the NEPRA (Sale of Electric Power by Renewable Energy Companies) Guidelines, 2015.

6 Interconnection

Energy generated by the Project shall be dispersed to the load center of Multan Electric Power Company Limited ("MEPCO"). The proposed interconnection arrangement comprises a direct 11 kV triple circuit line of approximately 2.5 km length using Osprey conductor to be laid from the 11 kV bus bar of the Project to the 132/11 kV Harappa Grid Station. Two circuits are to be connected to Harappa 132/11 kV T-1 and one circuit to be connected to Harappa 132/11 kV T-2. An interconnection study for the Project has been conducted by Power Planners International and approval from MEPCO has already been received. The interconnection study has also been submitted to NTDC for their vetting as required under the upfront tariff.

7 Project Tariff

NEPRA on January 22, 2015 announced an upfront tariff for solar PV power projects which is valid for six months from the date of its notification. The Company intends to apply to NEPRA for allotment of this tariff within the period of validity. The Project falls within the 1-20 MW band in the North Zone as per the upfront tariff determination.

8 Energy Purchase Agreement ("EPA")

A standardized EPA for Solar PV projects has been prepared by AEDB and approved by the Government of Pakistan. The EPA shall be executed between the Company and Power Purchaser for sale and purchase of power, generation and despatch methodology, operating procedures and practices, and commercial terms including billing and payments. The EPA shall become effective in its entirety upon the date of financial closing and delivery of a standby letter of credit by the Company backstopping its obligation to achieve COD on or before a stipulated time. The term of the EPA shall extend until the 25th anniversary of the COD.

The 25-year Upfront Tariff to be determined by NEPRA shall form the basis of the EPA and allow the necessary revenue predictability and consistency that is the key to any investment. As is the case with wind power projects, the compensation is based on energy payments divided into O&M (local & foreign), insurance, return on equity and the debt (principal and markup) components.

9 Implementation Agreement ("IA")

As is the case with the EPA, a standardized IA for Solar PV projects has been approved. The IA shall be negotiated and signed between the Project Company and the Government of Pakistan. The term of the IA shall commence from the execution of the EPA and continue for the rest of its term. The IA defines the Government of Pakistan's ("GoP") obligations with respect to the GoP guarantee for payment of amounts due by the Power Purchaser, compensation payments in case of termination due to Seller/Power Purchaser event of default or Force

Majeure, provision of additional security, fast-track clearance of imports equipment at port, provision of consents etc. The IA also includes provisions related to protection against any discriminatory action by the GoP or public entity which materially and adversely affects the Project or its ownership.

10 Solar PV Technology

There are several kinds of solar technologies that are currently available. However, each of them is based on quite different concepts and science, and each is at a different stage of commercialization and bankability.

10.1 Types of Solar Technology

Different types of energy converting options and techniques are given below:

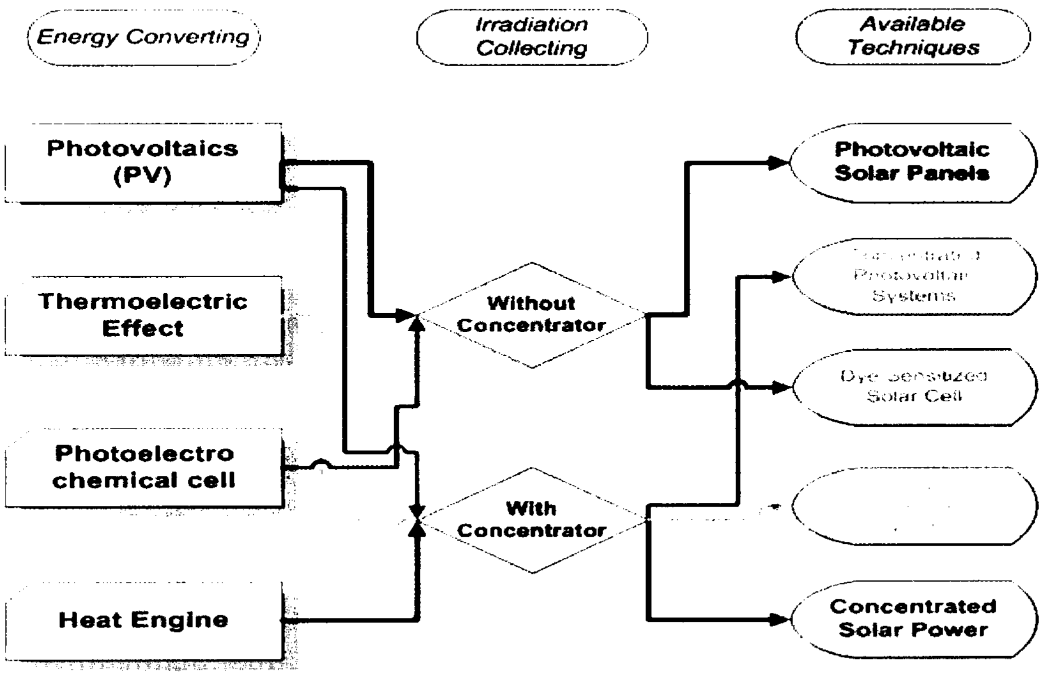

Figure 10-1

10.2 Popular Solar Technologies

Photovoltaic Solar Panels (PV) and Solar Thermal / Concentrated Solar Power (CSP) are the two most mature technologies. They have been commercialized and are expected to experience rapid growth in future. A brief overview on different technologies in PV and Solar Thermal are given in the figure below:

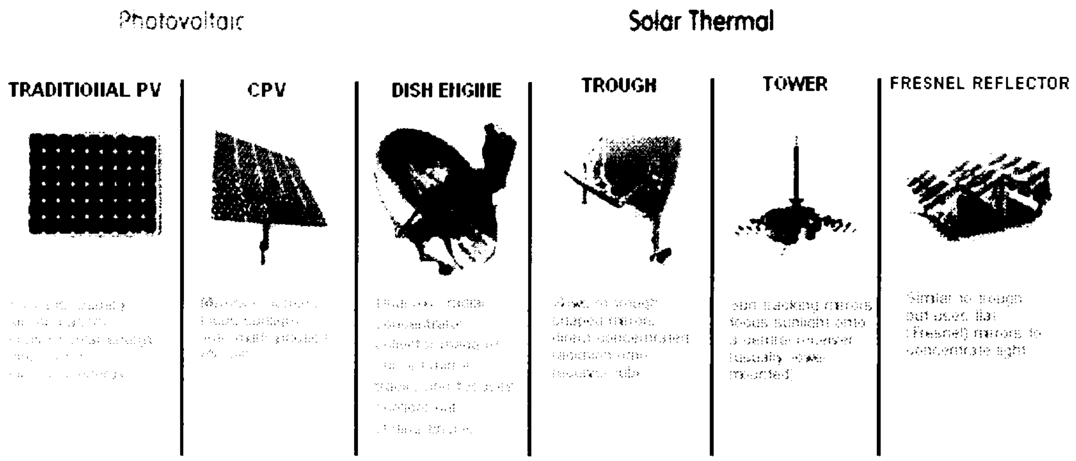

Figure 10-2

Solar Thermal Plants have advantages in certain applications needing steam and for higher capacities (above 50MW) with storage options.

At present, photovoltaic installations have about 97.5% share while solar thermal plants have about 2.5% share globally. Hence, Solar PV technology has been chosen for the Project.

10.2.1 Photovoltaic Plants

In the Photovoltaic ("PV") category, panels without concentrators are widely used. These panels are either with fixed tilt or manual seasonal tilt or single axis / dual axis tracking arrangements. Fixed tilt arrangements are in majority, as generally the benefits (i.e. additional generation) are not significant in comparison to the additional cost, system reliability and maintenance considerations.

In PV category, two broad types of panels are used:

- Crystalline (mono or poly) Silicon panels, which will have cells in series assembled in each module / panel.
- Thin film panels, made by depositing extremely thin layers of photosensitive materials in nano-micrometer range on a substrate (mostly glass). Amorphous Silicon (a-Ci)/ micromorph silicon (A-Si/μC-Si), Cadmium Telluride (CdTe), Cadmium Indium Selenide (CIS)/Cadmium Indium Gallium Selenide (CIGS) are different types in thin film technology.

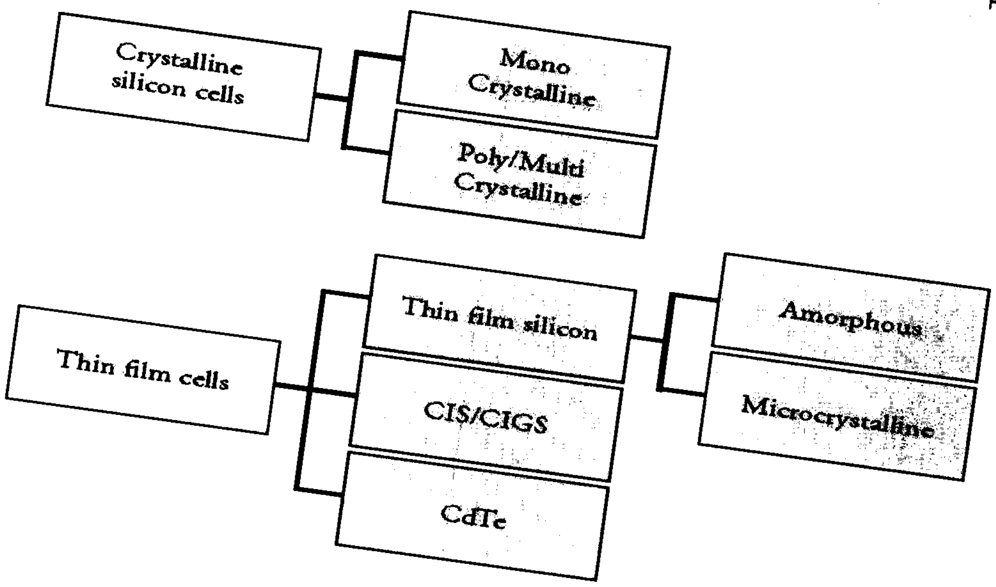

Figure 10-3

Crystalline based systems occupy about 4-5 acres per MW of installation, while thin film based systems will require about 6-9 acres per MW of installation. Crystalline Silicon based systems have over 85% market share worldwide.

11 Photovoltaics, How Does Solar Work?

Figure below gives an overview of a megawatt scale grid-connected solar PV power plant and the main components included.

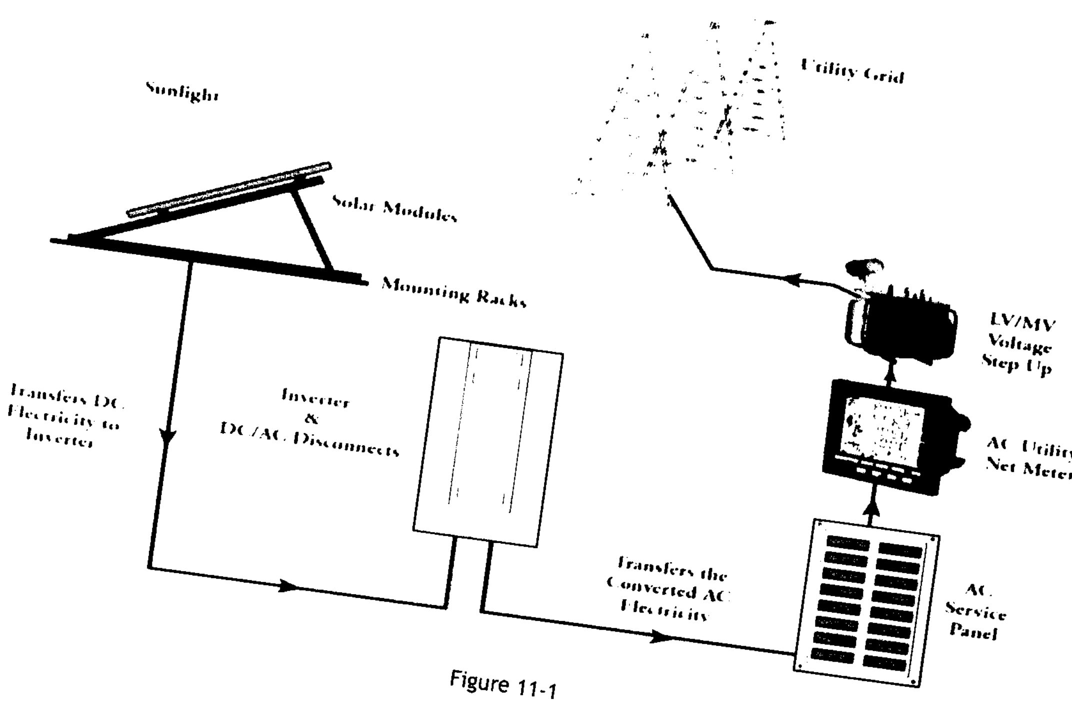

Figure 11-1

11.1 Solar PV modules

These convert solar radiation directly into electricity through the photovoltaic effect in a silent and clean process that requires no moving parts. Solar panels are made up of a network (or array) of interconnected solar cells which convert solar radiation into electricity. The output from a solar PV cell is direct current (DC) electricity. A PV power plant contains many cells connected together in modules and many modules connected together in strings to produce the required DC power output.

The effectiveness of solar panels is subject to a number of factors such as the solar irradiation available at a particular location, shade from the surroundings or other panels and dirt or dust on the panels. These factors reduce the effectiveness of the solar panels. Panel degradation also occurs over time where the panels become less effective due to degradation of the components. These factors are taken into account in determining figures for projected production and profits.

11.2 Mounting or Tracking Systems

These allow PV modules to be securely attached to the ground at a fixed tilt angle, or on sun-tracking frames. These pile foundations may be set up on piled foundations or directly rammed into the ground, although piled foundations are recommended for a longer life.

11.3 Inverters

Inverters are a key component of solar farm technology used to convert the direct current (DC) collected from the solar panels into the alternating current (AC) for connection to the utility grid. Many modules in series strings and parallel strings are connected to the inverters.

11.4 Step Up Transformers

A simple yet highly efficient and integral component not only on solar farms but in electricity distribution in general, step up transformer converts electricity from high voltage/low current to low voltage/high current and vice versa. On the solar farm, step-up transformers raise the voltage which allows electricity to be transmitted economically over large distances with minimum loss of energy. At the consumer end, step-down transformers are used to convert electricity back to high current/low voltage to make it safe and efficient for use in domestic appliances.

11.5 Cables

Cables are the means of transportation of the electricity from the solar panels directly to the electricity company. A loss of energy is expected in during the transfer of electricity via cabling. This is due to electrical resistance present in all conductors. The conversion of electricity to high voltage/low current by transformers for transport keeps this loss to a minimum and this minimal loss is anticipated in the calculations and projections for power production.

11.6 Sub Station

This is the grid connection interface, where the electricity is exported into the grid network. The substation will also have the required grid interface switchgear such as circuit breakers and disconnects for protection and isolation of the PV power plant as well as generation and supply metering equipment.

11.7 Balance of Systems

The balance of plant systems typically consists of string combiner boxes, HT Panels/RMU Units, SCADA System, grounding system, illumination system, module cleaning system and civil works including foundations, inverter rooms, staff housing, leveling, grading, fencing etc.

11.8 Performance Ratio

The Performance Ratio (PR) is stated as percentage and describes the relationship between the actual output and theoretically possible energy output of the PV plant. It shows the proportion of the energy that is actually available for export to the grid after deduction of energy loss. PR is affected by a number of factors including cables and panels (as outlined above), shade and temperature which affects the efficiency at which the panels operate.

11.9 Monitoring

Monitoring of grid-connected solar power plants is carried out locally as well as remotely through the internet. Weather monitoring station, string currents, inverter parameters, transformer protections and temperature, HT Panel parameters, export & import (auxiliary) energy, etc. are all hooked up to SCADA system and can be reviewed in real-time and on an hourly, daily and other aggregated basis. This tracking occurs 365 days a year and can be used to pinpoint faults in individual panels or production loss allowing for immediate correction and is an essential part of achieving availability and generation targets.

12 EPC Contractor

The Company intends to finalize the EPC contract with a reputable EPC contractor who will take the responsibility of delivering the Plant as per specifications and time schedules. The Company has initiated discussions with potential EPC solution providers with the requisite expertise. It is anticipated that the EPC contractor shall be finalized and selected out of the four shortlisted companies below.

a. **ET Solar**
   - Tier 1 solar PV module manufacturer
   - Annual production capacity of 1,000 MW
   - 3,500 MW cumulative capacity of modules installed globally
   - Diversified into solar IPP development and investment as well
   - Strong project references in Europe along with countries in the Middle East

b. **China Electric Equipment Group (CEEG)**
   - Parent company of China Sunergy, which is a Tier 1 module manufacturer
   - Annual production capacity of 1,200 MW
   - 2,500 MW cumulative capacity of modules installed globally
   - Various project references in Europe, India and Japan

c. **Chint Group**
   - Large and diversified electrical equipment conglomerate
   - Parent company of Astronergy, which is a Tier 1 module manufacturer
   - Annual production capacity of 1,300 MW
   - Project references across Europe, China, India and Japan

d. **SUMEC**
   - Diversified engineering, contracting and trading company
   - Part of the SINOMACH group, which is a large-scale Fortune 500 enterprise
   - Parent company of Phono Solar, which is a Tier 1 module manufacturer
   - Annual production capacity of 450 MW, with another 150 MW under construction
   - 1,800 MW cumulative capacity supplied to date, primarily in Europe and China
   - Recently commissioned a 1.25 MW captive solar power plant in Pakistan on EPC basis

The EPC contractor shall be responsible for delivering the goods to the site, their installation as well as testing and commissioning. The scope will be comprehensive and the contractor shall be responsible for engineering and procuring from outside

Pakistan; supply of equipment, material and services required for the Project; and contracts with other local or international vendors.

The EPC contract shall have a typical payment stream starting with an advance payment secured by advance payment guarantee. The EPC Contractor shall be required to provide warranties and securities to design, construct, commission, test and deliver the Plant within the stipulated period and as per agreed design parameters to avoid losses to the Project Company. These commitments shall be secured by bank/performance guarantees which are typical for project finance of this size and nature. The EPC contractor shall also secure performance guarantees for post COD period of 12 months. The structure of the EPC Contract and accompanying securities are expected to be such which are acceptable to financiers and are in line with project finance precedents.

13 Operations & Maintenance (O&M)

Operation & Maintenance for a Solar PV Plant is relatively straightforward and less intensive compared other power generation technologies and has four major components: (i) periodic cleaning of PV Panels; (ii) plant security covering entire fenced area; (iii) general shift operations for coordinating plant operation, maintenance & liaison with power purchaser; and (iv) spares for plant & equipment. Given the Sponsors' experience in more complex power plant operations, the Company intends to carry out the O&M for the plant internally. However, long-term power output guarantees even with internal O&M shall be secured from EPC contractor and/or equipment manufacturers.

14 Solar Irradiation Assessment

14.1 Resource Quantification

Site selection and planning of PV power plants requires reliable solar resource data. The solar resource of a location is usually defined by the values of the global horizontal irradiation (GHI), direct normal irradiation (DNI) and diffuse horizontal irradiation (DHI), defined below:

Global Horizontal Irradiation (GHI) - GHI is the total solar energy received on a unit area of a horizontal surface. It includes energy from the sun that is received in a direct beam and from all directions of the sky when radiation is scattered off the atmosphere (diffuse irradiation). The yearly sum of the GHI is of particular relevance for PV power plants, which are able to make use of both the diffuse and beam components of solar irradiance.

Direct Normal Irradiation (DNI) - DNI is the total solar energy received on a unit area of surface directly facing the sun at all times. The DNI is of particular interest for solar installations that track the sun and for concentrating solar technologies.

Diffuse Horizontal Irradiation (DHI) - DHI is the energy received on a unit area of horizontal surface from all directions when radiation is scattered off the atmosphere or surrounding area.

Irradiation is measured in kWh/m^2, and values are often given for a period of a day, a month or a year. A high long term average annual GHI is typically of most interest to PV project developers and financiers. Average monthly values are important when assessing the proportion of energy generated in each month. Figure below is a global solar resource map for Pakistan provided by National Renewable Energy Laboratory, Department of Energy USA showing the annual average of GHI for Pakistan.

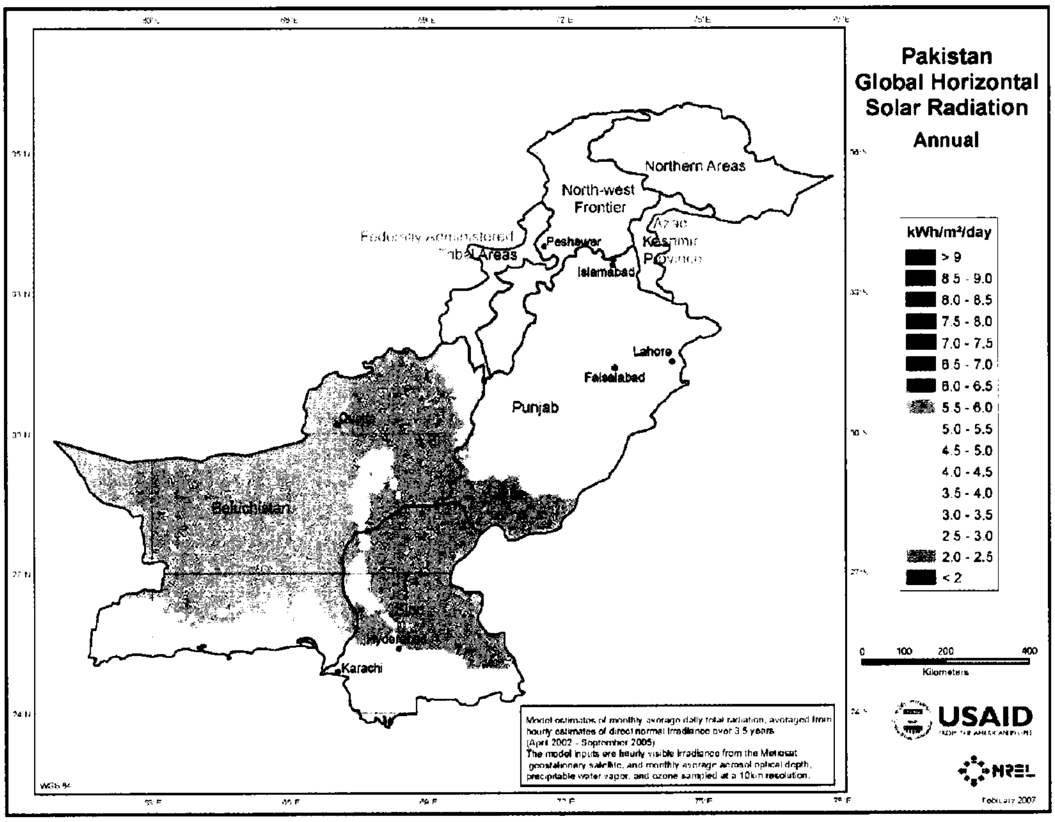

Figure 14-1

Based on the map, average annual GHI on a $kWh/m^2/day$ for various regions of Pakistan are as follows:

Region	Global Horizontal Irradiation
Northern parts of Baluchistan	5.5-6.5 $kWh/m^2/day$
Central & East Baluchistan, Southern parts of Punjab & North & North-East parts of Sindh	5.0-5.5 $kWh/m^2/day$
Major parts of Punjab (other than north-west zone), Central parts of Baluchistan & Sindh	4.5-5.0 $kWh/m^2/day$

14.2 Solar Resource Assessment

There are a variety of possible solar irradiation data sources that may be assessed for the purpose of estimating the irradiation at a potential solar PV site. The datasets either make use of ground-based measurements at well-controlled meteorological stations or use processed satellite imagery. As the distance between a solar resource and a ground-based sensor increases, the uncertainty of interpolated irradiation values increases. Under such circumstances, satellite derived data is preferred. Specific land-based sensors such as pyranometers or silicon sensors may be used but in Europe it is not common for the solar resource to be measured at the site of a PV plant for any significant length of time, prior to construction. Energy yield predictions typically rely on historical irradiation data taken from nearby meteorological (MET) stations or satellite based imagery. Most common data sources include the following:

14.2.1 Meteonorm

Meteonorm contains a comprehensive database of ground station measurements of irradiation and temperature at various locations across the globe. Meteonorm uses long term data sets to calculate hourly values, monthly average values and yearly sums for various meteorological parameters such as radiation, temperature, precipitation and sunshine durations. For locations where there is no data available from measurement stations, the data is calculated by means of an interpolation between the closest available stations, based on a 3-D inverse distance model. For locations where there are not enough nearby stations available for interpolation, satellite data is used to fill the gaps.

For the Project Site location radiation interpolation has been arrived at from Multan (147 kms), Lahore (172 kms), Quetta (572 kms) and temperature interpolation from Lahore Civ/Mil (175 kms), Amritsar (220 kms) and Patiala (342 kms).

14.2.2 NASA

NASA's Surface Meteorology and Solar Energy dataset comprises satellite-derived monthly data for a grid of 1°x1° covering the globe for a 22 year period (1984-2005). The data is considered accurate for preliminary feasibility studies of solar energy projects. It is also particularly useful for estimating the inter-annual variability of the solar resource.

14.2.3 NREL

The National Renewable Energy Laboratory (NREL), located in Golden, Colorado, is the United States' primary laboratory for renewable energy and energy efficiency research and development. NREL also performs research on photovoltaics (PV) under the National Center for Photovoltaics. NREL has developed high-resolution solar resource maps and data products for various countries including Pakistan. The data is presented in Geographic Information Systems (GIS) format. The high-resolution (10-km) annual and seasonal solar resource maps were developed using weather satellite data incorporated into a site-time specific solar mapping approach developed at the U.S. State University of New York at Albany.

14.2.4 SolarGIS

The SolarGIS database is a high resolution database recognized as amongst the most reliable and accurate source of solar resource information. The database resides on about 100 terabytes of data and it is continuously updated on daily basis. The data is calculated using in-house developed algorithms that process satellite imagery and atmospheric and geographical inputs. SolarGIS provides recent 10 years data for the solar resource and energy yield estimation. One of the major factors for considering recent 10 years solar data is due to reduced uncertainties with the coverage of high resolution (daily) aerosol data for improved irradiation distribution since 2003.

For bankable energy yield assessments of grid-connected solar projects, it is prudent to utilize Meteonorm and/or SolarGIS data as these two sources are typically more conservative compared to alternatives such as NASA, NREL, etc.

15 Project Generation Capacity

The 18 MW_p plant is estimated to generate 26.342 million units at the end of Year 1 based on SolarGIS database with P90 probability. This would result in a capacity utilization factor of 16.71%.

16 Project Cost

The total Project Cost has been estimated at USD 28.38 million including an EPC Component of USD 25.40 million and interest during component (IDC) of USD 0.46 million. IDC has been calculated based on a construction period of 8 months from Financial Close. The Project Cost is a budgetary estimate at this stage and shall be firmed up as the EPC contract is executed and the financing arrangements are finalized.

PROJECT COST	USD million
EPC Cost	25.40
Non-EPC Cost	0.86
Development Costs	0.73
Insurance During Construction	0.18
Financing Fees & Charges	0.75
Contingencies	-
Project Cost Before IDC	27.92
Interest During Construction	0.46
Total Project Cost	**28.38**

17 Project Funding Plan

The Sponsors plan to fund the Project based on a 75:25 Debt to Equity ratio. Foreign currency debt is expected to constitute 50% of the total debt with the remaining 50% to be funded through local currency debt. However, the financing plan is subject to change based on the outcome of further negotiations with lenders. The summary financial plan for the Project is as follows:

PROJECT COST	USD million
Equity	7.10
Debt	21.29
Foreign Currency Debt	*10.64*
Local Currency Debt	*10.64*
Total Project Cost	28.38

Key assumptions for the tenor of the loan and funding costs have been assumed in line with the NEPRA determination as follows:

Loan Tenor	11 years
Grace Period	12 months
Repayment	Quarterly
Interest, Foreign Currency Debt	3-month LIBOR plus 4.50%

Interest, Local Currency Debt	3-month KIBOR plus 3.50%
Base LIBOR	0.31%
Base KIBOR	10.06%

18 Current Status

The project is currently in an advanced stage of development prior to financial close. The following landmarks have been achieved to date:

- Incorporation of project company
- Issuance of Letter of Intent by AEDB
- Arranging project land
- Topographic and soil investigation surveys
- Rigorous solar resource assessment and basic plant design
- Approval of grid interconnection study by MEPCO and submission to NTDC for further vetting
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The following activities are currently being pursued on a fast track basis:

- Commercial and technical negotiations with shortlisted EPC contractors
- Finalization of project capital structure
- Drafting EPC, land and other project agreements for sharing with lenders
- Procurement of various other regulatory approvals and consents

Financial close for the project is targeted by November 2015 while commercial operations date is expected to be achieved by June 2016. The timelines shall be finalized and divided into more detailed milestones in consultation with the project lenders and other stakeholders.

****

ANNEX - II

Government of Pakistan
ALTERNATIVE ENERGY DEVELOPMENT BOARD
2nd Floor, OPF Building,
Shahrahe Jamhoriat, Sector G-5/2
Islamabad.
Tel: 051 9222360 Fax: 051 9222364

AEDB

B/3/2/SPV/LOI-44 December 31, 2014

M/s Harappa Solar (Private) Limited
1485/C-2A,
Asad Jan Road,
Lahore Cantt.
Ph: 042-36687823
Fax: 042-36687825

Subject: **LETTER OF INTENT FOR 10 MW SOLAR PV POWER GENERATION PROJECT**

Reference: Your Proposal dated October 14, 2014.

In terms of the Policy for Development of Renewable Energy for Power Generation 2006 ("Policy"), the Alternative Energy Development Board ("AEDB") hereby confirms its interest in your proposal for establishing an approximately 10 MW solar PV power generation project in Harappa, District Sahiwal, Punjab province. The Sponsor(s) is responsible for arranging the land for the project. AEDB may facilitate the Sponsor(s) in arranging the land for the project; however AEDB has no obligation to provide land to the Sponsor(s) for the project. AEDB acknowledges receipt of the bank guarantee No. IGT1242003092 dated December 23, 2014 in the sum of US Dollar (US $ 5000/-).

2. The Sponsor(s) is required to complete the feasibility study and achieve the milestones listed at the Annex to this LOI ("LOI Milestones") for the subject project, at no risk and at no cost to, and without any obligation on the part of the AEDB, the Government of Pakistan, any Provincial Government or their respective agencies, within a period of Eighteen (18) months from the date of issuance of this Letter of Intent ("LOI").

3. The Sponsor(s) is required to carry out and complete the feasibility study at internationally acceptable standards and in accordance with the terms and conditions stipulated in the Policy and this LOI. The feasibility study must include, inter alia, Solar PV Plant equipment siting details, detailed power production estimates based on solar irradiance data of project site, soil tests reports, technical details pertaining to solar PV panels and other allied equipment to be used in the Solar PV Plant, grid tied solar PV project, electrical studies (including but not limited to short-circuit study, power quality study, load flow study and stability study), environmental study, project costing, financing plan, carbon credits, financing terms, tariff calculations and assumptions for financial calculations including economic/financial analysis. The Sponsor is also advised to liaise with the power purchaser while determining the site, project layout, sub-station design and layout, the transmission line, interconnection arrangements, and other related matters.

4. The validity of this LOI is not more than 18 months from the date of its issue, where after it will automatically lapse immediately (unless extended pursuant to clauses 5 or 6), being the 30th June, 2016 (the "**Expiry Date**"). Issuance of this LOI or the lapsing of its validity, or your conducting a feasibility study there under, cannot form the basis of any claim for compensation or damages by the Sponsor(s) or the project company or any party claiming through or under them against the Government of Pakistan, the Provincial Government, AEDB or any of their agencies, employees or consultants on any grounds whatsoever, during or after the expiry of the validity of the LOI.

5. The Sponsor(s) is therefore required to complete the feasibility study and achieve the LOI Milestones for the subject project within the validity of this LOI. The Sponsor(s) is also required to submit quarterly progress reports. Provided the Sponsor(s) meets the LOI Milestones on the stated dates, the Expiry Date of this LOI shall be extended on a day-for-day basis for the number of days of delay by which the approval or review by the relevant public sector entity listed in the LOI Milestones is delayed beyond the corresponding period stated in the LOI Milestones. In case there is a delay in completion of the feasibility study within the validity of this LOI for reasons not attributable to a public sector entity, a one-time extension may be granted up to a maximum period of one hundred eighty (180) days if AEDB is satisfied that the feasibility study is being conducted in a satisfactory manner and is likely to be completed shortly, and provided the Sponsor(s) enhance the amount of the bank guarantee to twice its original amount and extend its validity for a period six (6) months beyond the extended Expiry Date. Furthermore, if the said feasibility study is technically approved by the Panel of Experts and later the tariff awarded by NEPRA is not agreed by the Sponsor(s) (such decision to be made within thirty (30) days of the award of the tariff, and in any event within the validity of the LOI), the bank guarantee less 10% deduction for administrative and ancillary charges, would be returned to the Sponsor(s).

6. The Sponsor(s) shall apply to NEPRA for award of tariff within the period of validity of this LOI. Upon tariff being given, the Sponsor(s) shall forthwith submit a new Performance Guarantee in the sum of US Dollars (USD 25000/-) and obtain the Letter of Support ("LOS") from AEDB within the validity period of this LOI, provided, if the award of the tariff is delayed beyond the initial validity of the LOI the Sponsor(s) shall extend the bank guarantee for a further period of six (6) months and the Expiry Date shall be extended *ipso facto* for a further period of six (6) months, and the Sponsor(s) shall obtain the LOS and submit the Performance Guarantee within the extended period afore-said. For the avoidance of doubt, the afore-said extension process may be repeated if the tariff is not announced (including on any review petition filed by the Sponsor(s), such review (if any) to be filed within the period prescribed in the NEPRA (Tariff Procedures and Standards) Rules) up to fifteen (15) days before the then prevailing Expiry Date.

7. In case the Sponsor(s) fails to meet the LOI Milestones or perform any other obligations set forth in the Policy and this LOI, including the extension of the date of expiry of bank guarantee as provided herein, AEDB will terminate this LOI and encash the bank guarantee.

8. (A) Pending the nomination of the Main Sponsor per sub-clause (B), the M/s Harappa Solar (Private) Limited is liable for all obligations and liabilities of and on behalf of all other shareholders/ Sponsor(s) (without relieving the other

shareholders/Sponsor(s) of their obligations and liabilities under this LOI). Accordingly, M/s Harappa Solar (Private) Limited, shall not transfer or assign its shareholding (or other participatory interest, if the project company is not formed by the date of issue of the LOI) in the project or the project company without the prior written approval of AEDB, which approval may be declined by AEDB in its discretion if the proposed transferee's financial and other relevant credentials are found unsatisfactory.

(B) The Sponsor(s) is advised to nominate the Main Sponsor *(being the individual or group holding at least 20% equity or participatory interest in the IPP project)* no later than the Expiry Date of the LOI. In default of nomination as aforesaid, the M/s Harappa Solar (Private) Limited will be deemed the Main Sponsor for all intents and purposes. The Main Sponsor, together with other initial project shareholders/Sponsor(s) (which shall, subject in each case to sub-clause (A) above, be firmly settled and announced to AEDB by the Expiry Date of the LOI), must hold 51% of the project equity for a period up to the project's Commercial Operations Date (COD).

(C) Any actual or purported transfer or assignment of the shares or other participatory interests by the Sponsor(s) / shareholders in contravention of the foregoing restrictions without prior written consent of the AEDB shall render this LOI void and the bank guarantee will be enchased in such case by AEDB.

9. This LOI is not assignable and non-transferable. This LOI shall be void upon any actual or purported assignment or transfer hereof without the prior written consent of AEDB.

10. This LOI is issued subject to the grant of a generation license and award of tariff by the National Electric Power Regulatory Authority ("NEPRA") to the subject project under the provisions of the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997 (the "NEPRA Act"). While AEDB shall extend its offices to support applications by the subject project before NEPRA under the current or any amended policy framework, by granting this LOI, AEDB does not make any representation or warranty on behalf of itself or the Government of Pakistan that the subject project will be granted a generation license or a tariff acceptable to the subject project or at all.

11. This LOI is issued in duplicate on the date hereof, and it shall come into effect when one copy is received by AEDB after being duly countersigned by you. Nevertheless, this LOI shall lapse if the countersigned copy is not received at AEDB within 15 days of its issuance.

(Musaddiq Rahim)
(Secretary)
M/s Harappa Solar (Private) Limited

(Asjad Imtiaz Ali)
(Chief Executive Officer)
AEDB

Annex-I

Milestones for the Letter of Intent (LOI)

Sr. No.	Milestones	Time Frame (in Months)
1.	Issuance of Letter of Intent (LOI)	T0
2.	Submission of complete Feasibility Study to AEDB, comprising of; (i) Technical study including resource assessment, plant & equipment details, layout and energy production analysis. (ii) Grid Interconnection Study (approved by NTDC) (iii) EIA / IEE study (approved by provincial Environmental Protection Agency)	No later than ten (10) months after issuance of LOI
3.	Vetting and approval of Feasibility Study by AEDB *(including verification of production estimates through third party consultant, if required, cost of which shall be borne by the Sponsor(s))*	Within two (2) months after submission to AEDB. *(provided any requisite modifications are timely made by the Sponsor(s) and the modified feasibility study is resubmitted within 15 days of a letter by AEDB requiring the modifications)*
4.	Tariff and Generation from NEPRA	Within four (4) months of approval of Feasibility Study by AEDB
5.	Acceptance of Tariff by IPP	Within fifteen (15) days of determination of tariff by NEPRA
6.	Posting of Performance Guarantee for Issuance of Letter of Support (LOS)	Within fifteen (15) day of acceptance of Tariff by IPP
7.	Issuance of Letter of Support (LOS) by AEDB	Within fifteen (15) days of posting of Performance Guarantee (PG)

ANNEX - 16

ALTERNATIVE ENERGY DEVELOPMENT BOARD
Government of Pakistan
2nd Floor, OPF Building, G-5/2, Islamabad
Tel: +92 (0)51 9222360-62 Fax: +92 (0)51 9222364

AEDB

No. B/3/2/SPV/HSPL/15 22nd April 2015

Mr. Musaddiq Rahim
Company Secretary
M/s Harappa Solar (Pvt.) Ltd.
1485/C-2A, Asad Jan Road,
Lahore Cantt.

Subject: **Enhancement of Capacity of LOI issued to Harappa Solar (Pvt.) Ltd. for Solar PV Power Generation Project to 18 MW**

Reference:
(i) AEDB LOI No. B/3/2/SPV/LOI-44, dated December 31, 2014 issued to Harappa Solar (Pvt.) Ltd. (HSPL)
(ii) HSPL letter dated February 27, 2015 on subject matter
(iii) Our letter of even number dated April 10, 2014, on the above subject
(iv) Receipt of enhance Bank Guarantee No. IGT124200309214 amounting US Dollar Nine Thousand Only (US $ 9,000/-)
(v)

. AEDB is pleased to inform that HSPL request to enhance the capacity of the proposed solar PV project from 10 MW to 18 MW is accepted. Therefore:

i. the project capacity in above referred LOI would be read as 18 MW;
ii. Rana Nasim Ahmed is nominated as the Main Sponsor in the project in pursuant to Clause 8 B of the LOI;
iii. Rana Nasim Ahmed will maintain 75% shareholding in HSPL until the LOS stage and will not transfer or dilute this shareholding without the prior written consent of AEDB;
iv. Rana Nasim Ahmed will not sell or dispose of his shares in M/s JDW Sugar Mills Ltd. or, if he decides to sell them, he will first satisfy AEDB of the availability of alternative liquid financial means of equivalent value for investment in HSPL;
v. All other terms, conditions and timelines stated in the LOI shall remain the same.

(Irfan Yousuf)
Director (CDM)

Copy to:

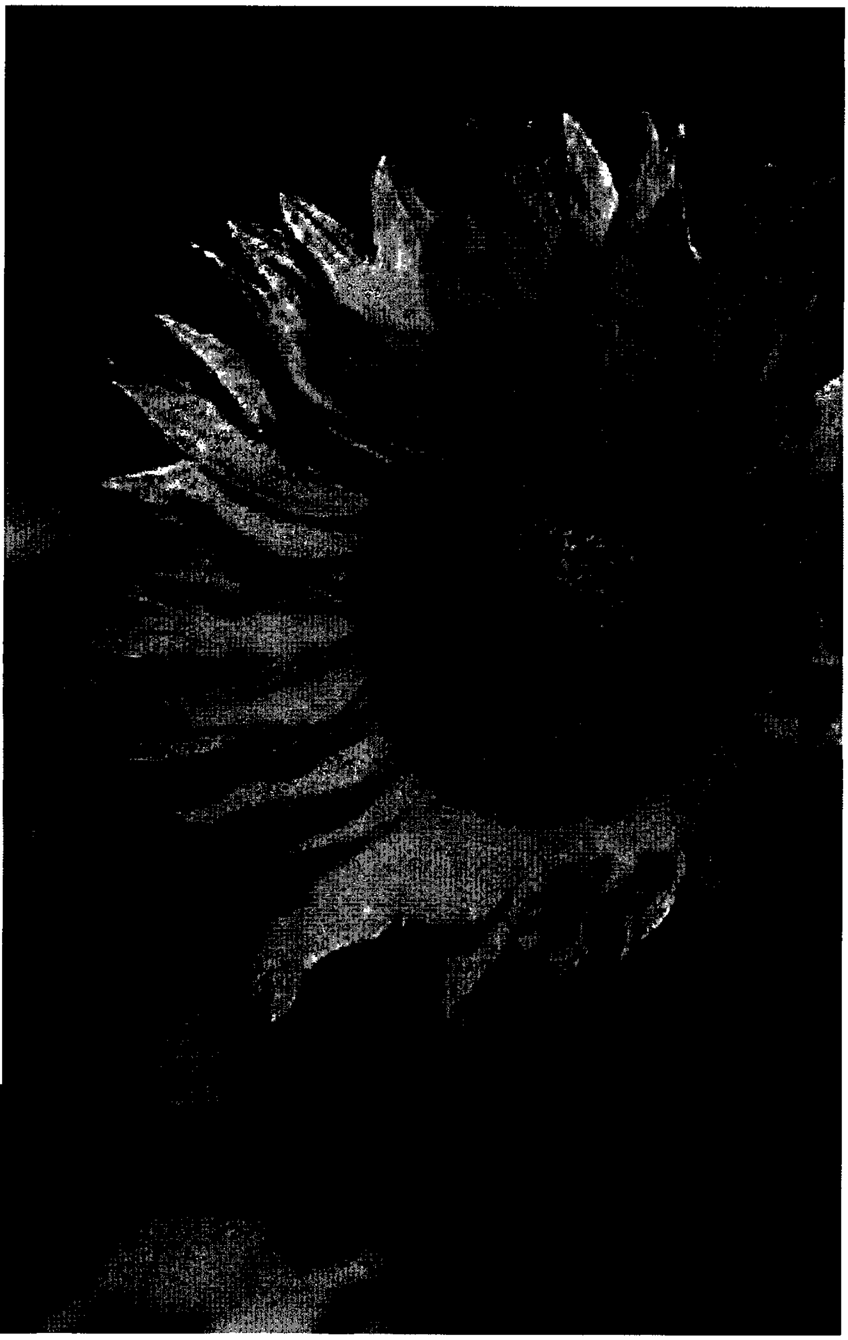
1. Chairman, National Electric Power Regulatory Authority (NEPRA), Islamabad
2. Managing Director, National Transmission and Despatch Company (NTDC), Lahore
3. Secretary, Energy Department, Government of Punjab, Lahore
4. Director General (F&A), AEDB, Islamabad
5. Director (F&A), AEDB, Islamabad
6. PS to CEO, AEDB, Islamabad

ANNEX-17

TECHNICAL STUDY

18 MWp SOLAR PV PROJECT FOR HARAPPA SOLAR (Pvt.) LTD. PAKISTAN

MAY 2015



AVANT-GARDE ENGINEERS AND CONSULTANTS (FZC)

Executive Suite , P.O.Box 122632,
Sharjah, U.A.E.
E-mail: avantgarde@vsnl.com
http://www.avantgarde-india.com

TECHNICAL STUDY ON 18MWp SOLAR PV PROJECT FOR HARAPPA SOLAR (Pvt.) LTD.,

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1 INTRODUCTION 2
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3 PROPOSED PLANT CONFIGURATION 9
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1 INTRODUCTION

1.1 Power is a vital input for economic development and sustenance of modern economy. However, providing adequate and clean power to face the ever-growing environmental degradation has been a great challenge of the current century. The inevitable increase in the use of fossil fuels to keep pace with the economic growth has associated side effects of threat to energy security of the country and environmental degradation through climate change. To achieve a stable atmospheric CO_2 concentration at any level would require that CO_2 emissions be cut by more than half from current levels, preferably within the next few decades. As world population increases, we have a great need for alternative and renewable energy sources like wind energy, bio fuels and solar power. Solar energy is the most abundant source of renewable energy on earth.

1.2 Generally, entire Pakistan has a high potential for solar energy. The annual average horizontal solar irradiation per day in these areas is more than 4.5 kWh/Sq.M. Acute electricity shortage in the country coupled with high solar irradiation in most parts of the country with enough available space provides high opportunity for solar power generation system.

1.3 The solar photovoltaic device systems for power generation are in use in various parts in the country for electrification, where the grid connectivity is either not feasible or not cost effective. A numbers of companies in Pakistan are involved in trading / manufacturing stand-alone photovoltaic systems and accessories like modules, invertors, solar lamps, regulators, batteries, etc., on small scale.

1.4 With the downward trend in the cost of solar energy and appreciation for the need of development of solar power, grid-connected solar power projects have recently been implemented in various countries through policy measures such as feed in tariffs, solar mandates, renewable energy certificates etc. In tune with global trend, Govt of Pakistan has taken steps to harness solar power potential by announcing upfront tariff mechanism through NEPRA.

1.5 Realizing the huge potential for solar power generation, M/s. Harappa Solar (Pvt.) Ltd plans to install a 18MW Solar Power Generation Plant near Harappa in District Sahiwal, Punjab.

1.6 This technical study covers the following major aspects related to Solar PV Generating Plant:

- ✓ Global Scenario & Solar Power Generation Technologies
- ✓ Elaboration of proposed system
- ✓ Climate Data, Yield & Variability Analysis
- ✓ Construction Schedule and Operation & Maintenance Requirements for Solar PV System
- ✓ Basic Plant Layout, Single Line Diagram and Simulation Details

2 GLOBAL SCENARIO & SOLAR POWER GENERATION TECHNOLOGIES

2.1 Solar Power Generation Technologies

2.1.1 There are several kinds of solar techniques that are currently available. However, each of them is based on quite different concepts & science and each has its unique advantages.

2.1.2 Different types of energy converting options & techniques are given below:

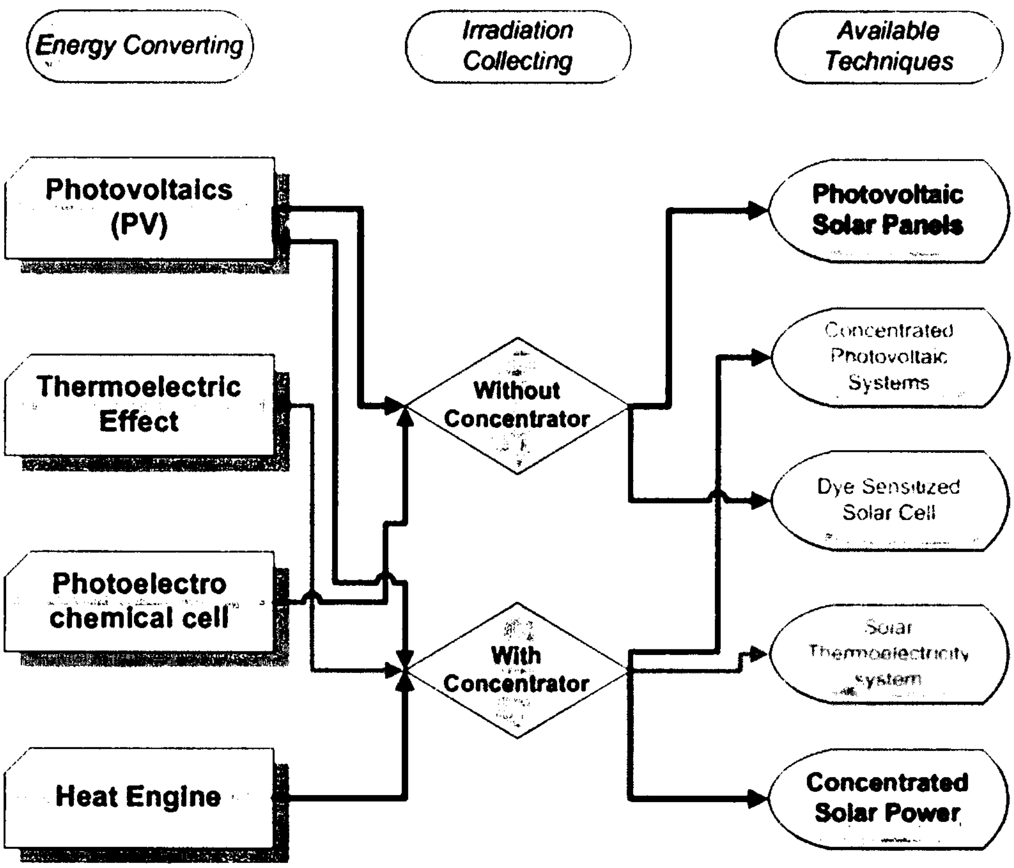


Figure 1 - Solar Technologies

2.1.3 Description of popular technologies

Photovoltaic Solar Panels (PV) and Solar Thermal / Concentrated Solar Power (CSP) are the two most mature technologies. They have been commercialized and expected to experience rapid growth in future. A brief on different technologies in PV & Solar Thermal are given in below picture:

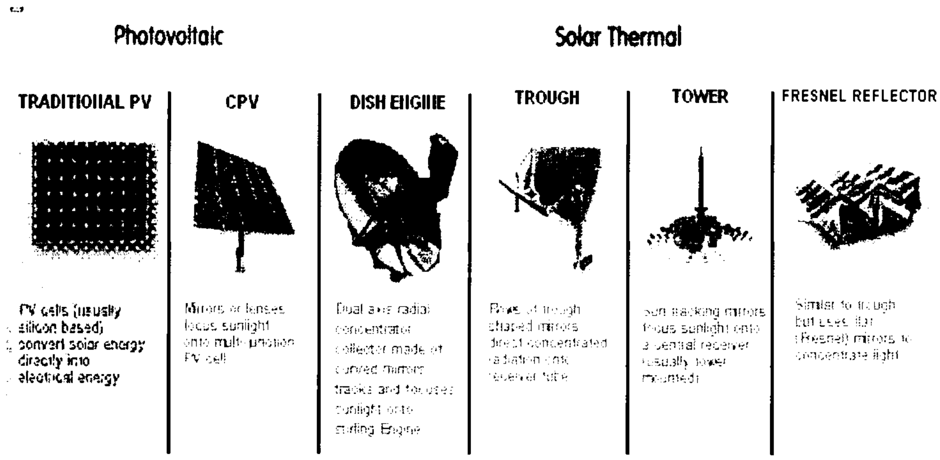


Figure 2 - Popular Technologies

2.1.4 Solar Thermal Plants have advantages in certain applications needing steam and for higher capacities (above 50MW) with storage options.

2.1.5 At present, photovoltaic installations have about 97.5% share while solar thermal plants have about 2.5% share globally. Hence, emphasis in this report is on Solar PV Plants.

2.1.6 Photovoltaic Plants

2.1.6.1 In Photovoltaic category, PV panels without concentrators are widely used. These panels are either with fixed tilts or manual seasonal tilts or single axis / dual axis tracking arrangements. Fixed tilt arrangements are in majority, as generally the benefits (additional generation) are not significant in comparison to additional cost, system reliability and maintenance considerations.

2.1.6.2 In PV category, two broad types of panels are used:

- ✓ Crystalline (mono or poly) Silicon panels, which will have cells in series assembled in each module / panel.
- ✓ Thin film panels, made by depositing extremely thin layers of photosensitive materials in nano-micrometer

range on a substrate (mostly glass). Amorphous Silicon (a-Ci) / micromorph silicon (A-Si/μC-Si), Cadmium Telluride (CdTe), Cadmium Indium Selenide (CIS) / Cadmium Indium Gallium Selenide (CIGS) are different types in thin film technology.

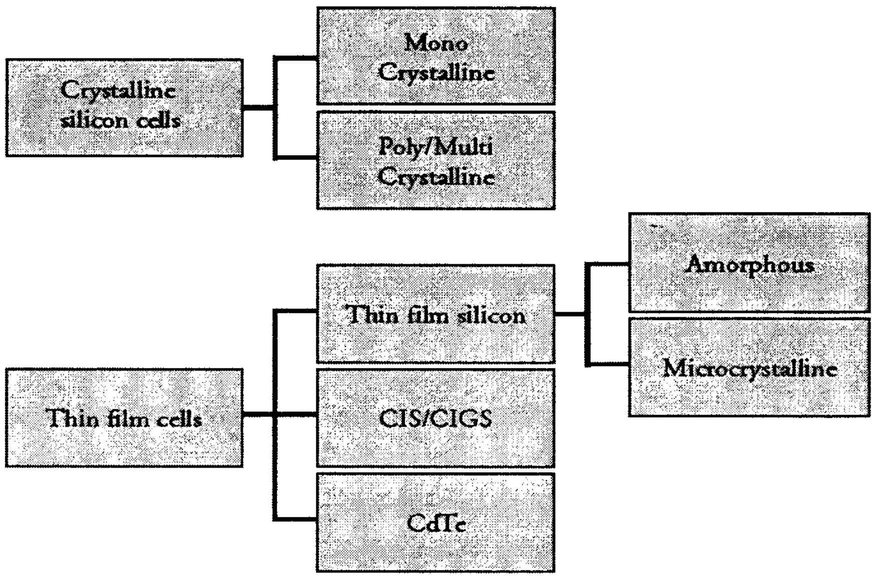


Figure 3 - Panel Types

2.1.6.3 Crystalline based systems occupy about 4-5 acres per MW of installation, while thin film based systems will require about 6-9 acres per MW of installation. Crystalline based systems have over 85% market share worldwide.

2.1.6.4 Solar PV plants can be designed for any capacity right from a fraction of kW rating roof top installation to any capacity, by repeating the blocks.

2.1.6.5 Major components of ground mounted systems are:

- ✓ Solar Modules / Panels
- ✓ Solar Inverters
- ✓ Balance of Systems (BoS) comprising of
    - o DC Cables
    - o String Combiner Boxes
    - o AC Cables
    - o Transformers
    - o HT Panels / RMU units
    - o SCADA & Monitoring System

- o Earthing system
- o Illumination system
- o Module cleaning system
- o AC / Ventilation System for inverter rooms

- ✓ Module Mounting Structures
- ✓ Civil works including foundations, inverter rooms, leveling, grading, fencing, etc
- ✓ Power Evacuation system to include evacuation transformers, switchyards, tariff metering arrangement, transmission line system, etc.

2.1.6.6 Solar PV plants have lifetime of 25 years. However, there will be output depreciation @3% by end of first year and @0.7% every year, thereafter.

2.2 Global Scenario

2.2.1 There had been a drastic growth in solar power generation, during the last one decade. Installed capacity of PV plants, which was less than about 5 GW (1GW=1000MW) in 2005 attained 100 GW milestone by 2012 & 140 GW by 2013.

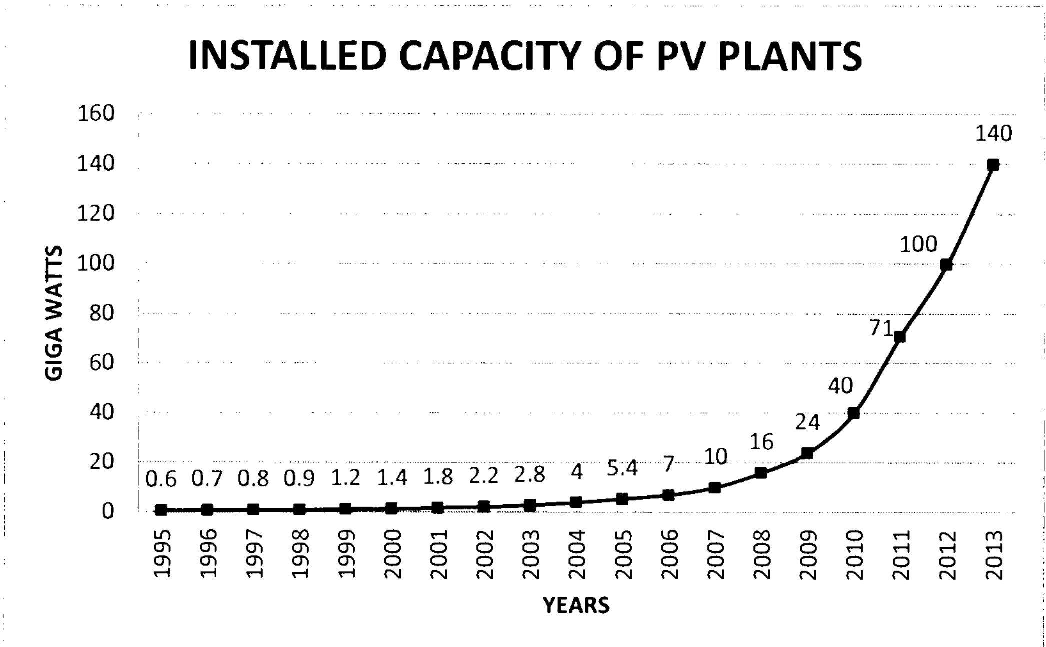


Figure 4 - Installed Capacity of PV Plants

2.2.2 Germany & Italy alone had contributed to about 50GW, till 2012.

2.2.3 In India, till 2010, there were hardly 10 MW Solar PV installations. Thanks to the National Solar Mission, installed capacity of Photovoltaic Plants had increased to 2643MW, by March, 2014. India expects to reach 10 GW by 2017 and 20 GW by 2022.

2.2.4 As per projections, there will be about 48-84 GW additions in PV segment (depending on global economy) by 2017. CSP plants of about 2.5 GW are under construction stage and there are about 17 GW of CSP projects under development worldwide (USA-8 GW, Spain-4.46 GW & China-2.5 GW).

3 PROPOSED PLANT CONFIGURATION

3.1 PV Technology

As the predominant & cost-effective technology with simple maintenance requirements, poly crystalline modules in fixed tilt arrangement is considered as base case in this report. Manual seasonal tilt and single axis automatic tilt arrangement particulars have also been touched upon in the end.

3.2 Location

The proposed plant is located at Harappa Bypass on the Lahore-Multan highway near the ancient town of Harappa in District Sahiwal, Punjab. It is about 175 km (3 hours by road) from Lahore and about 145 km from Multan. The approach to the road is to be planned from Harappa Bypass Road.

The weather is characterized by heavy sun shine, together with hot climate and moderate rain. There are no hills / tall structures that could cause shadow near the site. The indicative coordinates of the project site are given below:

North	East
30°34'57.55"	72°53'35.66"
30°34'57.27"	72°53'44.14"
30°34'52.69"	72°53'44.14"
30°34'52.69"	72°53'56.60"
30°34'57.54"	72°53'56.98"
30°34'57.55"	72°54'03.11"
30°34'47.97"	72°54'03.24"
30°34'47.99"	72°54'09.60"
30°34'42.08"	72°54'09.59"
30°34'41.93"	72°53'57.02"
30°34'47.94"	72°53'57.00"
30°34'47.73"	72°53'36.90"
30°34'43.85"	72°53'36.94"
30°34'43.84"	72°53'31.91"
30°34'45.78"	72°53'31.99"
30°34'45.78"	72°53'33.32"
30°34'47.72"	72°53'33.12"
30°34'47.79"	72°53'32.01"
30°34'52.81"	72°53'32.02"

3.3 Land Area

3.3.1 The plant will require about 66 acres which will be leased from the sponsors under a long term agreement. The proposed land is marked in Figure 5.

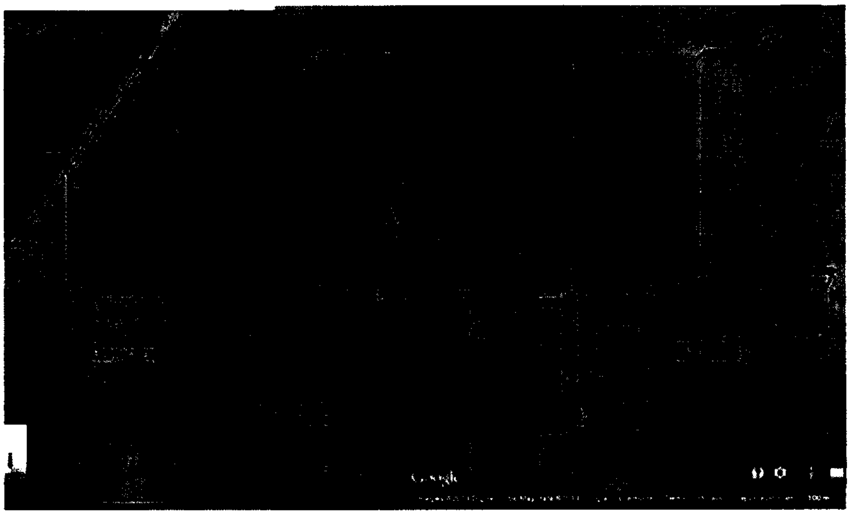


Figure 5 - Google Image of Site

3.3.2 The solar PV Plant comprising PV Modules, Inverter Rooms, Switchyard, and Module Cleaning System with water storage is proposed to be located within the identified area. A detailed layout indicating module arrangement, control room location and power evacuation system is attached along with this report.

3.3.3 Topographical and Geographical Aspects

The entire land available is almost flat and not much undulation.

3.3.4 Water Availability

The raw water for the plant is required for meeting the module cleaning requirements (after treatment, if required) will be drawn from Bore wells.

3.4 Proposed Scheme

3.4.1 It is proposed to install 18 MWp capacity Solar PV plant with polycrystalline solar PV modules in fixed tilt (23°) and Central Grid Tied Solar Inverters. Alternate seasonal Tilt arrangement with 10° summer Tilt & 35° Winter Tilt will be reviewed, during detailed engineering. Generated power shall be stepped-up to 11 kV through inverter transformers, as shown in the attached Single Line Diagram.

3.4.2 Power evacuation to National grid is planned at 11 kV level and shall be carried out with six pole structure arrangement. 11 kV triple circuit overhead line with Osprey conductors is planned between the 132 / 11 kV Grid Station at Harappa and the Solar PV Power Plant. Main & Check metering shall be planned at the 11 kV level as shown in the single line diagram.

3.4.3 PV Modules

It is proposed to consider 305 Wp polycrystalline modules, from Tier-1 Chinese PV module manufacturers. The modules shall be protected by high transmission tempered glass covered with anodized aluminium alloy frames. Serially connected cells shall be terminated to IP65 junction boxes at bottom with 4 Sq.mm multi-strand copper cables. Positive & Negative terminals shall be terminated with MC4 connectors and Y-connectors, for making module interconnections.

Typical parameters of the modules:

Electrical Characteristics at STC	Data
Maximum Power (Pmax)	305 W
Module Efficiency	15.72 %
Maximum Power Current (Imp)	8.21 A
Maximum Power Voltage (Vmp)	37.18 V
Short Circuit Current (Isc)	8.78 A
Open Circuit Voltage (Voc)	45.12 V
Temperature Coefficient of Voc	-0.34% / °C
Temperature Coefficient of Isc	0.04% / °C
Temperature Coefficient of Pmax	-0.44% / °C
Nominal Operating Cell Temperature (NOCT)	45.3°C ± 2° C

3.4.4 Solar Inverters

Solar Inverters are the most critical equipment in the Solar PV plant, as the reliability & performance of the inverters have great influence on the plant overall performance & availability. It is proposed to use Central Inverters of sixteen (16) numbers, with 1127.28 kWp PV modules per Inverter / Block. Negative earthing in inverters shall be planned to counter PID effect for the modules. Inverter shall be from ABB or equivalent. Inverters shall meet the performance requirements stipulated in NTDC's Pakistan Grid Code for Solar Power Plants.

Parameters (typical) of the proposed inverter:

Input (DC)

Description	Data
Max. DC power	1200 kWp
Max. input voltage	1100 V
MPP voltage range	600 V - 850 V
Max. input current	1710 A

Output (AC)

Description	Data
Rated normal power	1000kW
Maximum output power	1200kW
Power @ 0.95 PF	950kW
Nominal AC voltage	400 V
AC frequency / range	50 Hz
Max. output current	1445 A

3.4.5 String Combiner Boxes & DC Cabling

3.4.5.1 The modules will be connected with DC cables, in series & parallel combinations and hooked-up to Inverters, through string Combiner Boxes. Total 2816 strings (21 modules per string) shall be connected in nine inverters each with 12 inputs. There shall be eight (8) inputs in String Combiner Boxes (SCBs) with string current monitoring arrangement.

3.4.5.2 All solar field cables upto SCBs shall be of single core electron beam / UV resistant cables with multi-strand copper conductors.

3.4.5.3 SCB to inverters shall be with single core armoured multi-strand Aluminium cables with XLPE insulation.

3.4.6 Inverter Transformers

It is proposed use twin secondary oil filled transformers for stepping up the power generated from PV system, by connecting one inverter per secondary. The transformers intended for connecting to the Solar Inverters shall confirm to IEC:60076. The transformers will be as per the following specification:

Parameter	Data
Number of transformers and rating	8 Nos. of 2.25 MVA
Cooling	ONAN
Ratio	11/0.40-0.40 kV
Highest system Voltage	12 kV
Power frequency Voltage	28 kV rms
Impulse Withstand Voltage	75 kV peak
Taps and Range	Off-circuit, ± 7.5% in steps of 2.5%
Voltage Vector	Dy11y11
Impedance	6.25% / 6.25%

There shall be a 11/0.415 kV auxiliary transformer for meeting plant auxiliary power requirements.

3.4.7 HT Panels

It is proposed to provide 11 kV switchboards one at Plant Main Control building and One (1) more in Inverter Room. Also, Six (6) nos of inverter rooms are planned. Proposed hook-up arrangement is shown in the attached single line diagram. Brief parameters of 11 kV switchboards shall be as given below:

Parameter	Data

Rated Voltage	11 kV, 3 Phase, 50 Hz
Maximum Voltage	12 kV
Power frequency Voltage	28 kV rms
Impulse withstand Voltage	75 kV peak
Short time rating	26.2 kA for 3 Sec
Maximum bus bar temperature	85 Deg. C
Operating Duty	O-0.3sec-CO-3min-CO

Power evacuation to National grid through plant metering yard shall be planned, by providing three (3) outgoing feeders from main 11 kV switchboard, as shown in SLD.

3.4.8 Civil & Structural Works

3.4.8.1 PV modules shall be fixed on the Module Mounting Structures (MMS) in two rows in portrait arrangement. Main columns of these steel panel tables will be with galvanized MS hot rolled sections / GI cold formed sections, while the rafters cross bracing & purlins will be with GI cold formed sections / galvanized steel tubes. Structural materials foundation bolts, fastening bolts, screws, nuts, washers shall conform to the relevant International Standards. All mild steel members (inner & outer surface area) will be electro galvanizing/hot dip galvanizing to 85 microns.

3.4.8.2 In case of seasonal manual tilting arrangement, the rafter will be hinged on to the columns with bracings suitable for summer and winter positions supported on to the columns.

3.4.8.3 Soil Investigation has been conducted and the soil is found to be silty sand or lean clay or silty clay, as per the report. The SBC for isolated conventional RCC foundation is 7.5 T/sqm at 1m depth. There is no water table intervention. There is no harmful effect of chloride and sulphate, as per the report. To help faster construction, pile foundations are better and are recommended as they have long lasting life than direct ramming of the structure.

3.4.8.4 Main control building, inverter rooms and security buildings shall be single storey buildings with brick work & insulated pre-painted galvanized corrugated sheets. Alternatively, prefabricated rooms may also be planned. Inverter & control rooms shall be envisaged with pressurized ventilation arrangement.

3.4.8.5 Internal roads, fencing & gates shall be planned as in layout drawings.

3.4.8.6 Cables, Earthing and Illumination System

3.4.8.6.1 Power cables for 11 kV system will be with three core aluminium conductor, XLPE insulated, screened, armoured and overall PVC sheathed confirming to IEC:502. The power cables of 1.1 kV grade will be XLPE insulated, aluminium conductor with outer sheath of PVC compound conforming to latest version of IEC:227. The control cables for control / protection / indication circuit of the various equipment will be of 1.1 kV grade, PVC insulated annealed high conductivity stranded copper conductor, inner sheath PVC taped, flat/round wire armoured with outer sheath of PVC compound conforming to latest version of IEC: 227.

3.4.8.6.2 Non-current carrying parts of all electrical equipment viz. distribution boards, control panels, HT switchgears, and all lighting fittings shall also be earthed rigidly, to ensure safety. Building lightning protection system will be provided as per relevant IEC standards.

3.4.8.6.3 AC supplies of single / three phase, needed for internal use for several functions such as Illumination through lighting inverters, SCADA supply through UPS, Battery Chargers, Transformer tap-changer drives, Power supplies for communication equipment / surveillance system, Breakers / Disconnect switch motors, etc. Auxiliary transformer shall be planned in each inverter building for catering the auxiliary loads.

3.4.8.6.4 Good lighting in the plant will be ensured for maintenance requirement in control buildings and security / surveillances of the boundaries. All lighting supplies shall be extended through lighting inverters. Fence lighting shall be envisaged with low wattage LED lamps. Portable emergency lights shall be planned for security personnel.

3.4.8.7 Monitoring System & SCADA

3.4.8.7.1 Monitoring of system operation parameters will be monitored locally and also from remote locations through internet.

3.4.8.7.2 Weather monitoring station, for irradiance, wind velocity & ambient temperature, String currents, Inverter Parameters, Transformer protections and temperature, HT Panel parameters, Export & import (auxiliary) energy and Perimeter Security through CCTVs & alert systems are hooked-up to SCADA system.

3.4.8.8 Modules Cleaning System

Module cleaning system shall be envisaged for spraying the soft water over the modules manually, by providing storage tanks, water pumps, PVC piping network & valves. This cleaning process is to be carried out periodically depending upon the intensity of dust deposition over the PV modules.

3.4.9 A/C and Ventilation System

Suitable Air Conditioning or Ventilation (Wet or Dry pressurised) system shall be envisaged for the Inverter & control rooms.

3.4.10 Site Features and Plant Layout

3.4.10.1 Layout Suitability

Available area of 66 acres can comfortably accommodate 18MWp Solar PV plant.

The site is well suited for Solar PV plant on considerations like irradiance, reasonable leveling, water availability for module cleaning, nearness to sub-station for power evacuation and good connectivity for transportation.

3.4.10.2 Possibility of Vegetation below the panels

The feasibility of vegetation below the PV modules shall be explored. Any plantation that could grow in shadow with height not more than about 1M can be cultivated on the rear side in every row. Water network system sizing shall be reviewed to meet plantation watering requirement, during detail engineering.

3.4.10.3 PV Plant Specifics

- ✓ Based on inverter sizing of 1MW, each block comprises of 88 tables with each table planned with 42 panels of 305Wp each.
- ✓ There shall be 16 such blocks. Two blocks shall be connected to a single transformer with dual secondary combination and the last block will be separately connected to a distribution transformer
- ✓ The PV modules shall be fixed on table in two rows, with 21 modules in portrait arrangement. Collector width of the panel shall be 4.0M.
- ✓ The panels shall have fixed tilt of 23 Deg facing true South, with minimum of height of 600mm on front end.
- ✓ In case of seasonal manual tilting arrangement, summer tilt of 10° and winter tilt of 35° will be adopted.
- ✓ The modules shall be fixed on to the table by using aluminium mid clamps and end clamps or by using nuts & bolts.
- ✓ Plant HT panel, main control building and 11 kV switchyard shall be located on Eastern corner of the Plot. The 11 kV evacuation line is planned with double circuit Ospray AAC conductor with three (3) outgoing feeders through 11kV double circuit transmission system as per MEPCO standards to the existing 132/11kV grid sub-station at Harappa.
- ✓ Existing roads in the premises will be used as access to adjacent agriculture fields. All PV plant / areas shall be individually fenced by providing proper road access to inverter rooms, as in the layout drawings.
- ✓ Private Residence & worker accommodation shall be accommodated in the close vicinity of the power plant.
- ✓ LT Power Line which is passing through the proposed plant shall be either rerouted or changed to underground cables.

4 METEOROLOGICAL & CLIMATE DATA, YIELD & VARIABILITY ANALYSIS

4.1 Pakistan lies in an area of one of the highest solar insolation suitable for both Photovoltaic and Solar Thermal. The immense solar resource remains entirely untapped. The solar radiation maps of the region (Source: NREL) show the average insolation (Global Horizontal Irradiance in kWH/Sq.M/day) values, as below:

Description	Data
Northern parts of Baluchistan	5.5-6.5 kWH/Sq.M
Central & East Baluchistan, Southern parts of Punjab & North & North-East parts of Sindh	5.0-5.5 kWH/Sq.M
Major parts of Punjab (other than north-west zone), Central parts of Baluchistan & Sindh	4.5-5.0 kWH/Sq.M

4.2 Site selection and planning of PV power plants requires reliable solar resource data. The solar resource of location is usually defined by the values of the global horizontal irradiation direct normal irradiation and diffuse horizontal irradiation as defined below:

4.2.1 Global Horizontal Irradiation (GHI)

GHI is the total solar energy received on a unit area of horizontal surface. It includes energy from the sun that is received in a direct beam and from all directions of the sky when radiation is scattered off the atmosphere (diffuse irradiation). The yearly sum of the GHI is of particular relevance for PV power plants, which are able to make use of both the diffuse and beam components of solar irradiance.

4.2.2 Direct Normal Irradiation (DNI)

DNI is the total solar energy received on a unit area of surface directly facing the sun at all times. The DNI is of particular interest for solar installations that track the sun and for concentrating solar technologies
(As concentrating technologies can only make use of the direct component of irradiation).

4.2.3 Diffuse Horizontal Irradiation (DHI)

DHI is the energy received on a unit area of horizontal surface from all directions when radiation is scattered off the atmosphere or surrounding area.

4.3 Long term annual average values of GHI and DNI can be obtained for a site by interpolating measurements taken from ground based sensors or indirectly from the analysis of satellite imagery. Climate data input from **METEONORM** (Grid sensor measurement & extrapolation) and **SOLARGIS** (Satellite imaginary & simulation) have been used, in this report. The basic theory and methodology adopted for the above measurement tools are detailed below:

4.3.1 Solar Irradiation Data through Meteonorm (Ver 7.1) Software:

4.3.1.1 For the proposed site location radiation interpolation locations are arrived from Multan (147Kms), Lahore (172Kms), Quetta (572Kms) and temperature interpolation locations are arrived from Lahore Civ/Mil (175Kms), Amritsar (220kms) and Patiala (342Kms).

4.3.1.2 *Meteonorm* is a comprehensive climatological database for solar energy applications:

- ✓ *meteonorm* is a meteorological database containing comprehensive climatological data for solar engineering applications at every location on the globe. The results are stochastically generated typical years from interpolated long term monthly means. They represent a mean year of the selected climatological time period based on the user's settings. As such the results do not represent a real historic year but a hypothetical year which statistically represents a typical year at the selected location.
- ✓ *meteonorm* is a data source for engineering design programs in the passive, active and photovoltaic application of solar energy with comprehensive data interfaces.

4.3.1.3 Basic Theory of meteonorm

✓ *meteonorm* is primarily a method for the calculation of solar radiation on arbitrarily orientated surfaces at any desired location. The method is based on databases and algorithms coupled according to a predetermined scheme. It commences with the user specifying a particular location for which *meteorological* data are required, and terminates with the delivery of data of the desired structure and in the required format.

4.3.1.4 Usage of Data and Methodology Adopted in meteonorm

The following methods are used among the numerous procedures available in the *meteonorm*. While choosing any one of the following methods, the quality and relevance of the basis data sets must be considered:

✓ ***Measured and interpolated monthly values*** are of similar precision. Although measured data reflect the specific *characteristics* of a local site, they are always subject to measurement errors, and these tend to be compensated by the interpolation process. Interpolated data should therefore be used at sites with no weather station in the vicinity (approx. 20 km distance).

✓ ***Dependent parameters*** such as diffuse radiation, celestial radiation, dew point temperature etc., which are determined from *calculated* as opposed to measured data, are subject to greater inaccuracy owing to error propagation.

4.3.1.5 Solar irradiation data for the proposed site made available in meteonorm for the Radiation Period of 1986-2005 is given below:

Months	Radiation Period 1986-2005			
	GlobHor	T Amb	GlobInc	GlobEff
	kWh/m2	° C	kWh/m2	kWh/m2
January	98.0	11.27	131.5	124.4
February	116.4	15.46	146.6	139.0
March	159.0	21.17	181.9	172.3
April	179.3	26.66	187.4	176.8

Months	Radiation Period 1986-2005			
	GlobHor	T Amb	GlobInc	GlobEff
	kWh/m2	° C	kWh/m2	kWh/m2
May	199.0	32.16	194.6	182.9
June	186.6	31.95	177.4	166.6
July	182.1	30.81	174.4	163.3
August	183.1	30.21	185.3	174.1
September	169.3	28.02	187.6	177.7
October	141.5	24.65	171.1	162.0
November	111.5	18.02	151.2	143.3
December	96.7	13.25	136.6	129.2
Year	**1822.5**	**23.67**	**2025.6**	**1911.8**

Meteonorm data file for Harappa location is attached with this report as Annexure-A for reference.

4.3.2 Solar Irradiation Data through SolarGIS Software:

4.3.2.1 The SolarGIS database is a high resolution database recognized as the most reliable and accurate source of solar resource information. The database resides on about 100 terabytes of data and it is continuously updated on daily basis. The data is calculated using in-house developed algorithms that process satellite imagery and atmospheric and geographical inputs

4.3.2.2 The model runs 24 hours a day and processes data from 4 geo-stationary satellites, which cover almost Earth's entire surface. More than 5 GB of data is processed every day. The database resides on about 100 terabytes of data. This is equivalent to 100,000 times the size of some other solar resource databases.

4.3.2.3 Variability and characteristics of solar radiation are influenced by a number of factors. Many reasons, such as day-night cycle, seasonal cycle, and shading by cloud formations or surrounding terrain, are quite obvious. Others are not so easy to track e.g. content of water vapour and aerosols in the atmosphere, thickness of ozone layer, etc. In the past only simple observation were carried out.

4.3.2.4 These obstacles have been overcome by calculation of solar radiation from satellite and atmospheric data. This approach has several benefits:

- ✓ Satellite sensors are precisely calibrated and maintained during the whole life-cycle, data delivery is stable (e.g. reliability of MeteoSat is more 99%)
- ✓ Geostationary satellites provide near-real-time global coverage data, which allows monitoring, now-casting and forecasting
- ✓ Historical sets of satellite and meteorological data enable backward analysis of solar radiation components. Thus a statistically comprehensive dataset (representing 10+ years of data) can be acquired
- ✓ Atmospheric data come from physical models, run by leading meteorological institutions; New models are more and more accurate

4.3.2.5 The first efforts of modeling the solar radiation from satellite data was in the 1980'ies. Since that time the models have improved considerably. In the SolarGIS model latest scientific knowledge is implemented.

4.3.2.6 Solar irradiation data for the proposed site made available in Solar GIS from METEOSAT IODC satellite for duration of 1999-2011, with 30 Minutes interval values. SolarGIS data file for Harappa location is attached with this report as Annexure-B for reference.

4.3.2.7 Comparison between meteonorm and solarGIS monthly average GHI Data:

Month	Meteonorm GHI [kWh/m2]	Solar GIS GHI [kWh/m2]
Period	Temperature period 2000-2009 & Radiation Period 1986-2005	1999-2011 (30 Min Average from Meteostat IDOC Satellite)
January	98	93
February	116.4	115
March	159	172
April	179.3	191
May	199	204
June	186.6	182
July	182.1	169

Month	Meteonorm GHI [kWh/m2]	Solar GIS GHI [kWh/m2]
Period	Temperature period 2000-2009 & Radiation Period 1986-2005	1999-2011 (30 Min Average from Meteostat IDOC Satellite)
August	183.1	176
September	169.3	165
October	141.5	146
November	111.5	105
December	96.7	97
Year	**1822.5**	**1815**
Variability of Gh/Year	4.6%	4%
Avg ambient (Deg)	23.67	26.5

For computation of yield analysis, both solar irradiance value from Meteonorm and Solar GIS is considered in this report, with higher average ambient of 26.5° on a conservative basis. GHI data from SolarGIS were also found to be generally matching with Site Meteorological Observations.

4.4 Solar Yield Analysis using PVSYST

4.4.1 The PVSyst software, widely being used by most of the developers, has been used to ascertain yield and performance of the systems / options considered in this report.

4.4.2 Yield from the Solar system varies depending on the following factors:

- ✓ Direct Irradiance
- ✓ Tilt and Facing of the module with respect to Sun
- ✓ Selection of Solar PV Technology and Make of the module
- ✓ Inverter Type and Make
- ✓ Cable sizing and cable losses
- ✓ Grid availability

4.4.3 Losses Considered for Yield Calculation

PVSYST calculates the direct current (DC) electricity generated from the modules in hourly time steps throughout the year. This direct current is converted to alternating current (AC) in an inverter. A number of losses occur during the process of converting irradiated solar energy into AC electricity. Some of these losses are calculated within the PVSYST software, whilst others are assumed figures based on the performance of similar PV plants. The losses are described in the following subsections.

4.4.4 Incident Angle Losses

The incidence angle loss or "Incidence Angle Modifier" (IAM) accounts for losses in radiation penetrating the front glass of the PV modules due to angles of incidence other than perpendicular. This loss is derived from the ratio of direct and diffuse radiation, sun angles and the tilt of the modules.

4.4.5 Low Irradiance Loss

The conversion efficiency of a PV module reduces at low light intensities. This causes a loss in the output of a module compared with the standard conditions at which the modules are tested (1000 W/Sq.M). This "low irradiance loss" depends on the characteristics of the module and the intensity of the incident radiation.

4.4.6 Module Temperature

The characteristics of a PV module are determined at standard temperature conditions of 25°C. For every °C temperature rise above 25°C there is reduction in performance of modules. This temperature dependent performance differs for different PV technologies. The performance of crystalline silicon module reduces by ~0.45%.

4.4.7 Module Quality

Most PV modules do not match exactly the manufacturer's nominal specifications. Modules are sold with a nominal peak power and a given tolerance within which the actual power is guaranteed to lie. In practice PV modules usually lie below the nominal power but within the tolerance. For this project, it is proposed to use only positive tolerance modules.

4.4.8 Module Mismatch

Due to the inherent inaccuracy of the silicon photovoltaic cell manufacturing process, PV modules, expected to have the same electrical features, will not be identical. This (relatively small) heterogeneity among modules is at the basis of the mismatch loss. The mismatch loss depends both on the specific PV modules used for the project and on the procedure followed to assemble the modules on site.

4.4.9 DC Cable Resistance

Electrical resistance in the wires between the power available at the modules and at the terminals of the array gives rise to ohmic losses (I^2R).

4.4.10 Inverter Performance

The inverters used at any PV plant convert from DC power into AC power with a maximum efficiency of 98.8%. The same is reflected in the Inverter datasheet. However, depending on the inverter load, they will not always operate at maximum efficiency.

4.4.11 Soiling

In order to produce maximum energy on any given day, it is best to keep the panels clean at all times. The cleaning of modules will depend on the rainfall and cleaning strategy defined in the O&M contract; thus it may not be possible to retain the panels clean all the time. Unless a particularly robust cleaning strategy is employed, the soiling loss for horizontally mounted modules may be expected to be higher than modules that are inclined, as inclined modules will benefit more from the cleaning effect of rainwater run-off.

4.4.12 Degradation

The performance of a PV module can decrease over time. The degradation rate is typically higher in the first year upon initial exposure to light and then stabilizes. The extent of degradation and the process by which it occurs varies between module technologies.

The initial degradation occurs due to defects in the cell, which are activated on exposure to light. The subsequent degradation occurs at the module level and may be caused by:

- ✓ Effect of the environment on the surface of the module e.g. pollution
- ✓ Mechanical stress and dampness on the contacts
- ✓ Cell contact breakdown
- ✓ Wiring degradation
- ✓ Factors affecting the degree of degradation include the quality of materials used in manufacture, the manufacturing process, and also the O&M regime employed at the site.

4.4.13 The following table indicated the inputs considered for the PVsyst analysis:

Description	Values
Site Co-Ordinate	30.6deg N & 72.9deg E
Plane Tilt	23Deg
Number of Sheds	5
Pitch	7.00 Mtrs
Collector Band Width	4.00 Mtrs
Meteo Data	Solar GIS - 1815 kWh/m^2
Meteo Data	Meteonorm - 1822.5 kWh/m^2

4.4.14 The following table gives the extract of loss distribution in yield simulation:

Description	Loss - Using GIS	Loss - Using Meteonorm
Horizontal Global Irradiation	1815 kWh/m^2	1822 kWh/m^2
Incidence angle	(+)10.0%	(+)11.1%
Near Shading	(-) 2.4%	(-) 2.3%

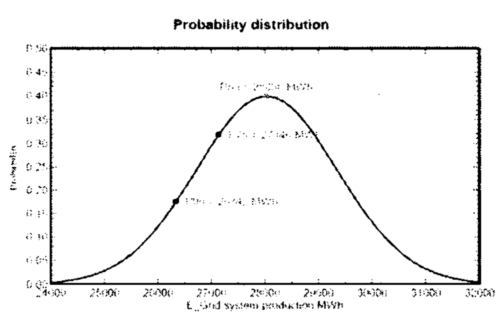
Description	Loss - Using GIS	Loss - Using Meteonorm
IAM Factor	(-) 2.8%	(-) 2.7%
Soiling Loss	(-) 1.0%	(-) 1.0%
Effective Irradiance on Collector at STC efficiency 15.74%	1875 kWh/m^2 on collector area of 114513m^2	1906 kWh/m^2 on collector area of 114513m^2
Array Nominal Energy at STC efficiency	33863 MWh	34425 MWh
Low Irradiance Performance	(-) 0.4%	(-) 0.4%
Temperature	(-) 9.1%	(-) 8.2%
Light Induced Degradation (LID)	(-) 3.0%	(-) 3.0%
Module Quality Loss	(-) 0.7%	(-) 0.7%
Mismatch	(-) 2.3%	(-) 2.3%
Ohmic Wiring Loss	(-) 2.3%	(-) 2.3%
Array Virtual Energy at MPP	28844 MWh	29642 MWh
Inverter Loss during Operation	(-) 1.7%	(-) 1.7%
Available Energy at Inverter Output	28353 MWh	29139 MWh
AC Ohmic Loss	(-) 0.6%	(-) 0.6%
External Transformer Loss	(-) 0.6%	(-) 0.6%
Energy Injected into Grid, for 18036 kWp modules	28037 MWh	28815 MWh
Performance Ratio (After the Losses)	77.9%	78.9%
Revenue Yield (kWh/kWp) after First Year degradation	**1554**	**1598**

4.4.15 Evaluation of the production probability forecast for analysis using SolarGIS & Meteonorm Software:

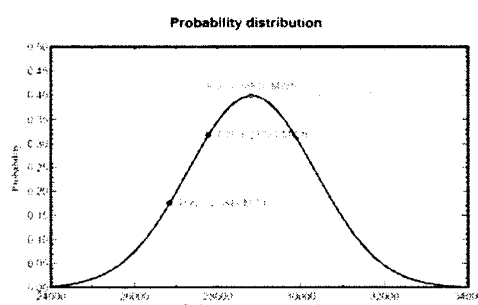
The probability distribution of the system production forecast for different years is mainly dependent on the meteo data used for the simulation. P50 (50% probability) is the value obtained based on average generation and used in financial analysis. P90 (90% probability) value is used in sensitivity /

risk analysis. The following are the general probability general distribution variance:

Description	Data (SolarGIS)	Data (Meteonorm)
Specified Deviation - Year Deviation from average	3%	3%
Year-Year variability variance	4%	4.7%
System Parameters Uncertainties		
PV module modeling/parameters	2.0%	2.0%
Inverter efficiency uncertainty	0.5%	0.5%
Soiling and Mismatch uncertainties	1.0%	1.0%
Degradation Uncertainties	1.0%	1.0%
Global Variability (Meteo+System) Variance	4.7% (Quadratic Sum)	4.7% (Quadratic Sum)
Annual Production Probability	P50 - 28037 MWh P75 - 27145 MWh P90 - 26341 MWh	P50 - 28815 MWh P75 - 27781 MWh P90 - 26848 MWh



Probability Graph - GIS



Probability Graph - Meteonorm

Figure 6 - Probability Graph

Note: PVSYST analysis report for the above arrangement and yield is attached with this report as Annexure-C (SolarGIS) & Annexure-D (Meteonorm) with this report

4.4.16 Module Degradation Table for 25 years

PV modules by virtue of aging have tendency to degrade over the years. The following table indicates the typical degradation in the energy yield for each year of operation:

Year of operation	% of degradation at end of year	Accumulated degradation in %	Energy at the end of year in million units (MU) - SolarGIS	Energy at the end of year in million units (MU) - Meteonorm
1	Considered in PVSYST	(3% for First Year)	**28.03**	**28.81**
2	0.88%	0.88%	27.78	28.56
3	0.88%	1.76%	27.54	28.31
4	0.88%	2.64%	27.30	28.06
5	**0.88%**	**3.52%**	**27.06**	27.81
6	0.88%	4.40%	26.82	27.56
7	0.88%	5.28%	26.58	27.32
8	0.88%	6.16%	26.35	27.08
9	0.62%	6.78%	26.18	26.91
10	**0.62%**	**7.40%**	26.02	26.75
11	0.62%	8.02%	25.86	26.58
12	0.62%	8.64%	25.70	26.42
13	0.62%	9.26%	25.54	26.25
14	0.62%	9.88%	25.38	26.09
15	**0.62%**	**10.50%**	25.23	25.93
16	0.62%	11.12%	25.07	25.77
17	0.62%	11.74%	24.91	25.61
18	0.62%	12.36%	24.76	25.45
19	0.62%	12.98%	24.61	25.29
20	**0.62%**	**13.60%**	24.45	25.13
21	0.62%	14.22%	24.30	24.98
22	0.62%	14.84%	24.15	24.82
23	0.62%	15.46%	24.00	24.67
24	0.62%	16.08%	23.85	24.52
25	**0.62%**	**16.70%**	23.70	24.36

4.4.17 Seasonal Tilt Arrangement

In countries where the labour cost is low, manual seasonal tilt arrangement offers an worthwhile option. With seasonal tilt arrangement, 10 Deg tilt of modules for summer months (April to September) and 35 Deg tilt of modules for winter months (October to March) shall be planned.

The revenue yield (kWh/kWp) after first year degradation shall be **1602 kWh/kWp (P50 Value),** which is about 3.1% higher when compared with fixed tilt arrangement generation of 1554kWh/kWp.

5 PROJECT IMPLEMENTATION SCHEDULE AND O&M REQUIREMENT

5.1 General

5.1.1 The most essential aspect regarding the implementation of this Solar PV based 18MWp power plant is to ensure the project completion within the schedule.

5.1.2 A good planning, scheduling and monitoring program is imperative to complete the project on time and without cost overruns.

5.2 Project Implementation

5.2.1 The development and the size of the project organization must be based on the tasks that need to be performed in the project. For a project the following are the identified important phases. These phases are not mutually exclusive and some degree of overlapping is envisaged.

- ✓ Planning and preliminary design
- ✓ Various Statutory Approvals
- ✓ Project appraisal by lender (s)
- ✓ EPC Contract finalization for PV Plant
- ✓ Financial Closure
- ✓ Construction and Installation of PV Plant
- ✓ Interconnection system implementation with National grid
- ✓ Commissioning and performance testing

5.3 Project Schedule

5.3.1 This schedule envisages the project commissioning and export to grid in six (6) months from the date of ordering.

5.3.2 Level 2 Schedule to be prepared at the time of contract planning will include all these activities.

- ✓ Request for EPC proposals
- ✓ Receipt of offers, evaluation, discussions and purchase order placement.
- ✓ Review of detailed design

- ✓ Foundation and civil works
- ✓ Manufacturing and delivery
- ✓ Erection and other works at site
- ✓ Commissioning, trial run and testing

5.3.3 In the plant the PV modules, inverters, transformers, switchyard and transmission line are the long lead items and the planning of the schedule for the project implementation should provide adequate time period for the installation of these equipment.

5.4 O & M Requirement

5.4.1 Operation & Maintenance for Solar PV Plant has major four (4) components:

- ✓ Cleaning of PV Panels periodically (says once in 15-20 days)
- ✓ Plant security, covering entire fenced area
- ✓ General shift operator for coordinating plant operation, maintenance and liaison with national grid
- ✓ PV Plant system spares

Annex - 18

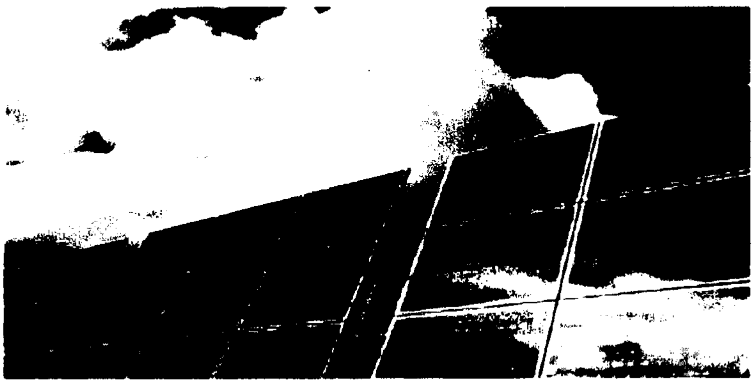
Report No. PPI-120.4-Draft/15

PPI

INTERCONNECTION STUDY

For

18 MWp Solar Power Project by Harappa Solar Pvt. Ltd near Harappa, District Sahiwal, Punjab



Final Report
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Executive Summary

- The study objective, approach and methodology have been described and the plant's data received from the client Harappa Solar Pvt. Ltd is validated.
- The expected COD of the project is April 2016. Therefore the month of June 2016 has been selected to carry out the study as it will allow the maximum impact of the project to be judged.
- The MEPCO system data as available with PPI for other studies have been used.
- The nearest substation of MEPCO is Harappa 132/11 kV. The following scheme of interconnection of Solar Power Plant by Harappa to evacuate maximum AC power of 15.2 MW is envisaged and studied in detail:
  - A direct 11 kV triple circuit of 2.5 km length using Osprey conductor to be laid from 11 kV Bus Bar of Harappa Solar-PP till Harappa 132/11 kV substation. Two circuit to be connected to Harappa 132/11 kV T-1 and one to be connected to Harappa 132/11 kV T-2.
  - In this context two 11 kV breaker/line bays need to be added in the 11 kV switchgear hall of Harappa 132/11 kV Substation.
- Detailed load flow studies have been carried out for the peak load conditions of June 2016 for the proposed scheme under normal and N-1 contingency conditions to meet the reliability criteria.
- Steady state analysis by load flow reveals that proposed scheme is adequate to evacuate the maximum power of 15.2 MW of the plant under normal and contingency conditions.
- The short circuit analysis has been carried out to calculate maximum fault levels at the Harappa Solar Power Plant at 11 kV, and the substations of 132/11kV in its vicinity. We find that the fault currents for the proposed scheme are much less than the rated short circuit capacities of switchgear installed at these substations. There are no violations of exceeding the rating of the equipment due to contribution of fault current from the Harappa Solar Power Plant.

  The maximum short circuit level of 11 kV bus bar of Harappa Solar Power Plant 11 kV is 12.72 kA and 12.29 kA for 3-phase and 1-phase faults respectively. Therefore industry standard switchgear of the short circuit rating of 25 kA is considered adequate with enough margins for future increase in fault levels due to future reinforcements in this area.

- The dynamic stability analysis of proposed scheme of interconnection has been carried out. The stability check for the worst case of three phase fault right on the 11 kV bus bar of the Harappa solar power plant substation followed by the final trip of 11 kV circuits emanating from this substation, has been performed for fault clearing of 10 cycles (200 ms) as understood to be the maximum fault clearing time of 11 kV protection system. The system is found strong enough to stay stable and recovered with fast damping. The stability of system for far end faults of 3-phase occurring at Harappa 132 kV bus bar has also been checked. The proposed scheme successfully passed the dynamic stability checks for near and far faults.
- The issues of power quality like flicker and voltage unbalance 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
- The proposed scheme of interconnection has no technical constraints or problems, it fulfills all the criteria of reliability and stability under steady state load flow, contingency load flows, short circuit currents and dynamic/transient conditions; and is therefore recommended to be adopted.

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1. Introduction

1.1 Background

Harappa Solar (Private) Limited is setting up an 18 MWp solar power plant near Harappa, District Sahiwal, Punjab. The site of the proposed project is located in the concession area of Multan Electric Power Company Limited (MEPCO). The peak AC net output planned to be generated from the project is about 15.2 MW which will start commercial operations by April 2016. The electricity generated from this project would be supplied locally to the Harappa Grid Station and to the MEPCO network through the 132/11 kV grid located in the vicinity of this project.

1.2 Objectives

The overall objective of the Study is to evolve an interconnection scheme between Harappa Solar Power Project and MEPCO network, for stable and reliable evacuation of 15.2 MW of electrical power generated from this plant, fulfilling N-1 reliability criteria. The specific objectives are:

1. To develop scheme of interconnections at 11 kV for which right of way (ROW) and space at the terminal substations would be available.
2. To determine the performance of interconnection scheme during steady state conditions of system, normal and N-1 contingency, through load-flow analysis.
3. To check if the contribution of fault current from this new plant increases the fault levels at the adjoining substations at 11kV 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 substation at the Harappa Solar Power Plant.
4. To check if the interconnection with stands dynamic stability criteria of post fault recovery with good damping after 3-phase faults on the system.

1.3 Planning Criteria

The planning criteria as per Grid Code required to be fulfilled by the proposed interconnection is as follows:

Steady State:

Voltage	± 5 %, Normal Operating Condition
	± 10%, Contingency Conditions
Frequency	50 Hz, Continuous, ± 1% variation steady state
	49.2 - 50.5 Hz, Short Time
Power Factor	0.95 Lagging; 0.95 Leading

Dynamic/Transient:

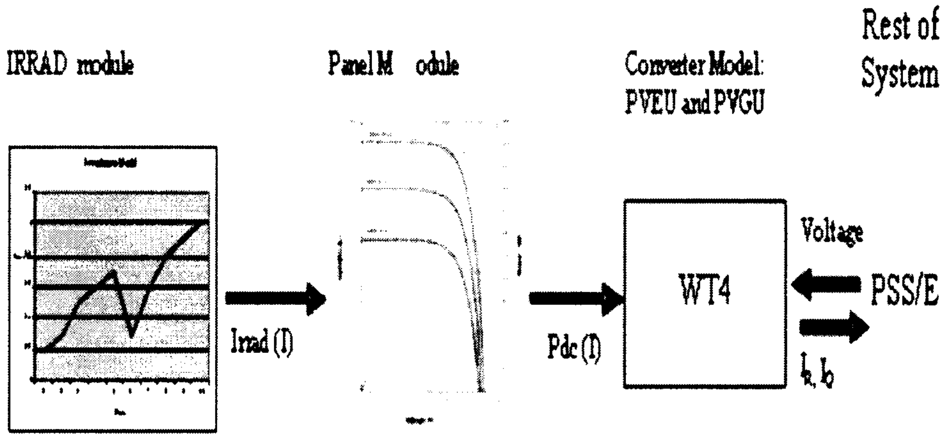
- The system should revert back to normal condition after dying out of transients without loosing synchronism with good damping. For 11 kV the total maximum fault clearing time from the instant of initiation of fault current to the complete interruption of current, including the relay time and breaker interruption time to isolate the faulted element, is equal to 200 ms (10 cycles).
- For the systems of 132 kV and above the 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, 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 180 ms (9 cycles).

2. Assumptions of Data

The detailed electrical parameters would be designed at the EPC stage. However for the purposes of this study, following assumptions have been made:

2.1 Solar Power Plant data

The Solar Power plant has been modeled according to the following block diagram



The way this works is that the irradiance profile from the sun is used as an input to the panel module which then calculates the DC power at that value of the irradiance. This value is then input to the electrical model of the solar power plant (inverter module) which then goes on to calculate the AC power supplied by the solar power plant.

Due to the presence of the inverter module, from the point of view of the network, the solar power plant is considered a voltage source convertor.

Dynamic Data:

Converter time constant for IQcmd seconds = 0.02 s

Converter time constant for IQcmd seconds = 0.02 s

Voltage sensor for LVACR time constants = 0.02 s

Voltage sensor time constant = 1.1 s

2.2 Network data

The 11 kV and 132 kV networks available for interconnection to Harappa Solar Power Plant are as shown in Sketches 1 and 2 in Appendix-A.

The PEPCO/MEPCO system data of National Grid have been assumed in the study as already available with PPI.

3. Study Approach and Methodology

3.1 Understanding of the Problem

The 18 MWp Solar Power Plant by Harappa Solar (Pvt.) Limited is going to be a Photovoltaic (PV) based solar project embedded in the 11kV distribution network of Harappa. It would run almost all the months of the year though with some variation in its output due to variation in the strength of light in winter and in rainy season.

The existing nearest grid station available for interconnection is Harappa 132/11 kV Substation. The addition of this source of power generation embedded in local distribution network of this area and shall provide relief to Harappa 132/11kV substation feeding the local network and also helps 11 kV network in terms of improving line losses and voltage profile. The 11 kV network surrounding Harappa has significant load demand, therefore most of the power from the Harappa Solar Power Plant will be utilized locally in meeting this load demand.

The adequacy of MEPCO network of 132 kV in and around the proposed site of Harappa Solar Plant would be investigated in this study for absorbing and transmitting this power fulfilling the reliability criteria.

3.2 Approach to the problem

The consultant has applied the following approaches to the problem:

- A base case network model has been prepared for June 2016 considering maximum AC out of 15.2 MW for the solar plant by Harappa Solar (Pvt.) Limited, comprising all 500 kV, 220 kV and 132 kV system and envisaging the load forecast, the generation additions and transmission expansions for that year particularly in MEPCO.
- The project is expected to be completed by April 2016. Therefore the month of June 2016 has been selected to carry out the study as it will allow the maximum impact of the project to be judged.
- Interconnection scheme without any physical constraints, like right of way or availability of space in the terminal substations, have been identified.
- Performed technical system studies for peak load conditions to confirm technical feasibility of the interconnections. The scheme has been subjected to

standard analysis like load flow and short circuit, transient stability study and power quality analysis to check the strength of the plant and the proposed interconnection scheme under disturbed conditions.

- Determine the relevant equipment for the proposed technically feasible scheme.
- Recommend the technically most feasible scheme of interconnection.

4. Development of Scheme of Interconnection

4.1 The Existing Network

The nearest existing MEPCO interconnection facilities at the time of commissioning of Harappa Solar Power Project would be as follows:

- Harappa 132/11 kV Substation
- Sahiwal-Old 132/11 kV Substation
- Chichawatni 132/11 kV Substation

The existing 132 kV network available around these 132 kV grid station is shown in Sketch-1 in Appendix-A.

Given the physical proximity of Harappa to Harappa solar power plant and that fact that the other facilities are at a considerable distance from the plant, the most feasible interconnection of the Harappa Solar Power Plant will be with Harappa 132/11 kV substation.

4.2 The Scheme of Interconnection of Solar Power Plant

Keeping in view of the above mentioned 11 kV and 132 kV network available in the vicinity of the site of the Harappa Solar Power Plant, the interconnection scheme has been developed as shown in Sketch-2 in Appendix A by laying down triple circuit using Osprey conductor of about 2.5 km from 11 kV Bus Bar of Solar-PP till Harappa 132/11 kV substation. Two circuit to be connected to Harappa 132/11 kV T-1 and one to be connected to Harappa 132/11 kV T-2.

4.3 Proposed additions at 11 kV in Harappa 132/11 kV Substation

Two breaker/panels of 11 kV along with respective protection equipment would be required to be added in 11 kV switchgear hall of Harappa 132/11kV substation to provide connection to direct 11 kV circuits from this Solar Power Plant.

5. Detailed Load Flow Studies

5.1 Base Case 2016, Without Solar Power Plant

A base case has been developed for the peak load of June 2016, using the network data of Harappa Solar-PP and MEPCO network.

The results of load flow for this base case are plotted in Exhibit 0.0 of Appendix-B. The system plotted in this Exhibit shows 132 kV network feeding Harappa connected to its surrounding substations through Sahiwal-Old and Chichawatni. Also the 11 kV network emanating from Harappa has been modeled showing each substation as 11 kV bus bars with loads connected to each bus.

The load flow results show that the power flows on all circuits are within their specified normal current carrying rating. The voltages are also within the permissible limits. We see that about 35.6 MW flows from Sahiwal-Old to Harappa and 2.1 MW flows from Chichawatni to Harappa which feeds the loads at the 11 kV bus bars of Harappa 132/11 kV Substation.

For N-1 contingency conditions we have performed the following cases

Exhibit-0.1	Sahiwal - Old to Harappa 132 kV Single Circuit Out
Exhibit-0.2	Chichawatni to Harappa 132 kV Single Circuit Out
Exhibit-0.3	Sahiwal - Old to Kassowal 132 kV Single Circuit Out
Exhibit-0.4	Kassowal to Chichawatni 132 kV Single Circuit Out
Exhibit-0.5	Chichawatni to Shah Fazal 132 kV Single Circuit Out
Exhibit-0.6	Sahiwal - Old to Sahiwal III 132 kV Single Circuit Out

In both cases the power flows on all circuits remain within their ratings. Thus we find that there are no capacity constraints in terms of MW or MVAR flow in the 11 kV or 132 kV network available in the vicinity of Harappa Solar Power Plant for its connectivity under normal and contingency conditions prior to its connection.

5.2 Load Flow with Harappa Star Electric Solar Power Plant

We have considered the scenario of June 2016 so that we can judge the maximum impact of the project on the system.

The scheme of interconnection modeled in the load flow for Harappa Solar Power Plant is developed by laying down triple circuit of 11 kV of about 2.5 km using Osprey conductor from 11 kV Bus Bar of Solar-PP to Harappa 132/11 kV substation. Two circuit to be connected to Harappa 132/11 kV T-1 and one to be connected to Harappa 132/11 kV T-2. The results of load flow with Harappa Solar Power Plant interconnected as per proposed scheme are shown in Exhibit 1.0 in Appendix-B. The power flows on the circuits are seen well within the rated capacities and the voltages on the bus bars are also within the permissible operating range of ± 5 % off the nominal.

We find no capacity constraints on 11 kV or 132 kV circuits under normal conditions i.e. without any outages of circuits.

With part of the load at Harappa fed by the Solar-PP locally, the flow from Sahiwal-Old to Harappa is reduced to 27 MW and 4.5 MW now flow from Harappa to Chichawatni.

N-1 contingency analysis has been carried out and the plotted results are attached in Appendix – B as follows;

Exhibit-1.1	Harappa-PP to Harappa-T1 11kV Single Circuit Out
Exhibit-1.2	Sahiwal - Old to Harappa 132 kV Single Circuit Out
Exhibit-1.3	Chichawatni to Harappa 132 kV Single Circuit Out
Exhibit-1.4	Sahiwal - Old to Kassowal 132 kV Single Circuit Out
Exhibit-1.5	Kassowal to Chichawatni 132 kV Single Circuit Out
Exhibit-1.6	Chichawatni to Shah Fazal 132 kV Single Circuit Out
Exhibit-1.7	Sahiwal - Old to Sahiwal III 132 kV Single Circuit Out

In all the above contingency cases, we find that in the event of outage of any circuit, the intact circuits remain within the rated capacity.

Also the bus bar voltages are well within the rated limits in all the contingency events. Thus there are no constraints in this scheme.

5.3 Conclusion of Load Flow Analysis

From the analysis discussed above, we conclude that the proposed interconnection scheme of a direct 11 kV tripple circuit of 2.5 km length using Osprey conductor to be laid from 11 kV Bus Bar of Harappa Solar-PP to Harappa 132/11 kV substation ensures its reliability and availability under all events of contingencies i.e. planned or forced outages.

6. Short Circuit Analysis

6.1 Methodology and Assumptions

The methodology of IEC 909 has been applied in all short circuit analysis in this report for which provision is available in the PSS/E software used for these studies. .

The maximum fault currents have been calculated with 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 1.10 P.U. i.e. 10 % higher than nominal, which is the maximum permissible voltage under contingency condition.

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 2016 i.e. all the generating units have been assumed on-bar in fault calculation's simulations.

6.2 Fault Current Calculations without Harappa Solar Power Plant

In order to assess the short circuit strength of the network of 11 kV and 132 kV without the Solar Power Plant for the grid of MEPCO in the vicinity of the site of the Plant near Harappa, fault currents have been calculated for balanced three-phase and unbalanced single-phase short circuit conditions. These levels will not only give us the idea of the fault levels without Harappa Solar Power Plant and later on how much the contribution of fault current from the Solar Power Plant may add to the existing levels, but also we get a feel of the strength of the proposed node to connect this Power Plant depending on its relative short circuit strength.

The results are attached in Appendix – C.

The short circuit levels have been represented graphically on the bus bars of 11 kV and 132 kV along with fault current contributions from the incoming circuits, which are shown in the Exhibit 2.0 attached in Appendix-C.

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-C for the 11 kV and 132 kV bus bars of our interest i.e. 11 kV and 132 kV circuits lying close to Harappa. 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 maximum fault currents for 3-phase and 1-phase short circuit at these substations are summarized in Table 6.1. We see that the maximum fault currents do not exceed the short circuit ratings of the equipment at these 11 kV and 132 kV substations which normally are 20 kA, 25 kA.

Table - 6.1
Maximum Short Circuit Levels without Harappa Solar PP

Substation	3-Phase fault current, kA	1-Phase fault current, kA
Harappa T-1 11 kV	11.20	10.86
Harappa T-2 11 kV	15.44	14.80
Harappa 132 kV	10.35	7.70
Sahiwal Old 132 kV	21.04	20.73
Kamalia 132 kV	15.67	15.77
Yousafwala 132 kV	30.80	32.25
Kassowal 132 kV	17.10	16.14
Noorpur 132 kV	10.35	9.81
Sahiwal III 132 kV	14.79	13.34
Chichawatni 132 kV	15.67	15.77
Shah.Fazal 132 kV	8.75	7.90

6.3 Fault Current Calculations with Solar Power Plant interconnected

Fault currents have been calculated for the electrical interconnection of proposed scheme. Fault types applied are three phase and single-phase at 11 kV bus bars of Harappa Solar Power Plant itself and other bus bars of the 132 kV substations in the electrical vicinity of Harappa. The graphic results are indicated in Exhibit 2.1.

The tabulated results of short circuit analysis showing all the fault current contributions with short circuit impedances on 132 kV and 11 kV bus bars of the network in the electrical vicinity of Harappa Solar Power Plant are placed in Appendix-C. Brief summary of fault currents at significant bus bars of our interest are tabulated in Table 6.2.

Comparison of Tables 6.1 and 6.2 shows slight increase in short circuit levels for three-phase and single – phase faults due to connection of Solar Power Plant on the 132 kV and 11 kV bus bars in its vicinity. This increase is limited from the point of view of the fact that the Solar Power Plant is a voltage source convertor. We find that even after some increase, these fault levels are much below the rated short circuit values of the equipment installed on these substations. The maximum short circuit level of 11 kV bus bar of Harappa Solar Power Plant 11 kV is 12.72 kA and 12.29 kA for 3-phase and 1-phase faults respectively. Therefore an industry standard switchgear of the short circuit rating of 25 kA should be installed at 11 kV switchyard of the Solar Power Plant leaving enough margin to accommodate fault current contribution from any future reinforcements taking place in that area.

Table-6.2
Maximum Short Circuit Levels with Harappa Star Electric Solar PP

Substation	3-Phase fault current, kA	1-Phase fault current, kA
Harappa PP 11 kV	12.72	12.29
Harappa T-1 11 kV	15.10	14.50
Harappa T-2 11 kV	18.69	17.77
Harappa 132 kV	10.39	7.73
Sahiwal Old 132 kV	21.07	20.76
Kamalia 132 kV	15.69	15.79
Yousafwala 132 kV	30.82	32.26
Kassowal 132 kV	17.11	16.15
Noorpur 132 kV	10.36	9.82
Sahiwal III 132 kV	14.80	13.35

Chichawatni 132 kV	**15.69**	**15.79**
Shah.Fazal 132 kV	**8.76**	**7.91**

6.4 Conclusion of Short Circuit Analysis

The short circuit analysis results show that for the proposed scheme of interconnection of Harappa Solar Power Plant with the Harappa11 kV distribution network, we don't find any problem of violations of short circuit ratings of the already installed equipment on the 132 kV and 11 kV equipment of substations in the vicinity of the Solar Power Plant due to fault current contributions from this plant due to three-phase faults as well as single phase faults.

The maximum short circuit level of 11 kV bus bar of Harappa Solar Power Plant 11 kV is 12.72 kA and 12.29 kA for 3-phase and 1-phase faults respectively. Therefore an industry standard switchgear of the short circuit rating of 25 kA should be installed at 11 kV switchyard of Harappa Solar Power Plant leaving enough margin to accommodate fault current contribution from any future reinforcements taking place in that area.

7. Transient Stability Analysis

7.1 Assumptions & Methodology

7.1.1 Stability Models

The assumptions about the generator and its parameters are the same as mentioned in Ch.2 of this report.

We have employed the generic stability models available in the PSS/E model library for dynamic modelling of the PV-Solar power generator, its electrical model and the panel as follows;

Generator	PVGU1
Electrical Model	PVEU1
Solar Panel Model	PANELU1

We have done studies with the inverter which has reactive support capability of ± 0.95 PF.

7.1.2 System Conditions

We have used the system conditions of June 2016 because in this season the irradiance from the sun is at its peak and hence the maximum impact of the Solar Power Plant can be judged.

The proposed scheme of laying a direct 11 kV triple circuit of 2.5 km length using Osprey conductor to be laid from 11 kV Bus Bar of Harappa Solar-PP till Harappa 132/11 kV substation. Two circuit to be connected to Harappa 132/11 kV T-1 and one to be connected to Harappa 132/11 kV T-2 , at Harappa 132/11 kV, has been modeled in the stability analysis.

All the power plants of WAPDA /NTDC from Tarbela to HUBCO have been dynamically represented in the simulation model.

7.1.3 Presentation of Results

The plotted results of the simulations runs are placed in Appendix - D. Each simulation is run for its first one second for the steady state conditions of the system prior to fault or disturbance. This is to establish the pre fault/disturbance conditions of the network under study were smooth and steady. Post fault recovery has been monitored for nine seconds. Usually all the transients due to non-linearity die out within 2-3 seconds after disturbance is cleared in the system.

7.1.4 Worst Fault Cases

Three phase faults are considered as the worst disturbance in the system. We have considered 3-phase fault in the closest vicinity of the Solar Power Plant i.e. right at the 11 kV bus bar of the solar power plant substation, cleared in 10 cycles, as normal clearing time for 11 kV i.e. 200 ms, followed by permanent trip of 11 kV single circuit emanating from this substation.

7.2 Transient Stability Simulations' Results

7.2.1 Fault at 132 kV Harappa (Far-End Fault)

We applied three-phase fault on far-end 132 kV bus bar of Harappa to study the impact of a disturbance in the grid on the performance of the plant. The fault is cleared in 5 cycles (100 ms) as standard clearing time for 132kV systems, followed by trip of 11 kV circuit between the Harappa Solar Power Plant and Sahiwal-Old . We monitored different quantities for one second pre-fault and nine seconds after clearance of fault (post-fault) conditions and plotted the results attached in Appendix – D and discussed as follows;

Fig. 1.1 Bus Voltages

The bus voltages of 11 kV bus bars of Harappa-PP, Harappa T-1,Harappa T-2 and 132 kV bus bars of Harappa ,Sahiwal-Old and Kassowal are plotted. The results show quick recovery of the voltages after clearing of fault.

Fig. 1.2 Frequency

We see the system frequency recovers back to normal quickly after fault clearance.

Fig. 1.3 MW/MVAR Output of Solar Power Plant

The pre-fault output of Solar Power Plant was 15.2 MW and it gets back to the same output quickly after fast damping of the oscillations in its output. However MVAR output acquires equilibrium at a new value.

Fig. 1.4 Voltage Sensor for LVACR

The value for LVACR is restored to its pre-fault value after the fault clears.

Fig. 1.5 MW /MVAR Flow from Harappa to Chichawatni 132kV

Followed by clearing of fault, the trip of 132 kV circuit between the Harappa to Sahiwal-old circuit caused the entire load of that circuit to flow through the intact 132 kV circuit between Harappa to Chichawatni. We plotted the flows of MW and MVAR on this intact circuit and see that the power flows on this circuit attains to steady state level with power swings damping down fast.

Fig. 1.6 Rotor Angles

The rotor angles of the generators of Liberty Power 132 kV, Guddu 220 kV, Engro-P 220 kV and Fauji-MR 220 kV are plotted relative to machines at Guddu-New 500 kV. The results show that the rotor angles gets back after the first swing and damps down quickly. The system is strongly stable and very strong in damping the post fault oscillations.

7.2.2 Fault at 132 kV Harappa (Far-End Fault with stuck breaker case)

We applied three-phase fault on far-end 132 kV bus bar of Harappa to study the impact of a disturbance in the grid on the performance of the plant. The fault is cleared in 9 cycles (180 ms) as standard clearing time for 132kV systems, followed by trip of 11 kV circuit between the Harappa Solar Power Plant and Sahiwal-Old . We monitored different quantities for one second pre-fault and nine seconds after clearance of fault (post-fault) conditions and plotted the results attached in Appendix – D and discussed as follows;

Fig. 2.1 Bus Voltages

The bus voltages of 11 kV bus bars of Harappa-PP, Harappa T-1,Harappa T-2 and 132 kV bus bars of Harappa ,Sahiwal-Old and Kassowal are plotted. The results show quick recovery of the voltages after clearing of fault.

Fig. 2.2 Frequency

We see the system frequency recovers back to normal quickly after fault clearance.

Fig. 2.3 MW/MVAR Output of Solar Power Plant

The pre-fault output of Solar Power Plant was 15.2 MW and it gets back to the same output quickly after fast damping of the oscillations in its output. However MVAR output acquires equilibrium at a new value.

Fig. 2.4 Voltage Sensor for LVACR

The value for LVACR is restored to its pre-fault value after the fault clears.

Fig. 2.5 MW /MVAR Flow from Harappa to Chichawatni 132kV

Followed by clearing of fault, the trip of 132 kV circuit between the Harappa to Sahiwal-old circuit caused the entire load of that circuit to flow through the intact 132 kV circuit between Harappa to Chichawatni. We plotted the flows of MW and MVAR on this intact circuit and see that the power flows on this circuit attains to steady state level with power swings damping down fast.

Fig. 2.6 Rotor Angles

The rotor angles of the generators of Liberty Power 132 kV, Guddu 220 kV, Engro-P 220 kV and Fauji-MR 220 kV are plotted relative to machines at Guddu-New 500 kV. The results show that the rotor angles gets back after the first swing and damps down quickly. The system is strongly stable and very strong in damping the post fault oscillations.

7.2.3 Fault at 11 kV Near Solar Power Plant

We applied three-phase fault on the Harappa Solar Power Plant 11 kV bus bar, cleared fault in 10 cycles (200 ms) followed by trip of 11 kV circuit between the Harappa Solar Power Plant and Harappa T-2. We monitored different quantities for one second pre-fault and nine seconds after clearance of fault (post-fault) conditions and plotted the results attached in Appendix – D and discussed as follows;

Fig. 3.1 Bus Voltages

The bus voltages of 11 kV bus bars of Harappa-PP, Harappa T-1,Harappa T-2 and 132 kV bus bars of Harappa ,Sahiwal-Old and Kassowal are plotted. The results show quick recovery of the voltages after clearing of fault.

Fig. 3.2 Frequency

We see the system frequency recovers back to normal quickly after fault clearance.

Fig. 3.3 MW/MVAR Output of Solar Power Plant

The pre-fault output of Solar Power Plant was 15.2 MW and it gets back to the same output quickly after fast damping of the oscillations in its output. However MVAR output acquires equilibrium at a new value.

Fig. 3.4 Voltage Sensor for LVACR

The value for LVACR is restored to its pre-fault value after the fault clears.

Fig. 3.5 MW /MVAR Flow from Harappa-PP to Harappa T-1 11kV

Followed by clearing of fault, the trip of 11 kV circuit between the power plant and Harappa T-1 circuit caused the entire load of that circuit to flow through the intact 11 kV circuit between the Solar-PP and Harappa T-1. We plotted the flows of MW and MVAR on this intact circuit and see that the power flows on this circuit attains to steady state level with power swings damping down fast.

Fig. 3.6 Rotor Angles

The rotor angles of the generators of Liberty Power 132 kV, Guddu 220 kV, Engro-P 220 kV and Fauji-MR 220 kV are plotted relative to machines at Guddu-New 500 kV. The results show that the rotor angles gets back after the first swing and damps down quickly. The system is strongly stable and very strong in damping the post fault oscillations.

7.3 Conclusion of Dynamic Stability Analysis

The results of dynamic stability show that the system is very strong and stable for the proposed scheme for the severest possible faults of 11 kV and 132 kV systems near to and far of the Solar Power Plant of Harappa. Therefore there is no problem of dynamic stability for interconnection of this Solar Power Plant; it fulfils all the criteria of transient stability. The reactive support from the inverter also helps the system stability.

8- Power Quality

The issues of power quality are of particular importance to PV solar power plants 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 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 Appendix-C.

8.1 Flicker

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

8.1.1 Continuous Operation

The probability of 99th percentile flicker emission from a single inverter 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 (ψ_k, V_a)	has a maximum value of 1
S_n	is the rated apparent power of one inverter
S_k	is the short circuit apparent power at the PCC
N_{wt}	is the number of inverters connected to the PCC

PCC is the point of common coupling of inverters that is MV bus of Harappa Farm substation.

For minimum short circuit case we have assumed that the output of Harappa Solar Power Plant is reduced as low as 20 % of its rated capacity. Therefore taking three collector groups we have calculated as follows;

S_n= 1 MVA

N_{WT} = 3

S_k for MV bus = 200 MVA

The value of c (ψ_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 one inverter

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

The value of c (ψ_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

$P_{St\Sigma} = P_{lt\Sigma} = 0.00825 = 0.825\ \%$

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

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

8.2 Voltage Unbalance

8.2.1 Voltage Step-Change

In low and medium voltage grids, the rise of the voltage with Solar PV units may not exceed the value of 3 % at the worst case PCC, compared to the voltage without Solar PV supply

With only one PCC, this condition is to be evaluated using the short-circuit capacity relationship:

$$k_{kl} = \frac{S_{kV}}{\sum S_{A\,max}}$$

with $k_{kl} \geq 33$ (Representing a less than 3% change)

S_{kv} - Short-circuit power at the PCC = 200 MVA

S_{Amax}- Maximum apparent power of one collector group that has been connected to the PCC. = 1 MVA

$$k_{kl} = 200$$

8.2.2 Voltage Variation

The operation of a Solar PV unit is acceptable if it is verified that the system complies with the standards IEC 61000-3-3 or IEC 61000-3-11. If this proof is not available, the variations of voltage caused by hooking up and turning off are acceptable, if the values in the following table are not exceeded at the PCC.

Voltage	Max. Voltage Variation	Max. Frequency: once in
Low Voltage	3%	5 Minutes
Medium Voltage	2%	1.5 Minutes

If there are only few operating cycles, for example one per day, the DNO may allow a higher variation of voltage. The voltage variation can be estimated via:

$$\Delta u_a = k_{i\max} \cdot \frac{S_{rE}}{S_{kV}}$$

$k_{i,max}$ - Maximum inrush current in relation to the nominal current
S_{kv} - Short-circuit power at the PCC
S_{rE} - Nominal apparent power of the Solar PV unit that is to be connected

This calculation gives an upper assessment and is basically a safe margin.

For Solar Power plants $k_{i,max}$ can be assumed to be 1. With this

S_{kv} = 200 MVA
S_{rE} = 1 MVA

$$\Delta u_a = 0.005 = 0.5\%$$

Which is much less than the maximum value of 2%.

9. Conclusions

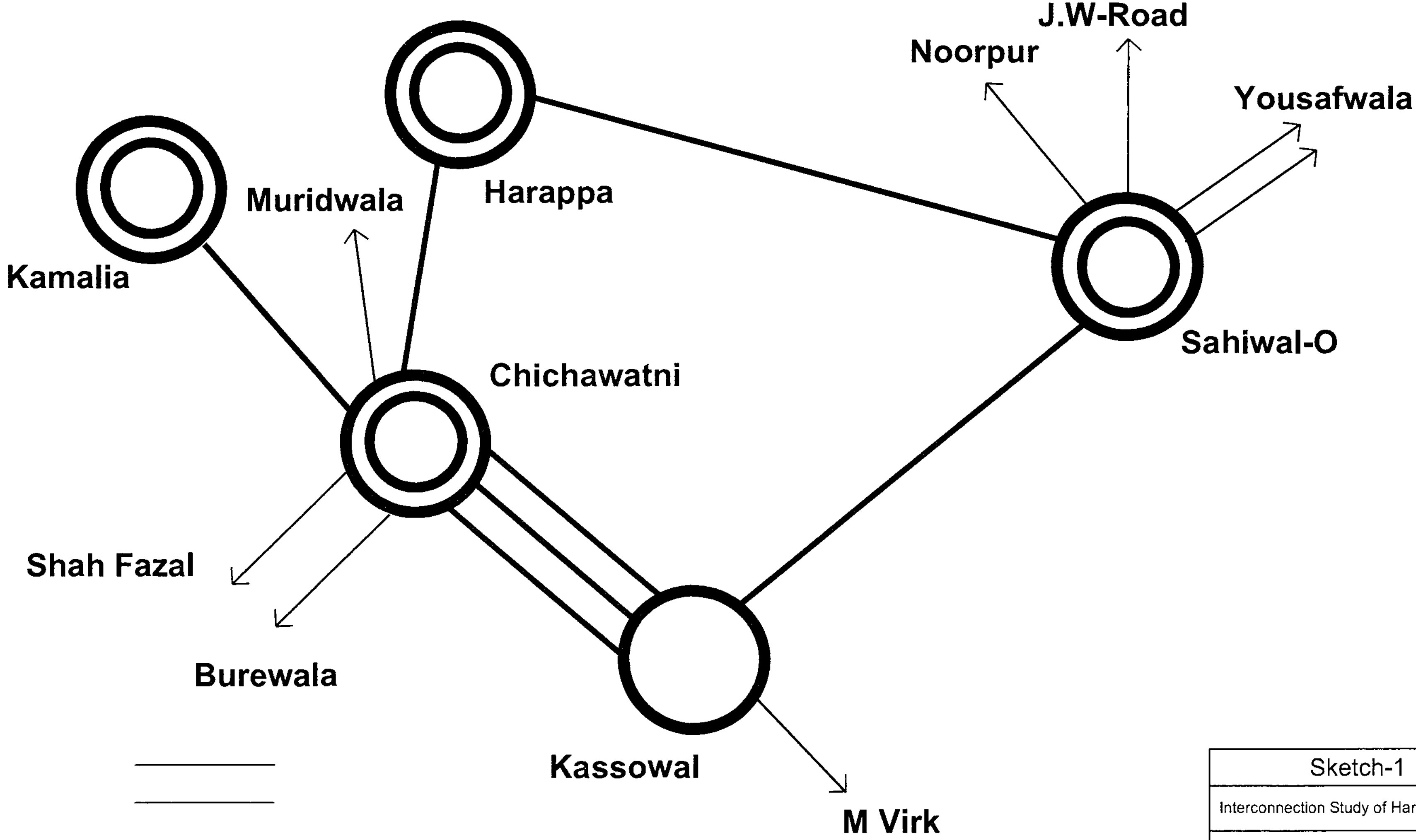
- The study objective, approach and methodology have been described and the plant's data received from the client Harappa Solar (Private) Ltd. is validated.
- The expected COD of the project is April 2016. Therefore the month of June 2016 has been selected to carry out the study as it will allow the maximum impact of the project to be judged.
- The MEPCO system data as available with PPI for other studies have been used.
- The nearest substation of MEPCO is Harappa 132/11 kV. The following scheme of interconnection of Solar Power Plant by Harappa-PP to evacuate its maximum AC power of 15.2 MW is envisaged and studied in detail:
  - A direct 11 kV triple circuit of 2.5 km length using Osprey conductor to be laid from 11 kV Bus Bar of Harappa Solar-PP till Harappa 132/11 kV substation. Two circuit to be connected to Harappa 132/11 kV T-1 and one to be connected to Harappa 132/11 kV T-2
  - In this context two 11 kV breaker/line bays need to be added in the 11 kV switchgear hall of Harappa 132/11 kV Substation
- Detailed load flow studies have been carried out for the peak load conditions of June 2016 for the proposed scheme under normal and N-1 contingency conditions to meet the reliability criteria.
- Steady state analysis by load flow reveals that proposed scheme is adequate to evacuate the maximum power of 15.2 MW of the plant under normal and contingency conditions.
- The short circuit analysis has been carried out to calculate maximum fault levels at the Harappa Solar Power Plant at 11 kV, and the substations of 132/11kV in its vicinity. We find that the fault currents for the proposed scheme are much less than the rated short circuit capacities of switchgear installed at these substations. There are no violations of exceeding the rating of the equipment due to contribution of fault current from the Harappa Solar Power Plant.

  The maximum short circuit level of 11 kV bus bar of Harappa Solar Power Plant 11 kV is 12.72 kA and 12.29 kA for 3-phase and 1-phase faults respectively. Therefore industry standard switchgear of the short circuit rating of 25 kA is considered adequate with enough margin for future increase in fault levels due to future reinforcements in this area.

- The dynamic stability analysis of proposed scheme of interconnection has been carried out. The stability check for the worst case of three phase fault right on the 11 kV bus bar of the Harappa solar power plant substation followed by the final trip of 11 kV circuits emanating from this substation, has been performed for fault clearing of 10 cycles (200 ms) as understood to be the maximum fault clearing time of 11 kV protection system. The system is found strong enough to stay stable and recovered with fast damping. The stability of system for far end faults of 3-phase occurring at Harappa 132 kV bus bar has also been checked. The proposed scheme successfully passed the dynamic stability checks for near and far faults.
- The issues of power quality like flicker and voltage unbalance 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
- The proposed scheme of interconnection has no technical constraints or problems, it fulfills all the criteria of reliability and stability under steady state load flow, contingency load flows, short circuit currents and dynamic/transient conditions; and is therefore recommended to be adopted.

Appendices

132 kV Network Near Harappa
Without Harappa Solar Power Plant, June 2016



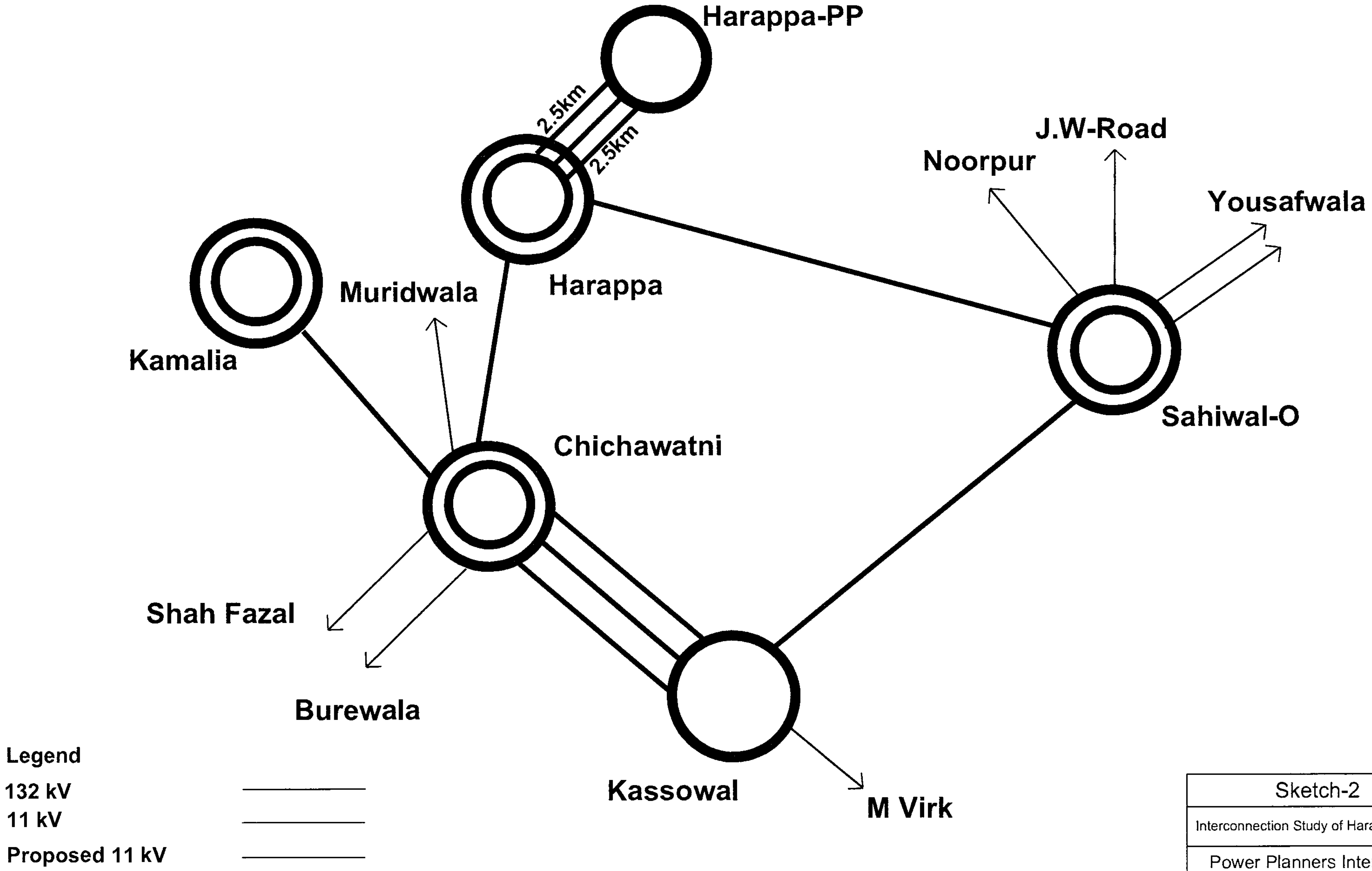
Legend

132 kV

11 kV

Sketch-1	
Interconnection Study of Harappa Solar PP	
Power Planners International	
DATE 2015	SHEET 1
DWG NO. Harappa Sketch-1.DWG	REV

132 kV Network Near Harappa
With Harappa Solar Power Plant, June 2016



Sketch-2			
Interconnection Study of Harappa Solar PP			
Power Planners International			
DATE 2015	SHEET 1	DWG NO. Harappa Sketch-2.DWG	REV