

DETAILED PROJECT REPORT

5 MW_p SOLAR PHOTOVOLTAIC POWER PLANT



PLANT LOCATION: KOMBUKARANATHAM VILLAGE,
SEKKARAKUDI PO, DISTT: TUTICORIN, TAMIL NADU

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Grid-Connected 5 MWp Solar Photovoltaic Power Generation Project

Detailed Project Report

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Abstract

The aim of this document is securing various government approvals and clearances and providing complete technical & financial information for supply and execution of 5MWp Crystalline Silicon Grid Connected solar photovoltaic systems proposed for Consolidated Construction Consortium Ltd/CCCL Infrastructure Ltd. at KOMBUKARANATHAM VILLAGE, SEKKARAKUDI PO, DISTT: TUTICORIN, TAMILNADU

Reviewer list

Name	Function	Name	Function
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1 ABOUT THIS DOCUMENT

1.1 Change control

1.1.1 Current status and anticipated changes

This is a final draft of the document and will undergo any further changes in consent with M/S CONSOLIDATED CONSTRUCTION CONSORTIUM LTD/CCCL INFRASTRUCTURE LTD.

1.1.2 Change history

The change history for this document is managed by History.Doc.

1.2 Terms and abbreviations

This document uses the following terms and abbreviations.

AC	Alternate current
BOS	Balance of the System
CERC	Central Electricity Regulatory Commission
CO ₂	Carbon Dioxide
CT	Current Transformer
CUF	Capacity Utilization Factor
DAS	Data Acquisition System
DC	Direct Current
DPR	Detailed Project Report
EPC	Engineering Procurement & Construction
IGBT	Insulated-gate bipolar transistor
IREDA	Indian Renewable Energy Development Authority
MNRE	Ministry of New and Renewable Energy
kWh	Kilo Watt Hour
NO ₂	Nitrous Oxide
MCB	Main Control Box
MPPT	Maximum power point tracker
MOSFET	metal–oxide–semiconductor field-effect transistor

MWp	Mega Watt Peak
NEDCAP	Non-conventional Energy Development Corporation of Andhra Pradesh Limited
NVVN	NTPC Vidyut Vyapar Nigam Ltd
NTPC	National Thermal Power Corporation
APEB	AP Electricity Board
PLF	Plant load factor
PFC	Power Finance Corporation
PPA	Power Project Agreement
PV	Photo Voltaic
PT	Power Transformer
SEB	State Electricity Board
SO ₂	Sulphur Dioxide
SPG	Solar Power Generation

1.3 Definitions

Direct solar radiation	It is the solar radiation propagating along the line joining the receiving surface and the sun. It is also referred as beam radiation. It is measured through pyrehiliometer.
Diffuse solar radiation	It is the solar radiation scattered by aerosols, dust and molecules. It does not have a unique direction and also does not follows the fundamental principles of optics. It is measured by shading pyrenometer.
Global solar radiation	The global solar radiation is the sum of the direct and diffuse solar radiation and is sometimes referred to as the global radiation. The most common measurements of solar radiation are total radiation on a horizontal surface often referred to as 'global radiation' on the surface. It is measured by pyrenometer.
Irradiance	Irradiance is the rate at which radiant energy is incident on a surface, per unit area of surface.
Direct Normal Insolation (DNI)	It is the direct component of the solar radiation incident on normal to the collector; means the angle of incidence of incident solar radiation with the normal of the collector is zero throughout the day.

2 EXECUTIVE SUMMARY

2.1 Project Overview

Project Promoter	Consolidated Construction Consortium Ltd/CCCL Infrastructure Ltd.
Project Scope	To arrange, construct and bring to full operation a 5 MWp PV Solar power Generation plant in Tamil Nadu, India.
Project Category	Renewable Energy Sector
Brief Project Summary	The project envisages development of a Solar Power Generation Unit of 5 MWp in Tamilnadu under various policy initiatives of state & Central Govt which makes installation and operation of Solar power generation economically and technically feasible.
Project Size / Scale	Output: - 5 MWp; Total Investment – Rs 844.99 Million

2.2 Location

State/District	Sekkarakudi PO, Distt: Tuticorin, Tamilnadu
Co-ordinates	8°46'38" N 77°56'56"E

2.3 Design & Technology

Description of the project design	The Solar Power Generation plant will produce 5 MWp of electricity using Solar Photo Voltaic technology. The design and installation is to be done on a turnkey basis.
Technical details of the project design	The technical design and the preliminary outline diagrams are included in the DPR.
Operational lifetime	25 years
Project Size / Scale	Total Investment – Rs 844.99 million

2.4 Implementation Schedule

Project start date	April 2010		
Project finish date	August 2011		
Tentative schedule	<p>Phase 1 (2MWs) to be completed by May 2011.</p> <p>Phase 2 (3MWs) to be completed progressively @ 1MW per month till August 2011.</p>		
Milestone activity	Start	Finish	Status
a) Project concept and design	April 2010	July 2010	In Process
b) Clearances and approvals (Government and local authorities)	August 2010	October 2010	
c) Financial Closure	January 2011		
d) Implementation and construction	February 2011	<p>Ph 1: May 2011</p> <p>Ph 2: August 2011</p>	
e) Project commissioning	Ph I: May 2011	Ph II: August 2011	

2.5 Financial Data

i) Costs	Rupees (millions)	USD (millions)	%
a) Preliminary and Land	12.92	0.258	1.5%
b) All others to Completion	832.075	16.64	98.5%
c) Total Costs	844.99	16.899	100.0
ii) Annual operating costs	4.5	0.09	
iii) Financing Structure			
a) Equity	253.49	5.069	30%
b) Loan	591.5	11.82	70%
iv) Performance Indicators	Impact of GHG or CDM taken into consideration		
b) Pre Tax Equity IRR	11%		

2 – PROJECT OVERVIEW (continued)

2.6 Key Assumptions

Following are the key assumptions while preparing financial indicators:

Means of Finance (Share Capital, Term Loan)	Debt: Rs 591.5 million at interest rate of 14.29% Equity: Rs 253.49 million
Electricity Tariff	Rs. 17.90/Unit
Sunshine Hours	2000 hours/annum
Plant Load Factor	14.6%
Interest on Term Loans	14.29%
Cost of Equipment/Installation	Rs 166.4 million per MW
Wheeling Charge	Nil.
Inflation Factor on Operation Costs	5.72% per annum
Inflation Factor on Revenues	Nil.
Depreciation Rate	Depreciation Rate for First 10 Years- 7% Depreciation Rate from 11 th year onwards- 1.33%
Plant Life	25 years
Invertors Life	10 years
SPG Build Time	10-12 months
Loan Period	10 years
Moratorium	Nil
Tax Holiday	MAT for the first 10 years @ 16.995%
Income Tax Rate	33.99% (from 11th year)
Exchange Rate	Rs 50 to \$1

2.7 Basic Project Requirement

Based on a nominal 5 MWp Solar PV plant development, an area of 25 Acres would be required.

Required physical characteristics for a location include:

- cleared land with no significant shading from vegetation, structures or hills;
- level land with only a gentle gradient, preferably north-facing;
- land suitable for access roads to all parts of the plant to allow regular vehicular access to solar PV array
- located as near as practical to a connection point to Utility's Distribution high voltage transmission network;
- access to a water supply and waste water disposal;
- appropriate separation from domestic residences, noise and visual impact-sensitive areas;
- located such that the site is not overlooked by significant population centers;
- located away from major plumes or sources of dust which could obscure sunlight and coat module surfaces with a film that would reduce plant efficiency; and appropriate zoning and environmental considerations.



3 COMPANY PROFILE



Consolidated Construction Consortium Ltd/CCCL Infrastructure Ltd. is an ISO-certified company with a turnover of around Rs. 18.41 billion. It has a significant presence in India, with offices in Chennai, Bangalore, Hyderabad, Delhi, Kolkata, Pune and Trivandrum. An office recently opened in Middle East marks the beginning of its international visibility.



Infosys office erected by CCCL at Bangalore

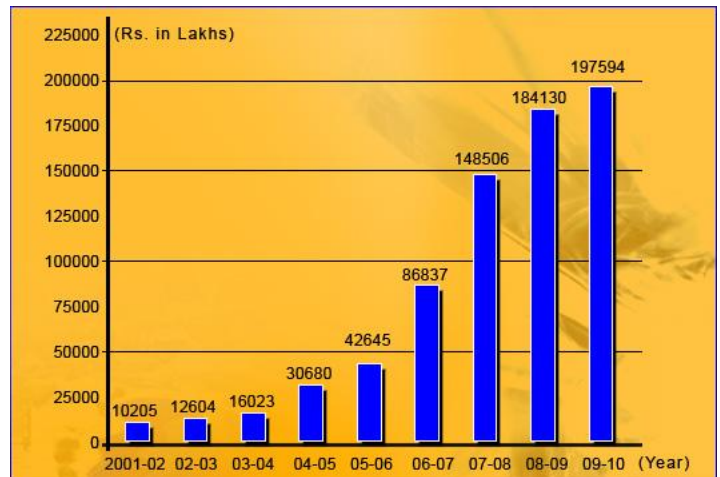


Fig above shows the annual turnover of CCCL

CCCL offers a broad array of services specializing in the following fields:

- Construction
- Engineering & Specialization
- Mechanical & Electrical Division
- RMC & Building products Division
- Design and Build Sector
- Interior Division
- Glazing Division
- Design & CAD BPO Division
- IT Division

- Skill development center
- CCCL Infrastructure Limited (SEZ, BOT projects)

CCCL has successfully commissioned numerous power plants across the country and therefore has contributed to the cause of emission footprint reduction efficiently. A few power plant projects in the pipeline are,

- 16.8 MW Captive Power Plant at Pothavaram, Rajamundry for Jeypore Sugars Pvt. Ltd, Andhra Pradesh
- 43 MW Power Plant at Chhattisgarh, Chhattisgarh State for Arasmata Captive Power Company Pvt. Ltd.
- 80 MW Power Plant at Tamilnadu for OPG Power Generation (P) Ltd.
- Pile foundations for 600 MW plant in Chennai for BHEL

PROMOTERS:

Mr. R.Sarabeswar is its *Promoter, Chairman and Chief Executive Officer*.

Graduated with a bachelor's degree in civil engineering from the Regional Engineering College, Trichy and a Management Degree in strategy from London University. Mr. Sarabeswar has over 30 years of experience in the construction sector and has previously worked for Larsen and Toubro Limited.



Mr. S.Sivaramakrishnan is its *Promoter and Managing Director*. He has bachelor's degree in civil engineering from Coimbatore Institute of Technology and a Masters Degree in Business Administration from the University of Madras. He has over 30 years of experience in the construction sector and has served as Engineer with the ECC division of Larsen and Toubro.



Mr. V.G.Janarthanam is its *Promoter and Director (Operations)*. He holds a degree in civil engineering from University of Madras. He has served as manager with Larsen and Toubro Limited and has over 15 years of experience in the construction sector with special emphasis on tendering and contract management.



4 SOLAR IN INDIA: AN INTRODUCTION

Non-conventional energy has a dominant role to play in the contribution to the Energy Pool. The alarming depletion of fossil fuel levels boosts the need to further work sincerely to develop efficient devices to convert naturally available resources into useful power generators.

The most viable forms of these natural or renewable resources are Hydro, Solar and Wind Energy. R & D is being made all over the world to develop the other forms like Tidal, Geothermal, biomass etc and very encouraging results are emerging from the tireless efforts.

In 2007 a total of 1740 megawatts (MW) of solar energy generating capacity was added to the grid worldwide, bringing total solar power capacity in the world to 2287 MW. Solar power grew at an average 35% annually over the past five years with increase by 49% in 2007, establishing solar as the world's fastest-growing energy source.

With the ever increasing threat of global warming, developing countries, countries in transition and the developed countries have addressed the issue of Climate Change. We must accord greater reorganization to environmentally friendly technologies especially those like Solar Power which are already mature. They are established globally and have an excellent performance track record of more than two decades.

It is expected that 10 per cent of the proposed capacity addition in India of 100,000 MW in the next 10 years i.e. 10,000 MW would come from the Renewable Energy Sector. From zero to 1,500 MW has taken us about 20 years in India but from 1,500 MW to 10,000 MW shall take us ten years. Solar Power has come of age and the next 20 years will see greater and enhanced deployment of Solar Farms as a clean and green source of Power Generation both onshore and offshore

Solar energy has vast potential and the industry stands every chance of being able to realize it. This event will discuss issues of importance in wind markets around the world, including the expansion of the industry into emerging and developing country markets and the issue of EU enlargement. It will look in depth at the drivers for this expansion such as the need to combat climate change and to guarantee a secure energy supply.

4.1 Benefits of Grid Connect Solar Energy:

- a) Power from the sun is clean, silent, limitless and free.
- b) Photovoltaic process releases no CO₂, SO₂, or NO₂ gases which are normally associated with burning finite fossil fuel reserves and don't contribute to global warming.
- c) Photovoltaic are now a proven technology which is inherently safe as opposed to other fossil fuel based electricity generating technologies.
- d) Reduces or avoids the necessity to build new transmission/distribution lines or upgrade existing ones.
- e) Solar power shall augment the needs of peak power needs.
- f) Increases the grid reliability i.e., voltage and frequency.
- g) Reduces the transmission line losses.
- h) Solar Powered Grid Connect Plants can act as tail end energizers, which in turn reduces the transmission and distribution losses.
- i) provides a potential revenue source in a diverse energy portfolio
- j) Assists in meeting renewable portfolio standards goals.

4.2 Socio Economic Benefits of Grid Connect Solar Power Plants:

- a) Nuclear energy is costly to install, full of risks for operation and maintenance, and too costly to de-commission.
- b) Solar energy is inexhaustible and readily available almost all over the country all round the year.
- c) According to a recent report of the United Nations, solar energy falling over an area of 800 km x 800 km harvested with the currently available technology is enough to meet the energy needs of the whole world.
- d) The solar energy radiation falling over India is estimated to be about 5,000 trillion kWh a year.
- e) In India, assuming a population of 1.5 billion in 2025, if even 1 per cent of this can be harvested, it will provide about 90 kWh a day per capita, which is more than ample.
- f) Has no moving parts and involves negligible running costs.
- g) It is amenable to decentralized generation at the points of consumption, not only eliminating transmission losses, but offering many socio-economic benefits by empowering families and communities to be self-reliant for their energy needs.

As a futuristic prophecy our then President Dr. A.P.J. Abdul Kalam said that with carbon-nano technology it is possible to develop solar cells with a conversion efficiency of 50 per cent.

4.3 Solar Energy Potential in Tamil Nadu

Being the closest to the Equator on the Indian mainland, Tamil Nadu receives very high amount of solar radiation per unit area (solar insolation). With an high average annual solar radiation , solar energy resources are among the highest in the country.

The State is making all efforts to increase the renewable energy share. The future is with solar power and the state has been making remarkable strides recording the highest share of 32 per cent in renewable energy. Tamil Nadu is blessed with conducive natural meteorological and topographical setting. Except for some of the experimental units, no major attempt has been made in the state for solar power generation. Based on MNRE's guidelines, Teda has initiated efforts for the establishment of grid-interactive solar photovoltaic power plants of 1-10 MW capacity in Tamil Nadu under build-own-operate basis.

For Tamil Nadu, which is reeling under severe power shortfall, any capacity addition will help the state to a great extent to tide over the shortages. The average power availability during the year 2009-10 (up to December 2009) was around 8,400 mw. The expected peak demand will be around 10,500 mw, leaving a deficit of around 2,100 mw.

After making rapid strides in wind power, Tamil Nadu is now betting big on the solar power sector. Tamil Nadu Electricity Regulatory Commission (TNERC) has come out with a consultative document for determination of tariff for solar photovoltaic and solar thermal plants with capacity up to 3 MW. The consultative paper has proposed a tariff of Rs 17.10 per unit for photovoltaic generation and Rs 14.38 per unit for solar thermal generation.

Tamil Nadu Electricity Board (TNEB) would execute a power purchase agreement with the promoters to purchase solar power at the tariff to be determined by TNERC. The state electricity board will be eligible to draw generation-based incentive from IREDA for the power purchased from these solar power projects that would be in the range of Rs 12 per unit (for solar PV).

Southern districts have many of the sites identified as suitable for solar power generation in Tamil Nadu. Ramanathapuram, Sivaganga, Kanyakumari, Tirunelveli and Tuticorin have immense potential.

4.4 Jawaharlal Nehru National Solar Mission

The National Solar Mission, also known as Jawaharlal Nehru National Solar Mission, is a major initiative of the Government of India and State Governments to promote ecologically sustainable growth while addressing India's energy security challenge. It will also constitute a major contribution by India to the global effort to meet the challenges of climate change. This is one of the several initiatives that are part of National Action Plan on Climate Change. The program was officially inaugurated by Prime Minister of India, Manmohan Singh.

Goals

The objective of the National Solar Mission is to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible. The immediate aim of the Mission is to focus on setting up an enabling environment for solar technology penetration in the country both at a centralized and decentralized level. The first phase (up to 2013) will focus on capturing of the low hanging options in solar thermal; on promoting off-grid systems to serve populations without access to commercial energy and modest capacity addition in grid-based systems. In the second phase, after taking into account the experience of the initial years, capacity will be aggressively ramped up to create conditions for up scaled and competitive solar energy penetration in the country.

Timeline

The Mission will adopt a 3-phase approach, spanning the remaining period of the 11th Plan and first year of the 12th Plan (up to 2012-13) as Phase 1, the remaining 4 years of the 12th Plan (2013-17) as Phase 2 and the 13th Plan (2017-22) as Phase 3. At the end of each plan, and mid-term during the 12th and 13th Plans, there will be an evaluation of progress, review of capacity and targets for subsequent phases, based on emerging cost and technology trends, both domestic and global. The aim would be to protect Government from subsidy exposure in case expected cost reduction does not materialize or is more rapid than expected.

Technologies

For Phase 1 projects, MNRE proposed for 50:50 allocations towards Solar PV and Solar thermal. The latter is quite ambitious given India has no operational Solar Thermal projects and less than 10MW of Solar PV projects. While growing at a rapid pace lately, solar thermal technologies are still evolving globally.

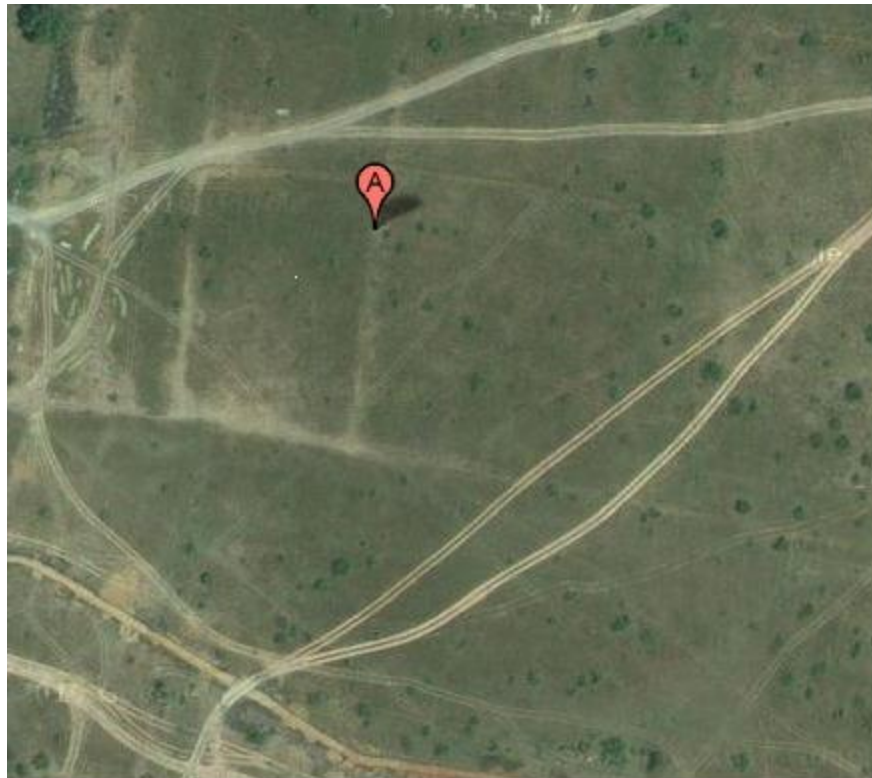
5 PROPOSED PROJECT

5.1 Location of Proposed Project Site: : Kombukaranatham(V), Sekkarakudi PO, Distt: Tuticorin

The site for the solar power project has excellent connectivity with all the major cities and districts bounding it. Following is the distance chart of the site from major cities and ports,

Tuticorin Town	23 KM
Tirunelveli Town	27 KM
Tuticorin Airport	15 KM
Railhead at Tuticorin	30 KM
Railhead at Tirunelveli (Major junction)	35 KM
Trivandrum Airport	150 KM
Madurai International Airport	150 KM

Tuticorin is a main Port city of India. The major harbor of Tuticorin is well known as pearl diving, fishing centre and shipbuilding. The city is also known as "Pearl City". Tuticorin is famous for pearl fishing, production of salt, fishing and other related business. Totally 70% salt is manufactured in Tuticorin. Tuticorin is having an All India Radio Station and a Doordharshan Relay Station.



Proposed 5 MWp Solar Power Generation Project Site

The proposed location of the solar power plant based on Solar PV technology, is near Sayarpuram in (latitude 8°46'38" N and 77°56'56"E) of Tuticorin district of Tamil Nadu state. The location is well connected with the National Highway NH 7A. The proposed location has shadow free area (almost flat terrain) and located at very close to a 110/33/22 kV substation from where the power generated through the solar power plant can be feed to the grid. The distance of 110/33/22 kV substation from the proposed site is around 4 km. Figure below represents the road and rail connectivity of the proposed project location; where the important locations are marked.

5.2 Weather Data (METEONORM)

Name of site = Sayarpuram, Tuticorin

Latitude [°] = 8.777, Longitude [°] = 77.949, Altitude [m] = 15, Climatic zone = V, 2

Radiation model = Default (hour); Temperature model = Default (hour)

Tilt radiation model = Perez

Temperature: Old period = 1961-1990

Radiation: New period = 1981-2000

Month	H_Gh	H_Dh	H_Bn	Ta
	[kWh/m ²]	[kWh/m ²]	[kWh/m ²]	[C]
Jan	173	59	182	25.8
Feb	171	65	157	26.9
Mar	202	73	177	28.2
Apr	183	86	131	28.8
May	173	87	115	28.7
Jun	144	84	81	27.3
Jul	161	83	108	26.7
Aug	171	93	104	26.9
Sep	173	77	133	26.8
Oct	165	80	119	26.7
Nov	142	71	104	26.2
Dec	156	65	141	25.8
Year	2015	922	1553	27.1

Legend:

H_Gh: Irradiation of global radiation horizontal

H_Dh: Irradiation of diffuse radiation horizontal

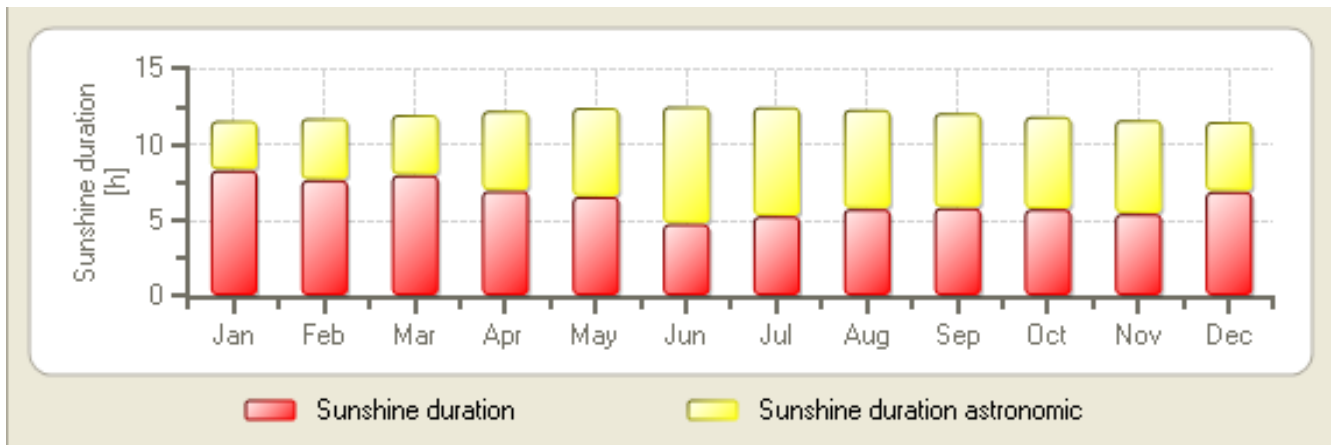
H_Bn: Irradiation of beam

Ta: Air temperature

5 MWp Solar PV Power Generation – Detailed Project Report



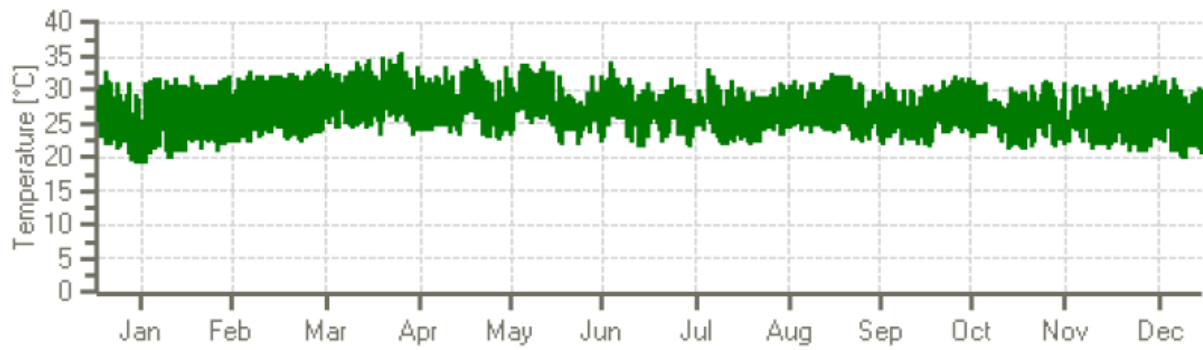
Graph 1: Monthly irradiation Graph for proposed site



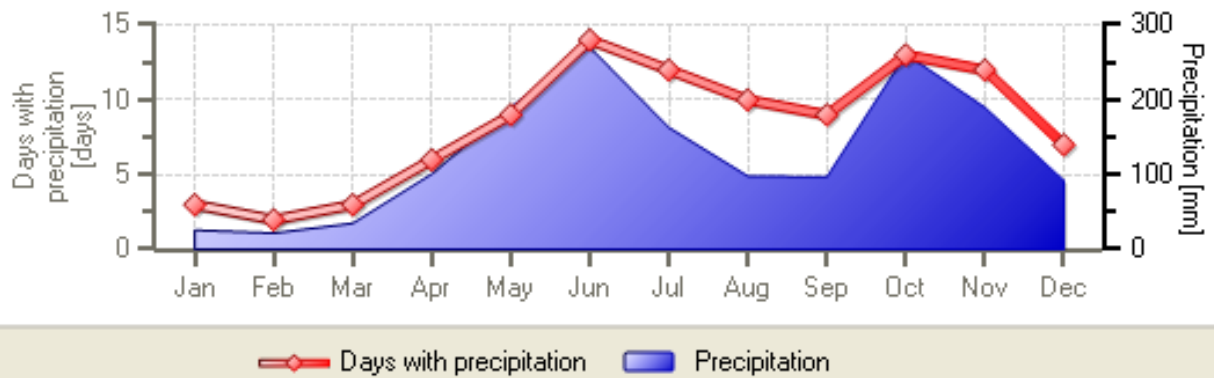
Graph 2: Monthly Duration of sunshine for proposed site



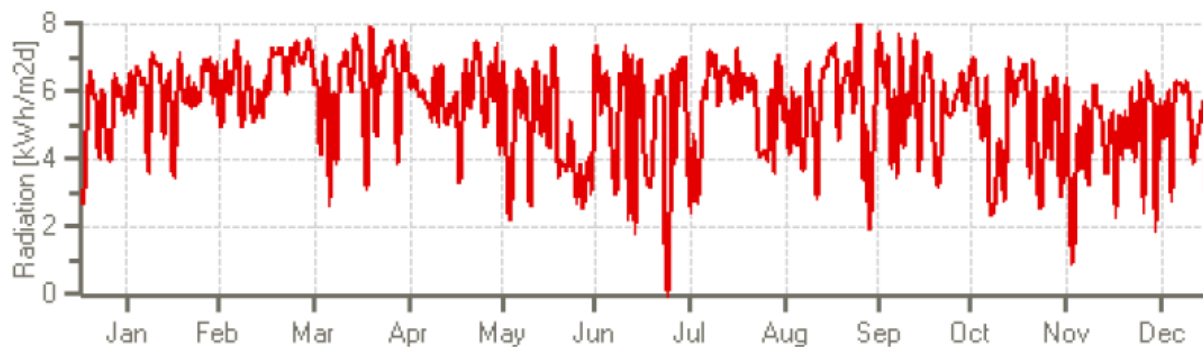
Graph 3: Monthly Temperature Range Graph for site



Graph 4: Daily Temperature graph for site



Graph 5: Precipitation Graph



Graph 6: Daily irradiation graph for site

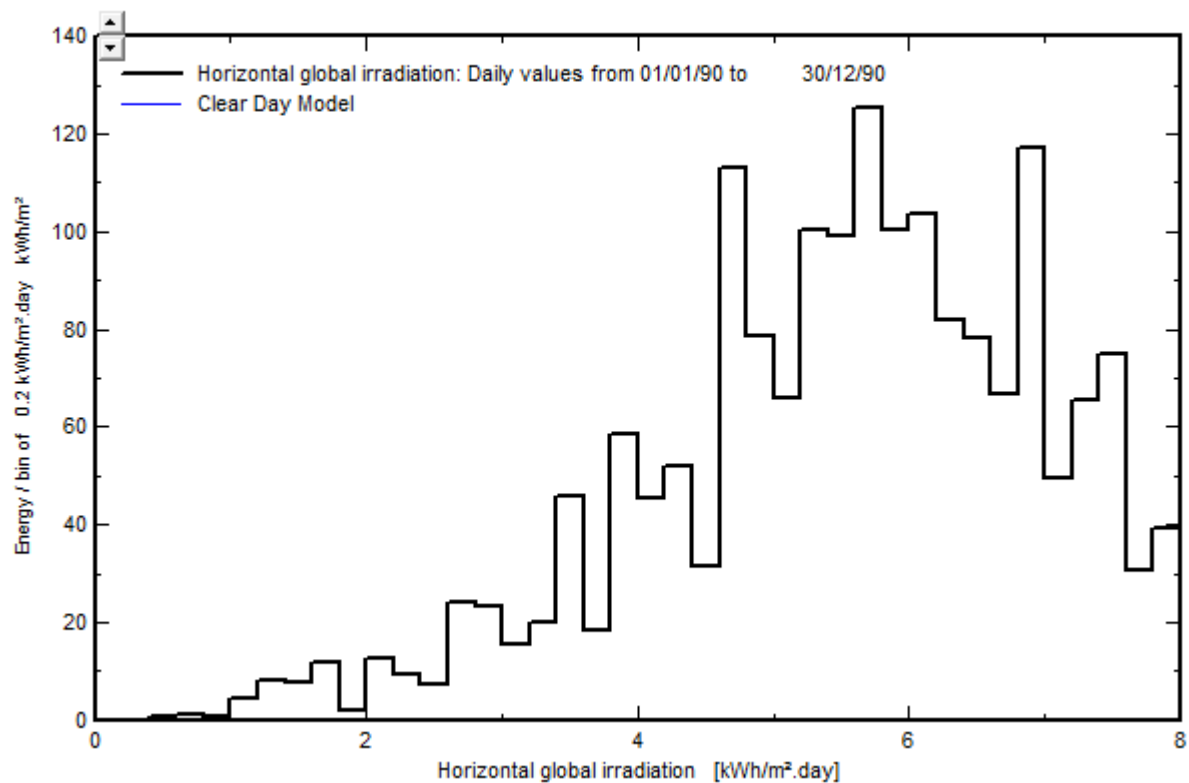
5.2.1 Weather Data (PVSYST)

Meteo for kombu, Synthetic data

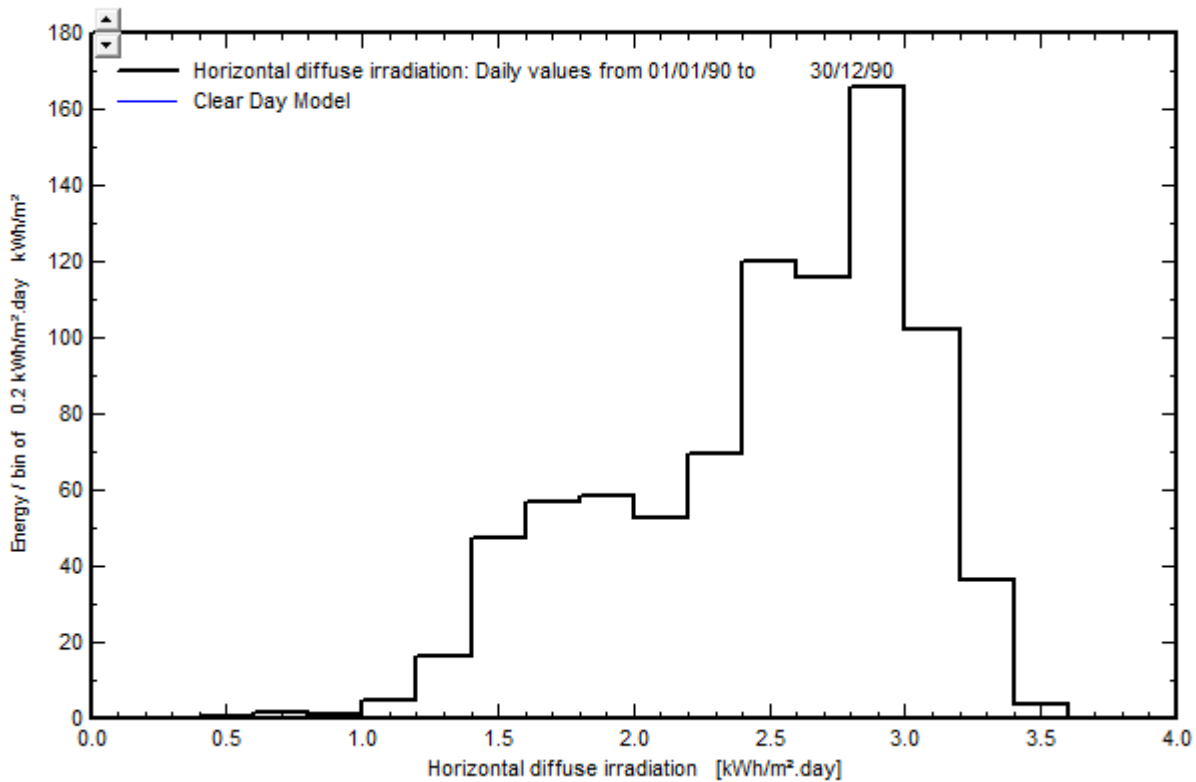
Plane: tilt 30°, azimuth 0°, Albedo 0.20

Interval beginning	GlobHor kWh/m ² .mth	DiffHor kWh/m ² .mth	BeamHor kWh/m ² .mth	GlobInc kWh/m ² .mth
January	150.0	65.02	85.0	171.6
February	156.2	65.31	90.9	166.8
March	190.3	66.47	123.8	185.1
April	165.6	75.23	90.4	145.1
May	164.6	79.04	85.5	133.4
June	133.8	69.06	64.7	105.8
July	140.4	81.84	58.6	115.3
August	151.0	74.11	76.9	129.1
September	153.9	76.53	77.4	142.6
October	137.0	66.06	70.9	140.0
November	119.1	68.45	50.6	128.5
December	131.1	66.76	64.3	149.4
Year	1793.0	853.89	939.1	1712.7

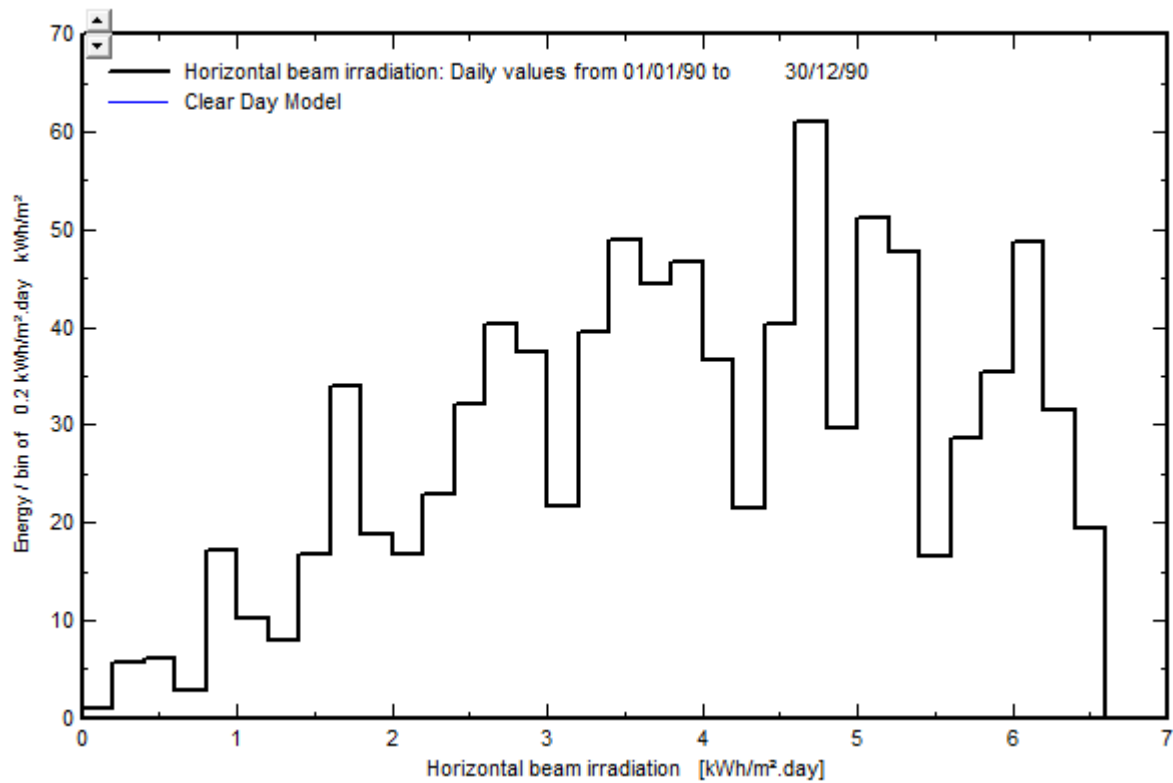
Meteo for kombu, Synthetic data



Meteo for kombu, Synthetic data



Meteo for kombu, Synthetic data



Source: Graphs produced from PVSYST 5.12 (which uses authentic data from WMO). We shall be using this data for energy yield calculations

6 TECHNOLOGY SELECTION & SYSTEM DESCRIPTION

6.1 Technology Selection

Photovoltaic cells are manufactured from various materials of mono crystalline, polycrystalline or amorphous structure. Generally, it can be stated that the greater the energy efficiency of cell is, the higher will be production cost. To decrease production costs and improve efficiency of solar cells new semi conductive materials are chosen.

The main factors determining the conversion efficiency are the following:

- the kind of semi conductive material (the width of band gap E_g),
- the incompatibility of solar radiation with the cell absorption,
- spectrum sensitivity of photo element and the construction of a cell

Efficiency improvement is possible mainly by means of the

- increase of fill factor coefficient FF of photo element by more advanced technology,
- a decrease of reflection by the application of antireflection layers,
- choice of more suitable semiconductor,
- decrease in temperature of absorbing surface, &
- the use of concentrated solar radiation

The aim of this work is the comparison of operating characteristics of mono crystalline, polycrystalline and amorphous silicon solar cells.

Methodology

Three kinds of photovoltaic cells (mono crystalline, polycrystalline, amorphous) are being compared.

Type of Cell	Anti-reflection layer	Total area of the cell, cm ²
Mono Crystalline	Transparent	65
Mono Crystalline	Mirror	52
Poly Crystalline	Transparent	156
Amorphous	Transparent	146

For the mono crystalline cell with transparent layer the increase of radiation intensity causes the increase of voltage.

For the mono crystalline cell with antireflective mirror layer the highest voltage $U = 0.53$ V for $I = 0.09$ A/m² is obtained for the radiation intensity $E = 130000$ lx. However if the cell is illuminated by the halogen lamp of 500 W power and the radiation intensity $E = 50000$ lx then the voltage of the cell

decreases to $U = 0.5 \text{ V}$ for $I = 0.09 \text{ A/m}^2$.

For the polycrystalline cell the highest voltage $U = 0.541 \text{ V}$ for $I = 0.032 \text{ A/m}^2$ is obtained for the radiation intensity $E = 130000 \text{ lx}$. However if the cell is illuminated by the halogen lamp of 500 W power and the radiation intensity $E = 50000 \text{ lx}$ then the voltage of the cell decreases to $U = 0.497 \text{ V}$ for $I = 0.03 \text{ A/m}^2$.

The comparison of $I (U)$ characteristics, $P (U)$ characteristics and delimitation the points of the maximum power of studied photovoltaic cells:

- Mono crystalline silicon solar cell with transparent layer
- Mono crystalline silicon solar cell with mirror layer
- Polycrystalline
- Amorphous

The obtained current – voltage characteristics and the point of maximum power allowed calculating the efficiency and filling factor FF of the investigated cells (Table below). On this basis it can be stated that the decrease of illumination causes the increase of the efficiency (for mono crystalline and polycrystalline cells). For the amorphous cell the decrease of illumination causes the decrease of the efficiency.

Solar Cell	Intensity of Radiation [lx]	Efficiency [%]	Maximum Power [w/m^2]	Fill Factor [FF]
Mono Crystalline Silicon Solar Cell with transparent layer	130000	8	15.32	0.86
	50000	18	13.57	0.80
Mono Crystalline Silicon Solar Cell with mirror layer	130000	9	17.90	0.84
	50000	22	16.74	0.83
Poly Crystalline Silicon Solar Cell	130000	7	8.29	0.89
	50000	12.5	7.84	0.87
Amorphous Silicon Solar Cell	130000	14.5	14.12	0.66
	50000	8	10.68	0.63

The account of calculations: efficiency, fill factor, power maximum of photovoltaic cells

Summary

On the basis of the above analysis it can be stated that the photovoltaic cells allow converting light radiation into electrical energy in the efficiency range 9 - 22% according to the construction of the cell and light intensity. Increase of the radiation intensity causes the increase of the cell power from the one hand and decrease of the efficiency and change of the point of maximum power accompanied by the increase of the cell voltage and short-circuit current from the other hand.

The highest efficiency of energy conversion is observed for the mono crystalline cell with antireflection mirror layer. For this cell the maximum power was equal to 17.9 W/m² for E=130000 lx. The efficiency of the mono crystalline cell with antireflection transparent layer is equal to 18% and the maximum power is equal to 15.32 W/m² for E = 130000 lx. The polycrystalline cells have the lowest efficiency (12.5 %), the maximum voltage is equal to 0,541 V and the current is equal to 12.79 A/m² for E = 130000 lx. The efficiency of the amorphous cell is equal to 14.5 % and it increases with the increase of the radiation intensity. However the amorphous cell has the worst current – voltage characteristic because of low value of the fill factor. The fill factor of the investigated cells decreases together with the increase of the radiation intensity. For the mono crystalline and polycrystalline cells the fill factor is in the range 0.8 – 0.89. For the amorphous cell the fill factor varies from 0.63 to 0.66. Main advantages of cells produced from amorphous and polycrystalline silicon are low cost of production and lack of geometrical limitations. But unfortunately there are limitations of utility properties resulting from relations presented in the work. It is possible to improve the utility properties of amorphous cells by means of texture forming methods.

With the above comparisons and analysis it is concluded Mono Crystalline cells with or without thin film coating are equally suitable for the above site conditions. Still as the capital cost of mono crystalline is on the higher side, Poly crystalline can also be considered.

PV Versus Thermal

PV Technology is fully commercial for fixed or tracking crystalline silicon flat plate systems.

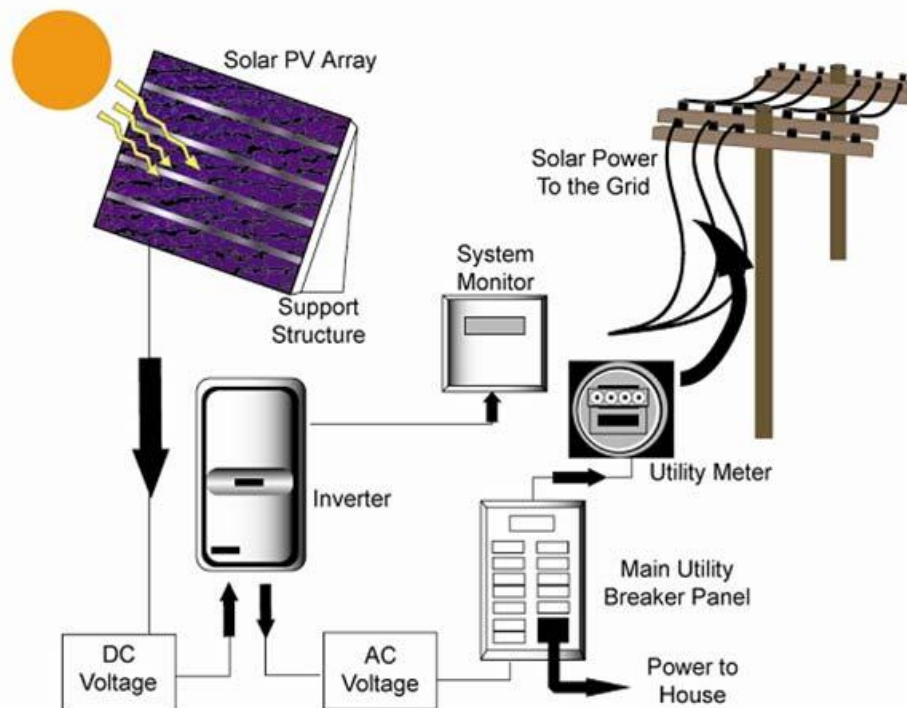
- Area/MW varies between 5 acres to 7.5 acres as per the fixed and tracking systems.
- Suppliers – Well established and number of domestic and international suppliers.
- The steam generation needs abundant water source, which the proposed location do not possess.
- The technology for CSP per say still not perfected and commercialization not in place
- Since the project is time bound as per the policy of NVVN R&D can ill afford and therefore time-tested technology of using Mono/Ploy-Silicon PV modules are chosen for the array part

6.2 Solar PV system Description

The Solar electricity is produced when the Photons from the sun rays hit the electrons in the Solar PV panels - this will generate Direct Current (DC). The DC electricity from the panels passes through DC distribution network to a grid-interactive inverter, which converts the DC electricity into 220V AC for single phase and 415V AC for 3 phase operation by using state of the art technology by MOSFET/ IGBT methodology and fed through A/C distribution system linked to the electricity supplied by the grid AC.

Grid connected solar power comprises of the main equipment and components listed below:

- (a) Solar PV Modules
- (b) Inverters (PCU)
- (c) Junction boxes
- (d) Module mounting system
- (e) Grid connection equipment
- (f) Monitoring system
- (g) Cable & connectors
- (h) Transformer
- (i) Storage hut for housing the electronics (Sub-station)



6.2.1 Brief Description

6.2.1.1 Solar Modules

A Photovoltaic module is a packaged interconnected assembly of photovoltaic cells, which converts sunlight into energy. For this project, crystalline type of solar module of 225 Wp is considered.

6.2.1.2 Inverters

The grid connected inverter range is a state of the art equipment with robust control platform, high efficiency, high availability, low maintenance features built with quality components. The Grid Connected Inverter (GCI) series comes with built in isolation transformers. The inverters (3-phase) will be designed with innovating, cutting edge technology. Optimized efficiency factor, higher availability (by proven long life components), the latest control procedure are key features.

6.2.1.3 Junction Boxes

In the junction boxes, Cable from individual module strings are bundled and safely routed to the inverter. It is a combination of an exact, well organized string monitoring system and a safety concept adapted to the PV technology. The junction boxes will have suitable cable entry points fitted with cable glands of appropriate sizes for both incoming and outgoing cables. They monitor the output of solar PV arrays. If difference between string outputs is too large, the operator is informed through monitoring system. These junction boxes are enclosed in IP 55 rated poly-carbonate housing.

6.2.1.4 Module Mounting Structure

The module mounting structure is design for holding suitable number of modules in series. There shall be specially designed 8~23 module mounting structures (Soil drill technology) to mount the solar modules on a free-field with special protection against corrosion. All nuts & bolts considered for fastening modules with this structure are of very good quality of stainless steel. The array structure is designed in such a way that it will occupy minimum space without sacrificing the output from SPV plants at the same time.

6.2.1.5 Grid Connecting Equipments

Solar module generated power in DC from which power will be inverted from DC to AC by using inverters. AC power is fed to power control centre. From PCC 3 phase 415V power will be further stepped up before feeding into the grid.

6.2.1.6 Monitoring System

The system also enables diagnostic and monitoring functions for these components.

6.2.1.7 Cable & Connectors

Cables will be extremely robust and resist high mechanical load and abrasion. High temperature resistance and excellent weatherproofing characteristics provide a long service life to the cables used. The connectors with high current capacity and easy mode of assembly are to be used for the connections of the power plant cables.

6.2.1.8 Transformers

Power Evacuation Transformer (5MVA-0.415/11KV) from ABB/equivalent High Performance and Low Loss

6.2.1.9 Building for Housing the Electronics

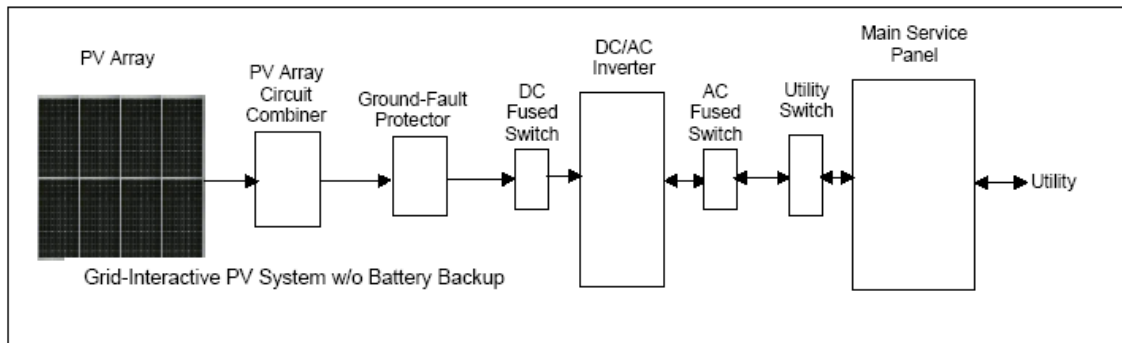
The substation building will house all the electrical and electronic equipments like Central inverters, Low Voltage Panels.

6.2.1.10 Panel Cleansing System

In Developed countries, Solar PV Module Panels Dust cleaning system is widely used in solar photovoltaic power station. Trees leaves, bird poop and airborne particles (from dirt and pollen) make solar panels dirty, dirty panels causes power loss. Dirt and debris reduce the ability of the solar array to perform at full capacity. The potential energy loss depends on the level of dust accumulated on solar panels. Energy loss could reach 25 percent of generating power. Cleaning system for solar panels will improve the photovoltaic conversion rate; keep the generation capacity steady all over the year capacity. Panels can be cleaned either manually or mechanically.

In Mechanical cleaning system mainly, water sprinkler system is used, but it needs lot of power to spray water in wide module area, Manual system need manpower for cleaning. Though mechanical Dust cleaning system are efficient than manual system. This solar PV plant manual cleaning is proposed because the plant is situated in Village area where manual labour cost is less compared to total auxiliary power cost.

6.2.2 Block Diagram of Grid Interactive PV Power Plant



Grid Connected PV System Block Layout

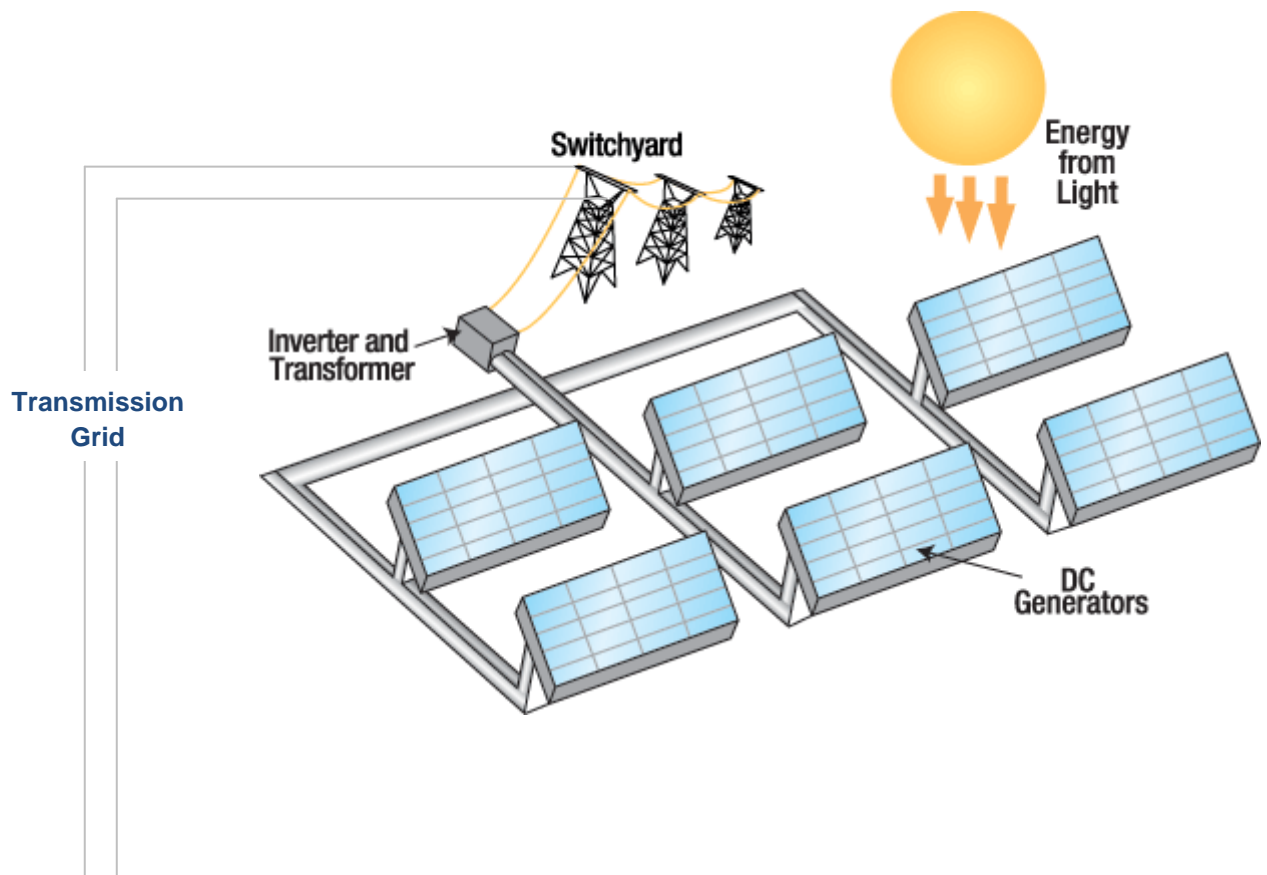
The output of the strings will be connected to Sunny Central 250HE-11 PCU. The PCU is nothing but converting the DC Power into AC power and feeding into the grid. It is design with a high efficiency >96% with IGBT technology, It is delivering the max. Power generated through solar modules in to grid due to its inbuilt feature of MPPT operations. The PCU is having internal self protection in case of any fault in the grid. Also the PCU has inbuilt contactors/breakers with fuses for self protections.

The PCU is having in-built microprocessor based controls. The Inverters is designed in such a way that it will synchronize with the utility (grid) power with respect to the Voltage and frequency of Grid and it gets corrected itself according to the grid parameters within its settable limits (please refer the PCU specs elsewhere in this report). The inverter is designed in such a way that it will sense the array power and grid power; if both are available it starts and stops automatically in the morning and evening respectively.

Each PCU is having a remote and local data monitoring system with which we can monitor all the parameters and current energy generation & past generation for the given period.

The output voltage of the inverter is connected to the LT side of the grid through step-up transformer of 0.415/11/33 KV or as per the customer requirement.

6.2.3 Typical System Diagram



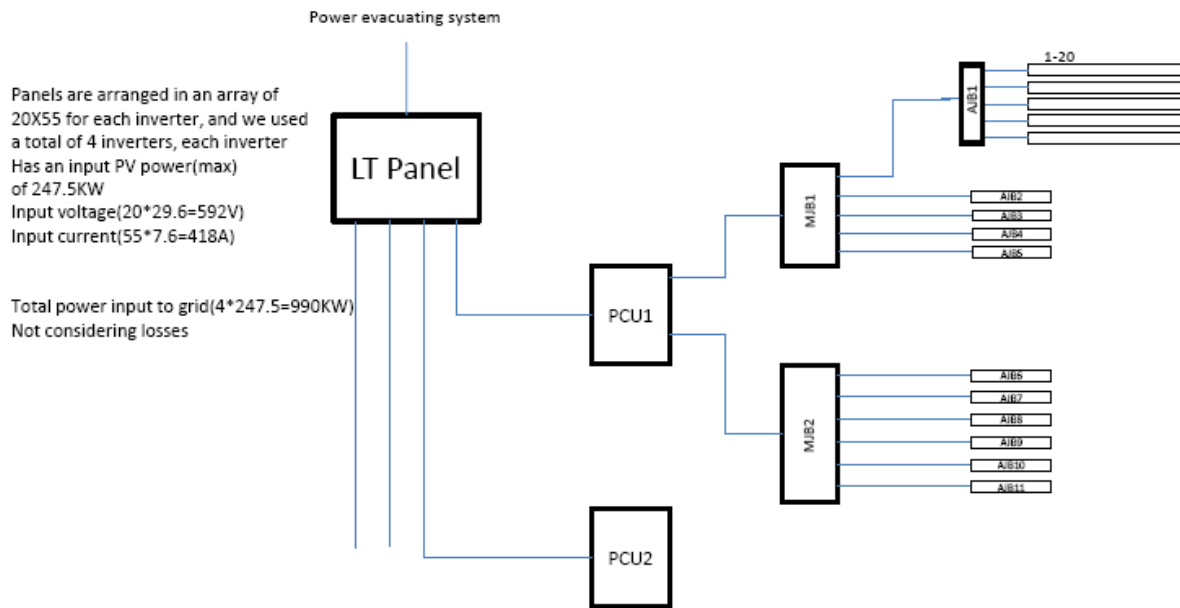
6.2.4 Technical System Details

The 5 MWp Solar photovoltaic power systems for this project comprise the following major components and services.

- 5 MWp Solar Array of the c-Si PV Modules of 225 Wp each. The Modules/Cells are internationally recognized and widely tested.
 - Specially designed 8~23 module mounting structures (Soil drill technology) to mount the solar modules on a free-field with special protection against corrosion
 - Junction boxes, mounted to the underside of the solar array structure, to parallel strings of modules so that maximum power is collected from the modules and transferred to the inverters – Hensel/ Fibox/ Equivalent.
 - 250 KV, 3 phases, 50Hz, 415V GC Central Inverters designed for maximum efficiency, reliability, and equipped with advanced monitoring, control alarms, safety features and remote monitoring display. The actual size of the individual inverter units may vary depending on the ground conditions, product availability with suppliers, etc.
 - Mounting hardware and system DC cabling – Finolex/ Asian Cables/ Equivalent
 - Project Management including, design, supply, installation, Construction and Commissioning
 - Power Evacuation Transformer (5MVA-0.415/11KV) from ABB/equivalent High Performance and Low Loss Manufacturers.
 - The Power Transmission lines have been kept out of our scope since the lumpsum cost depends on the distance between the GSS Evacuation point and the power plant.
 - Project Management Documentation, Construction, Mechanical Civil, Electrical. Drawings.
- Our emphasis on quality, throughout the organization, ensures that all components are mutually compatible and manufactured into a professionally engineered and integrated power system, thus enhancing system reliability, performance and longevity.

The emphasis on quality, throughout the organization, ensures that all components are mutually compatible and manufactured into a professionally engineered and integrated power system, thus enhancing system reliability, performance and longevity.

6.2.5 Schematic Diagram of Typical 1MWp System (Can be replicate to 5MWp)



Module specs

SSI-M6-225
SSI-3M6-225

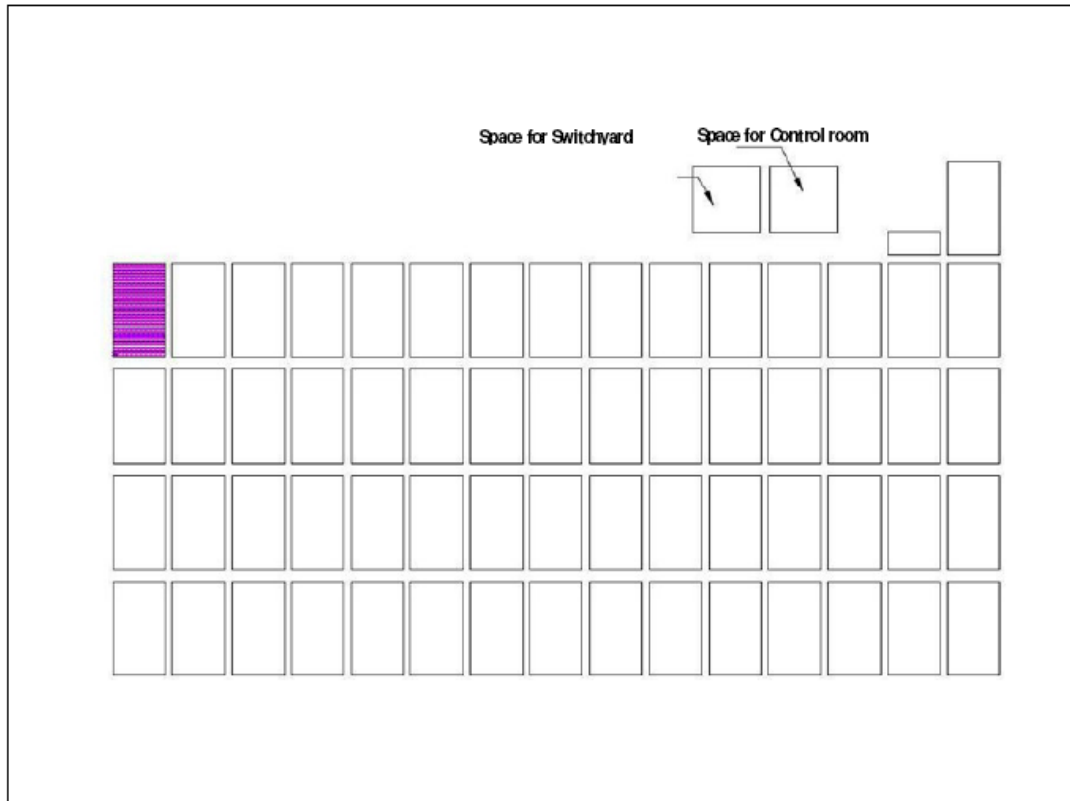
Peak Power (Pmax,W)	225
Power Tolerance (%)	± 3
Max Power Voltage (Vmp)	29.6
Max Power Current (Imp)	7.60
Open Circuit Voltage (Voc)	37.1
Short Circuit Current (Isc)	8.28

Inverter specs

Sunny Central
250

Nominal power DC	262 kW
Max. PV power (recommended), (P _{pv})	290 kWp
DC voltage range, MPPT (U _{dc})	450 V – 820 V
Max. permissible DC voltage (U _{dc,max})	880 V
Max. permissible DC voltage (U _{dc,env})	1000 V (optional)
Max. permissible DC current (I _{dc,max})	591 A
Voltage ripple, PV voltage (U _{pp})	< 3 %
Number of DC inputs / connection point	8 / DC fuse

5 MWp Solar PV Power Generation – Detailed Project Report



Site Layout Plan for the Proposed Plant (This is just indicative and can change during actual detailed engineering and commissioning of the project)

7 TECHNICAL SPECIFICATIONS

7.1 Solar Module



General Electrical Features of Crystalline silicon Solar photovoltaic modules (India Manufactured, 225MWp):-

1. Modules array consist of high efficiency Solar Modules utilizing crystalline high power silicon Solar Photovoltaic cells.
2. Solar module has laminated using lamination technology using established polymer (EVA) and Tedlar / Polyester laminate.
3. IEC 61215, IEC 61730 and CE Certified
4. 225Wp solar module has consisted of 60 crystalline silicon photovoltaic cells.
5. Solar Modules has made with High Quality, High Transmission 3.3mm tempered Solar Glass.
6. The efficiency of Solar Photovoltaic module is greater than 13%. It has made of high transmissivity glass front surface giving high encapsulation gain and hot butyl rubber edge sealant for module protection and mechanical support.

7. All materials used in manufacturing of module have a proven history of reliable and stable operation in external outdoor applications.
8. Solar module has designed to operate and perform in relative humidity up to 100% with temperatures between -10 Deg C and +85 Deg C and with stand gust up to 200km/h from back side of the panel.
9. Sturdy New screw type anodized Aluminum frame design using double sided tape for framing.
10. Degradation of power generated will not exceeding 20% of the min. rated power over the 25 year period. Efficiency of solar PV system is 90% for first 10 years & 80% thereafter till 25 years.
11. The solar modules have suitable encapsulation and sealing arrangements to protect the silicon cells from the environment. The arrangement and the material of encapsulation is compatible with the thermal expansion properties of the Silicon cells and the module framing arrangement/material.
12. Multilayered Back sheet giving weather-able barrier for modules and high performance in rugged environments around the world, high dielectric performance, superior partial discharge and electrical insulation properties.
13. Solar modules have Tedlar /Polyester trilaminate back surface

Mechanical Features-

Solar PV Module design has following Mechanical features-

1. Toughened, low iron content, high transmissivity front glass.
2. Ethyl Vinyl Acetate (EVA) encapsulant.
3. Silicon edge sealant around laminate.
4. Tedlar /Polyester trilaminate back surface.
5. ABS plastic terminal box for the module output termination with gasket to prevent water moisture.
6. Resistant to water, abrasion, hail impact, humidity & other environment factor for the worst situation at site.

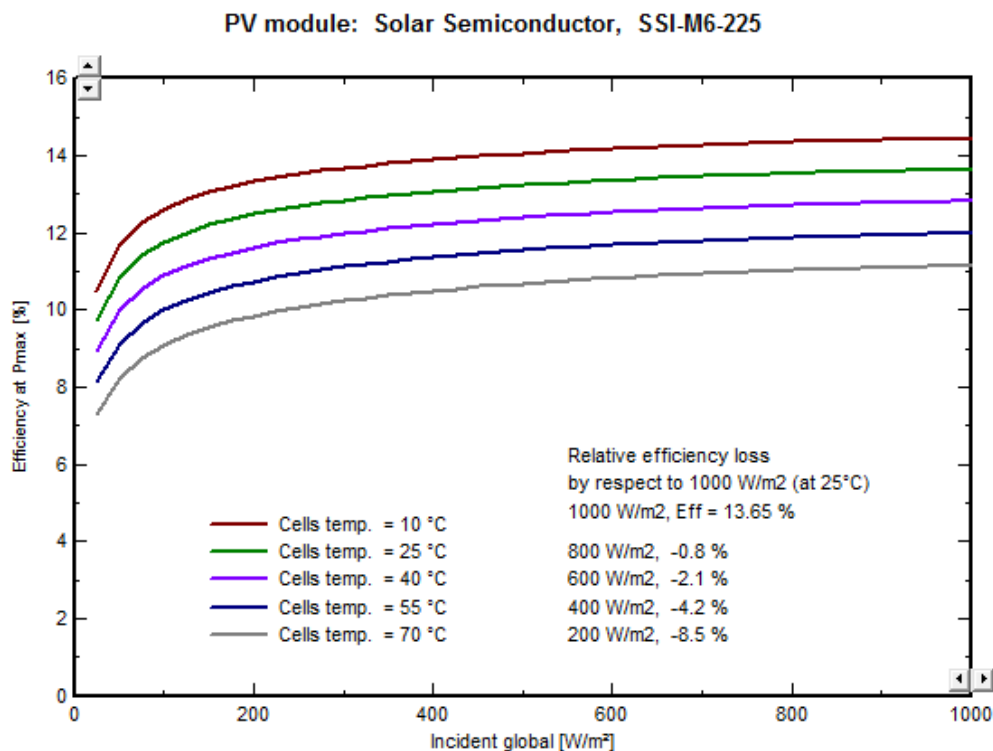
7.1.1 Probable Vendors

- Solar Semiconductor
- Moser Baer
- Sharp
- Tata BP Solar
- Green Brilliance

7.1.2 Performance Curves of Solar Semiconductor

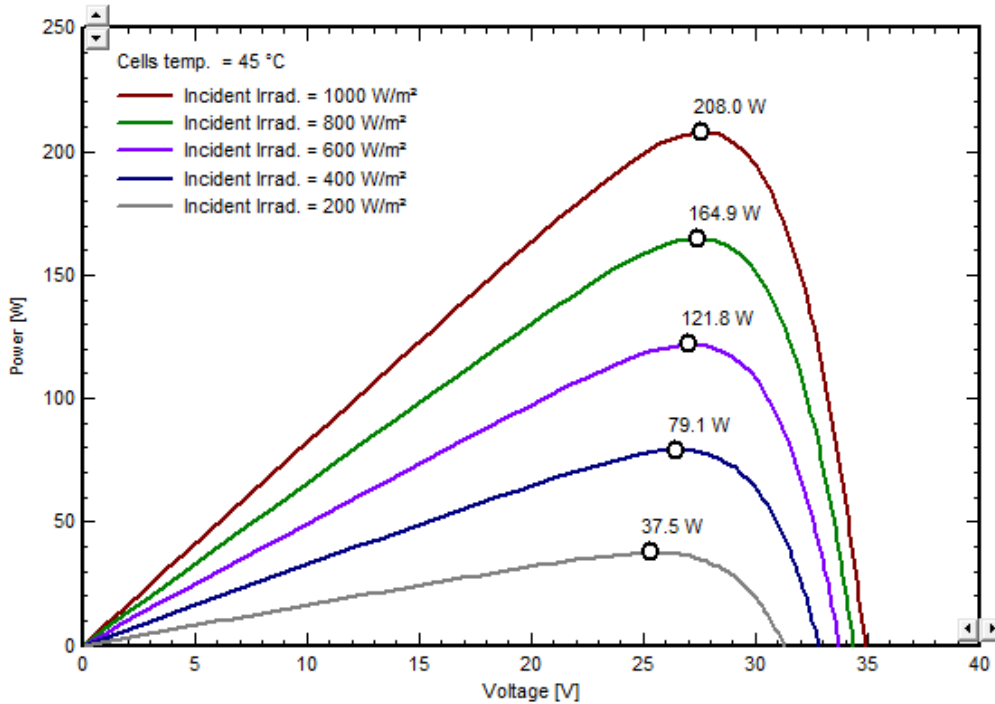
This DPR has been prepared for Solar Semiconductor's SSI-M6-225. Panels from other manufacturers can also be used and the performance curves and energy output shall change accordingly.

Below graph is the characteristic of the PV module made by "Solar Semiconductor" SSI-M6-225, it shows the variation of Efficiency of PV module at various values of global incident irradiation for different values temperature of the module.

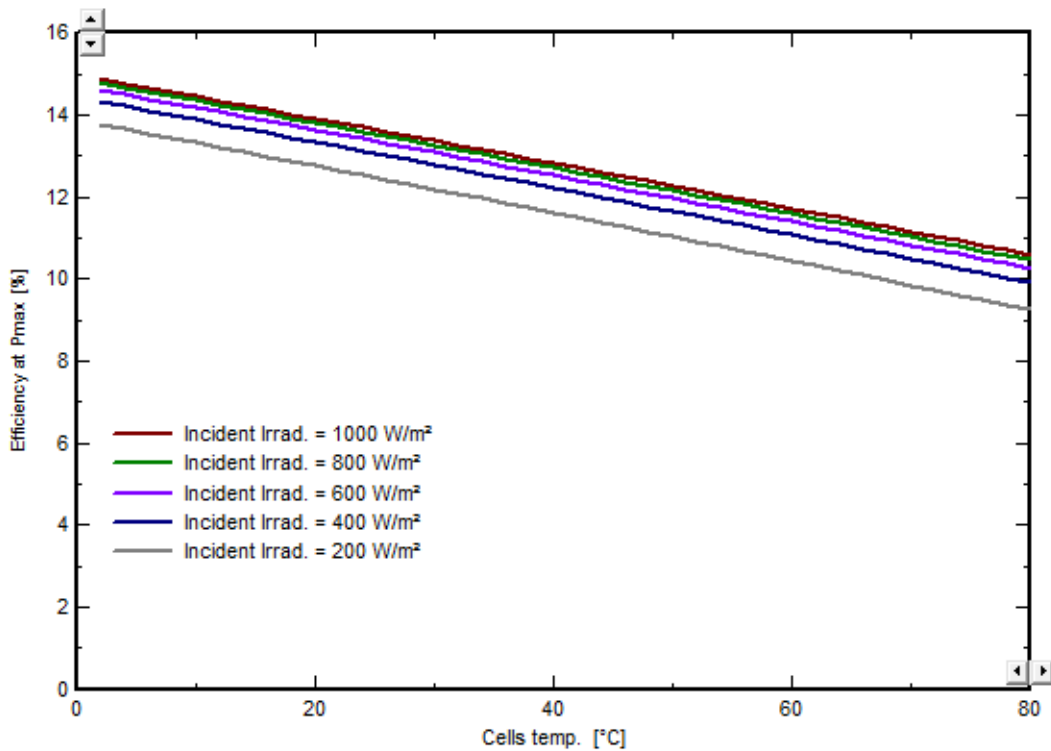


PV Module Characteristics

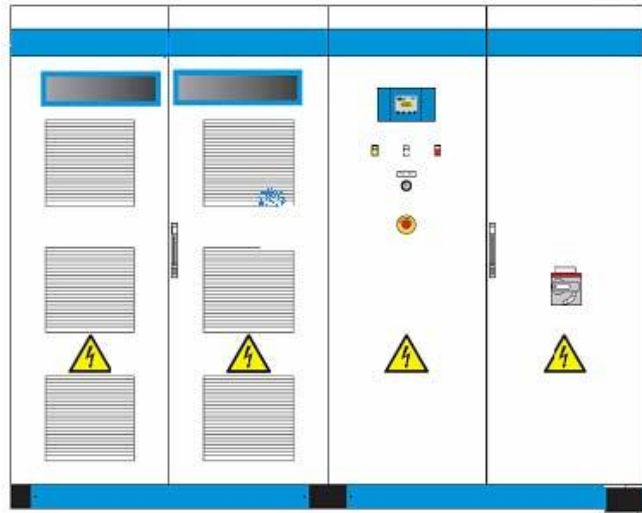
PV module: Solar Semiconductor, SSI-M6-225



PV module: Solar Semiconductor, SSI-M6-225



7.2 Solar Inverter (SMA Sunny Central 250)



The grid tied inverter is based on a reliable platform that is used in grid-connect photovoltaic application in North America and Europe. Easy to install and operate. This inverter automates startup, and shut down. It incorporates advanced maximum power point tracking technology to maximize the energy harvested from a PV array. To minimize the power losses during the conversion process, the inverter switching technology uses insulated gate bi-polar transistors. Multiple inverters can be paralleled for large power installations. It meets all applicable European, CE requirements.

Advantages of SPV Grid Tied Invertors

Economics: A high efficiency, achieved even under partial load, is the basis for the economic viability of the entire solar power station.

Suitable for Outdoors: Central inverters with their own weatherproof enclosures as option can be installed in close proximity to the generator. This does away with long transmission routes and construction measures.

Investment Security: Comprehensive communication interfaces provide all system monitoring options, even via Internet from any PC, anywhere in the world. Thus, yield losses can be detected quickly.

Increased Efficiency: By avoiding the use of a low-voltage transformer, the losses which occur during conversion to grid-compliant alternating current can be minimized, and the system price can be reduced.

Features

- 96.1% CEC weighted efficiency
- Integrated isolation transformer
- Graphical LCD interface
- Sunny WebBox compatible
- Optional combiner boxes
- Install indoors or out
- UL 1741 / IEEE 1547 compliant
- Inverter shutoff and disconnects.
- Over and under voltage and frequency protection, shutting down the inverter.
- Anti-islanding protection-prevents back feeding inverter generated power to grid in the event of utility usage.
- User definable power tracking allows the user to match the inverter to the array, as well as to adjust delay periods to customize system shutdown sequences.
- Graphical user interface software for real time communications, monitoring and control.

Options

- Remote monitoring via telephone modem.
- Faults notification via modem.
- Data acquisition and logging.
- DC monitoring.

7.2.1 Technical Data

Input data	Sunny Central 200	Sunny Central 250	Sunny Central 350
Nominal power DC	210 kW	262 kW	369 kW
Max. PV power (recommended), (P_{PV})	230 kWp	290 kWp	405 kWp
DC voltage range, MPPT (U_{DC})	450 V – 820 V	450 V – 820 V	450 V – 820 V
Max. permissible DC voltage ($U_{DC, max}$)	880 V	880 V	880 V
Max. permissible DC voltage ($U_{DC, EVR}$)	1000 V (optional)	1000 V (optional)	1000 V (optional)
Max. permissible DC current ($I_{DC, max}$)	472 A	591 A	800 A
Voltage ripple, PV voltage (U_{PP})	< 3 %	< 3 %	< 3 %
Number of DC inputs / connection point	5 / DC fuse	8 / DC fuse	12 / DC fuse

Output data			
Nominal AC output power (P_{AC})	200 kW	250 kW	350 kW
Operating grid voltage ± 10 % (U_{AC})	400 V	400 V	400 V
Nominal AC current ($I_{AC, nom}$)	289 A	361 A	505 A
Grid structure	TT, TN-S, TN-C grid	TT, TN-S, TN-C grid	TT, TN-S, TN-C grid
Operating range, grid frequency (f_{AC})	50 Hz – 60 Hz	50 Hz – 60 Hz	50 Hz – 60 Hz
Distortion of the grid current	< 3 % at nominal power	< 3 % at nominal power	< 3 % at nominal power
Phase shift ($\cos \varphi$)	≥ 0.99 at nominal power	≥ 0.99 at nominal power	≥ 0.99 at nominal power

Efficiency			
Maximum efficiency $P_{AC, max}$ (η)	95.7 %	96.1 %	96.0 %
Euro-Eta (η)	94.5 %	95.2 %	95.2 %

Protection rating and ambient conditions			
Protection rating as per EN 60529	IP20	IP20	IP20
Protection rating per EN 60721-3-3,			
Ambient conditions: fixed location, weather protection	Classification of •chem. active substances: 3C1L •mech. active substances: 3S2	Classification of •chem. active substances: 3C1L •mech. active substances: 3S2	Classification of •chem. active substances: 3C1L •mech. active substances: 3S2
Permissible ambient temperatures (T)	-20 °C ... +40 °C	-20 °C ... +40 °C	-20 °C ... +40 °C
Relative humidity, non-condensing (U_{AIR})	15 % ... 95 %	15 % ... 95 %	15 % ... 95 %
Max. altitude (above sea level)	1000 m	1000 m	1000 m
Fresh air consumption (V_{AIR})	3300 m ³ / h	4200 m ³ / h	6500 m ³ / h
Type designation	SC 200-10	SC 250-10	SC 350-10

7.2.2 Other Probable Vendors

- 1) Steca Solar
- 2) SatCon Power Systems
- 3) Xantrex Technologies Inc.

7.3 Module Mounting Structure

We shall be using mounting technology of a Spanish module mounting structures manufacturing company which has developed and patented many innovative mounting structure technologies which are extremely fast, reliable and robust. Some of the features of module mounting structure are,

- In place of concrete foundations, mounting structure are drilled and bolted in the ground
- Drill depth depends on the soil strength and profile
- Estimated life of such mounting structure is ~40 years
- Structures are made up of galvanized steel
- Widely tested with high reliability
- Can be erected at a speed of 2MWp/Week
- High speed of erection decreases the time of commissioning of the plant by 2-3 months hence increases the profitability of the plant.

Note: In case of supply constraints and high cost, conventional mounting structures can also be used. Specification for conventional mounting structure has been provided below.



Patented design based mounting structures for massively fast installations (2MWp/Week).

7.3.1 Specification for Conventional Mounting Structure

In case of supply constraints and high cost for Spanish technology, conventional mounting structures can also be used. The module mounting structure is design for holding suitable number of modules in series. The frames and leg assemblies of the array structure is made of Mild Steel, hot dip galvanized material of suitable sections of Angle, Channel, Tubes or any other section conforming to IS:2062 for steel structure to meet the design criteria. All nuts & bolts considered for fastening modules with this structure are of very good quality of stainless steel. The array structure is designed in such a way that it will occupy minimum space without sacrificing the output from SPV plants at the same time.

Conventional Mounting Structure		
1.0	Type	Ground Mounting
2.0	Material	MS Galvanized
3.0	Overall dimension	As per design
4.0	Coating	Hot dip (Galvanized) Minimum of 130 Micron size
5.0	Wind rating	150 km / hr
7.0	Foundation	PCC
8.0	Fixing type	SS 304 Fastners

7.4 Array Junction Boxes

The array junction boxes are dust, vermin and waterproof and made of thermo plastic with IP65 protection standards for outdoor applications.


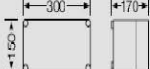
MOV's are used at the terminals of array junction boxes for external over voltage protection.

The junction boxes are suitable cable entry points fitted with cable glands of appropriate sizes for both incoming and outgoing cables.

Suitable markings are provided on the bus bar for easy identification and cable ferrules shall be fitted at the cable termination points for identification.



■ material high-quality polycarbonate	■ lid fasteners for tool operation
■ colour grey, RAL 7032	■ sealable
■ degree of protection IP 65	■ please order mounting rails or mounting plates additionally

Mi 0100	box size 1		
max. installation depth			
with built-in mounting plate 146 mm			
with built-in DIN rail 135 mm			

7.5 PVC Cables

All the cables will be supplied conforming to IS 694 & shall be of 650 V/ 1.1 kV grade as per Interconnections, array to junction boxes, junction boxes to DCDB, DCDB to PCU etc will be so selected to keep the voltage drop and losses to the minimum.

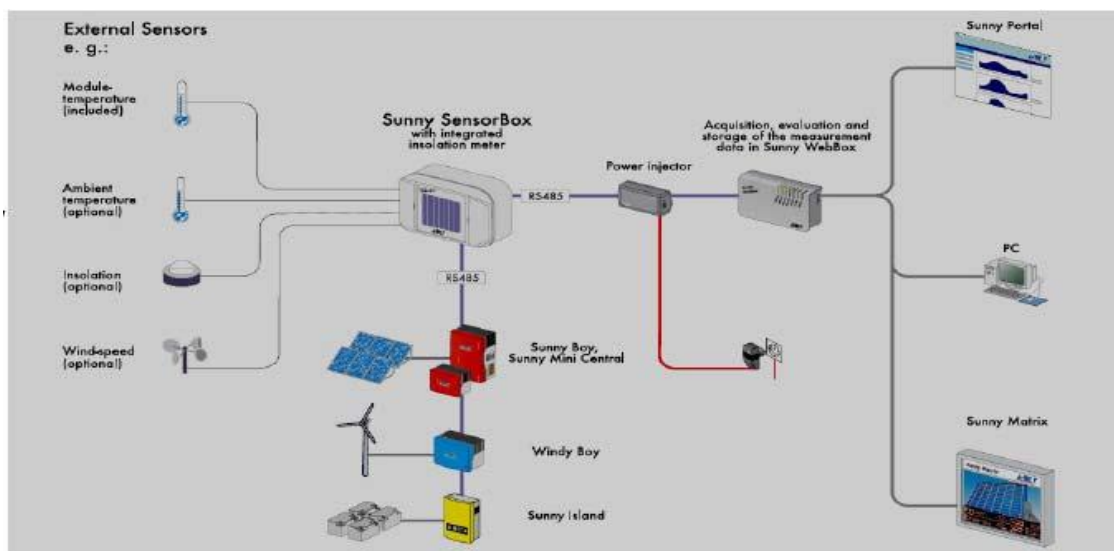
The bright annealed 99.97% pure bare copper conductors that offer low conductor resistance, they result in lower heating thereby increase in life and savings in power consumption. These wires are insulated with a special grade PVC compound formulated and manufactured in-house. The skin coloration offers high insulation resistance and long life.

Technical Specifications for Cables			
SR. NO.	ITEM	UNIT	
1.0	POWER CABLE		
1.1	Voltage Grade	V/V	1100V for 415V system
1.2	Frequency	Hz	50
1.3	Earthing system	-	Solidly earthed system for 415V system
1.4	Conductor	-	
1.4.1	Material	-	Annealed Cu
1.4.2	Max withstand Temp	-	
	(a) Normal condition	C	90
	(b) Short circuit condition	C	250
1.4.3	Conductor type	-	Stranded
1.4.4	Grade	-	H4
1.5	Insulation	-	
1.5.1	Material	-	XLPE
1.5.2	Reference standard	-	IS 7098, Part I and Part II
1.6	Inner Sheath	-	
1.6.1	Material	-	FRLS PVC
1.6.2	Type	-	ST2
1.7	Outer Sheath	-	
1.7.1	Material	-	FRLS PVC
1.7.2	Type	-	ST2

7.6 Remote Monitoring System

We can monitor our system from anywhere we want using remote monitoring system. Remote Monitoring is essential for every PV systems in order to ensure earnings.

1. Component Required for Remote Monitoring a system-
2. Sunny Sensor Box
3. Power Injector
4. Web Box
5. Module Temp. Sensor



Note: Due to continual improvement and development the data mentioned above may change without notice, some photos are for indicative purpose and for Requirement purpose only.

7.7 Earthing & Lightning Protection

7.7.1 Codes & Standards

The earthing of all outdoor equipment and provision of associated earthing systems, electrodes and connections shall be in accordance with the recommendations in the latest IEEE 80/IS 3043.

7.7.2 Design Criteria

7.7.2.1 Grounding System

The grounding design calculation shall conform to ANSI / IEEE Standard 80-2000.

Earth electrodes shall be provided throughout the plant areas along with the main earth grid. The number of earth electrodes shall be according to achieve the total earth grid resistance less than one (1) ohm. Earth electrodes shall be provided in earth pits. The earth pits shall be of two types namely treated with test links and untreated. Earth electrodes shall be of heavy duty GI pipes, 40 mm dia and 3 meter long. The main buried grid conductors shall be connected to all the earth electrodes to form a total earth grid.

7.7.2.2 Grounding Material

Galvanised steel flats of required size shall be used as per approved design. In any case the minimum size shall be 75 x 10 mm. GS strip for earthing conductor. Treated earth pits shall conform to relevant INDIAN Standards. The earth grid shall be installed specified / approved depth of minimum 600mm.

7.7.2.2.1 Equipment Earthing

The frames of all electrical equipment and structural steel work shall be earthed by connection to earth grid by branches of same cross sectional area of the earth grid.

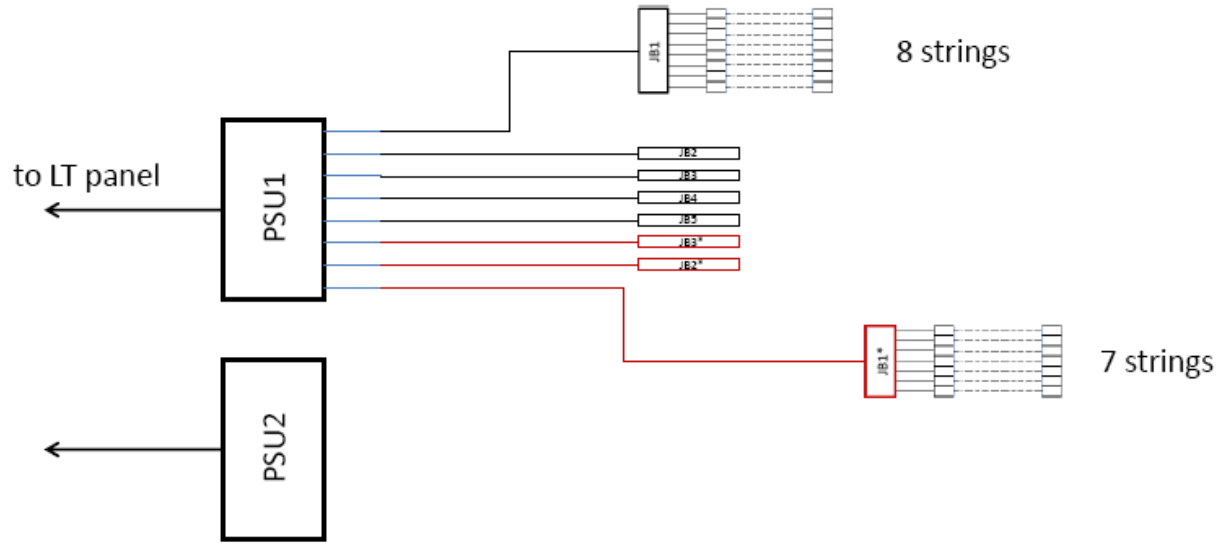
7.7.2.2.2 Lightning Protection System

Power plant needs protection against Lightning. The system will be designed as per IS: 2309 and Indian Electricity Rules.

Vertical air termination of 40mm diameter, 3 M long shall be provided above highest point of array to provide radius of protection full array.

7.8 Typical String Diagram

61 strings of 20 panels each for each inverter, for a total of 18 inverters.
 $61 \times 20 \times 18 \times 225 = 4941000 \text{ Wp}$



PSU model : SMA Sunny Central 250

Solar Module Model: Solar Semiconductor(SSI-M6 -225)

Total 18 PSU's
 21960 Panels

7.9 Warranty

1. The Inverters offered come with a 5 year factory warranty from SMA Germany and we will extend the same to you.

a. However, the same may be extended on mutually agreed terms

2. All other parts (Electrical only) will come with a 1 year warranty

3. The warranty for modules will be as follows:

a. 90% performance warranty for first 10 years and 80% after that upto 25 years

b. 5 years mechanical warranty

7.9.1 Performance warranties of the plant:

Committed Energy Generation (At Inverter output): 15% lower than the Design Calculation

Total Plant Performance warranty: For first 10 years, 90% of the Committed Energy Generation.

From 11th to 25th year, 80% of the Committed Energy Generation.

Module Performance warranty: For first 10 years, 90% output generation

From 11th to 25th year, 80% output generation

7.9.2 Mode of Performance Measurement & Penalties:

The plant performance (energy generation) will be measured at the Inverter output considering all losses. In case of default in generation of committed units, we will supply extra modules to match the commitment, provided the grid power shall not be failed during the operation hours of plants for 365 days in a year.

7.10 Bills of Material (BOM)

Tentative BOM is provided below,

Sr. No.	Description of Item	Qty	UoM
A	Civil Work		
1	Soil Testing	1	Set
2	Civil-Leveling of Land	94500	Sq. mtrs
3	Civil-Fencing Work	1800	mtrs
4	Internal Road With in Array Area	2000	Metrs
5	Water Supply		Lumsum
6	Control Room		Lumsum
7	Bore Well	2	Nos
8	Civil Foundation for Array Structure	1	Set
B	General Work		
1	Security for solar farm during execution		Lumsum
2	Pota Cabin	1	No .
3	Diesel Generator 15KVA with Diesel	1	No .
4	Electrical Design	1	Set
5	Yard Street Lighting with 11 or 18W CFL	100	Nos.
6	Lighting Arrestors	1	set
7	Earthing Kits	1	set
C	Solar Modules		
1	Solar Modules(225Wp)	21960	Nos
2	AJB 5 in 1 out	238	Nos
3	MJB 5in 1 out	48	Nos
D	M. S. Structure		
1	10 module M S Structure for solar modules with SS Hardwares	2381	Nos
E	PCU		
1	PCU-Make-SMA	18	Nos
2	PCU Mounting Structure	7	Nos
3	Weather Resistant, Water Resist, Junction Boxes between PCU to Grid	48	Nos
4	Communication Accessories web box and cable	16	Lumsum
F	Cables		
1	Interconnection between module & AJB	71430	Metr
2	Interconnection cable between AJB & Inverter (Copper)	36000	Metr
3	Interconnection cable between inverter & JB (Copper)	15000	Metr
4	Interconnection between Junction Box & LT Panel (Copper)	30000	Metr
5	Interconnection between LT panel and Transformers	6667	Metr

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G	Power Evacuation Transformer		
1	Transformer 2MVA-0.415/11KV	3	Nos
2	Transformer 5MVA-11/33-66KV (If required)	1	Nos
3	LT Panel CT/PT	3	MW
H	Installation & Commissioning Services		
1	Erection of Transformer & LT Panel etc.		Lumpsum
2	Installation & Commissioning		Lumpsum

8 POWER EVACUATION STRATEGY

It is important that the power plant is designed to operate satisfactorily in parallel with grid, under the voltage and frequency fluctuation conditions, so as to export the maximum possible units to the grid. It is also extremely important to safeguard the system during major disturbances like tripping, pulling and sudden over loading during the fluctuation of the grid loads on the generating unit in the island mode, under fault/feeder tripping conditions.

8.1 Grid Synchronization Scheme

As per the grid synchronization is concerned, the power plant generates power at 415 volts at the Inverter terminal. The power plant will have switchyard in the plant premises with single bus arrangement with one power transformer with control and protection equipment (breaker, CTs, PTs, isolators etc.).

Protection, metering and control panels for the switchyard and grid feeder will be accommodated in the plant's central control room. A hot line telephone communication system shall also be established between the feeder-station and the power plant control room to enable better co-ordination.

The 110/33/22 kV Vagaikulam Sub Station, is about 4 km away from the plant location.

As shown in the grid synchronization diagram, the power generated at the inverter terminal is fed through a step up transformers to the grid. The scheme will have High tension metering cubicle, Air/Vacuum circuit breakers. The detailed power evacuation scheme will be worked with the State Transmission Utilities (STU) during the project execution.

8.2 Interface Scheme Proposed

It is envisaged that the solar generation plant will be connected to the 66 KVA distribution network at Vagaikulam. The solar project size is proposed to be 5 MW. This higher rating solar power plant would feed the generated power to high voltage electricity grid of state distribution company.

The proposed plant will be connected to the 66 kVA transmission systems through the 110/33/22 kV Vagaikulam substation. This involves an 11/66 kV power transformer; underground cables and overhead lines at 11/33kV with at least 5 MVA rated transformer capacity. The network connection is designed to carry rated power on a 24-hour basis. For connection to the 33 kV transmission grid, Indian Electricity Rules / CEA's regulations will be followed and the connection will meet State Grid code requirements.

This study and design is based on the following

- Load flow studies,
- Dynamic stability assessment,
- Connection substation concept design, and
- Protection design (connection substation and transmission line)

8.3 Net Metering

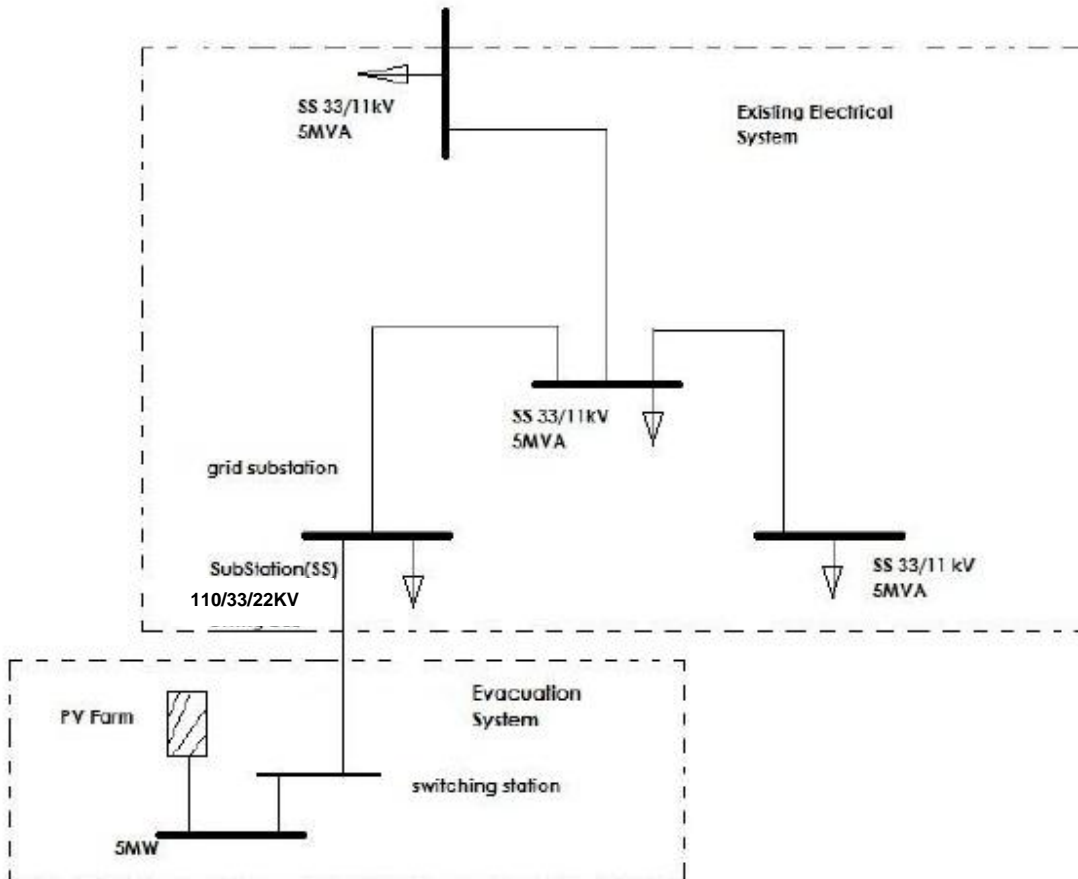
The Energy accounting metering system will be installed at 110/33/22 kV Power Station bus to account electric energy generated by the power plant and delivered to the local grid of TNTRANSCO or State Grid of TN and the electrical energy imported from the grid during the non – power period. The energy meter will measure import and export energy parameters. This meter will be sealed by TNTRANSCO/ TNSEB. Additionally energy management and control system will be installed in the solar plant which will monitor and record the performance at each power generator and each 1 MW module.

Factors to be considered when selecting meters are the

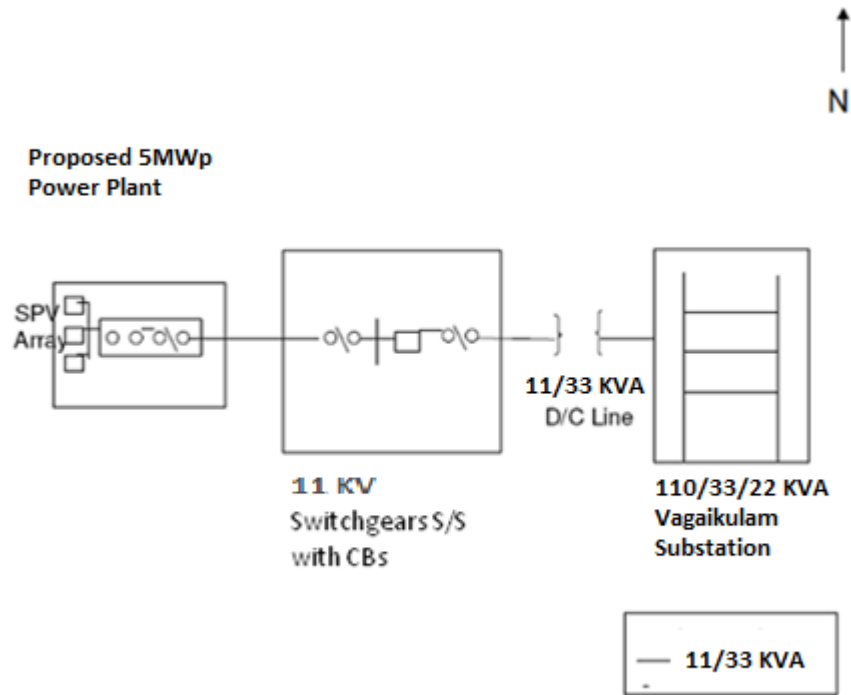
- Possible harmonics content of metering signals.
- Associated degree of inaccuracy of the meter selected; and
- Site specific that need to be considered in metering design.

8.4 Single Line Diagram for Power Evacuation (Typical)

Evacuation of 5MW PV farm



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9 SCOPE OF THE WORK & MODES OF IMPLEMENTATION

9.1 Indicative Scope of Work

9.1.1 Electrical

1. Supply, fitting, fixing of Solar PV Modules with appropriate module mounting structures and frames including overall planning and design of the power plant
2. Supply and installation of Junction boxes of appropriate standards with required Protection and Isolation system
3. Design, Supply and Installation of AC Power Conditioning Units with all protection and controlling arrangement as per specifications e.g. 250 kV, 3 Ph, 50 Hz, 415 V, 4 wire or a suitable mix of PCUs to get the desired performance. String monitoring and MPPT features are included as per your requirements.
4. Interconnection of Solar Modules, PCUs, transformers LT & HT side, LT switchgear, etc. with appropriate cables and associated materials including supply of materials.
5. Design, manufacture, supply, installation, interconnection and interfacing of Computer Aided Data Acquisition Unit as per our specification.
6. Supply, installation complete earthing as required for AC & DC power system, PCU, LT switchgear, transformer, all metallic cubicles, HT switchgear with materials as required as per relevant standards
7. Providing Earth Mat and Interconnection of array structures with earth pits in the PV Array Yard.
8. Design, fabrication, supply, installation of LT power interfacing panel to evacuate power to the Grid through PCUs with appropriate capacity circuit breakers, isolators, indicators, metering arrangement with selector switch, CTs, PTs and copper busbars as per requirement, in complete.
9. Design, fabrication, supply and installation of plant monitoring desk to monitor the status of all major equipments through remote monitoring system including connection to all major equipments and status to be monitored.
10. Supply of all other BOS parts e.g. Cables, electrical, etc. as per the Bill of Material (BOM) which is not covered above.
11. Metering Device

9.1.2 Control Room and Others

1. Electrical wiring in the control room and array yard with supply of cables and wires, switch board, switch, JB, distribution board for lights, fan, exhaust fan, power point for both 5A and 16A
2. Supply and installation of lightening arrestors for the control room as per relevant standards.
3. Supply, fitting and fixing of CFL lighting fixture, FL lighting fixture, LED lighting fixture for lighting indoor & outdoor various including array yard with required accessories.
4. Providing of 5A and 15A plug points in the control room as per requirement.
5. Supply, fitting and fixing of ceiling fan, exhaust fan, pedestal fan as per requirement.
6. Providing of fire extinguisher and sand buckets complying with national/international safety standards.

9.1.3 Civil Works for SPV System

1. Topographical survey
2. Design and construction of appropriate foundation base for holding the module mounting structure with supply of all requisite materials, excavation, concreting, back filling, shoring and shuttering, etc.
3. Construction of power plant building including control rooms as required, office, amphitheatre, etc.
4. Barbed wire fencing of 4ft height for complete array area at site
5. Cable trenches, Drainage, etc.
6. Main Gate and Security Guard room

9.1.4 Erection and Installation of Power Evacuation Arrangement

1. Erection, supply installation and commissioning of suitable transformers with associated switchgear comprising of circuit breakers, isolators, LT panels, CTs and PTs, etc. including metering and protection like over-current, earth-fault, reverse power protection & controls etc.

Other Fixed Assets

1. Furniture for Control Room and Administration / Office
2. Pantry Equipment, Change Room Lockers, etc.
3. Store Racks & Cupboards
4. Standard Mechanical Maintenance Tools

Engineering & Project Management

1. Design & Engineering
2. Project Management and Construction Supervision
3. Material unloading at site
4. Insurance during the project period of 6 months

Please note that is an indicative scope of work list.

9.2 Modes of Implementation

Pos.	Description
1	Construction Management
1.1	Construction management and planning for all materials and works delivered or executed by Subcontractor
1.2	Provide project management and supervision.
Pos.	Description
2	Modules
2.1	Receiving and unloading of Modules (delivered by customer) with appropriate vehicle (e.g. forklift truck, 4x4 forklift, etc.)
2.2	Check and comparison of modules delivered with delivery note and visual inspection of delivered modules
2.3	Storage of modules (temporary) with appropriate protection against weather impacts, damage and theft (e.g. lockable containers or lockable tents). In customer's scope; not in EPC contractor scope.
2.4	Transport from (temporary) storage to site/point of installation with appropriate vehicles (e.g. fork lift truck)
2.5	Passing of risk (from Customer to EPC Contractor) starts with delivery of modules to site/temporary storage and from the time the modules are taken by EPC contractor from the storage till the point they are installed and commissioned. However, after the commissioning, the risk of the performance of the modules will be entirely and severally of the customer.
Pos.	Description
3	Structures for modules with the general conditions:
3.1	Evaluation of soil/ground: The ground/soil must be prepared to endure transport of all components (modules, structure, connection boxes, etc.) to the installation point on site. The ground/soil must withstand the loads of wind and the weight of structures (incl. modules and other components).
3.2	Preparation of the soil/ground on site with all necessary works like earthmoving, digging holes for the foundations/pilings and leveling.
3.3	Surveying of structures for the modules and calibration and pitching for the foundations/pilings of the structures.

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3.4	Delivery and/or manufacturing of foundations/pilings for the structures on site including all necessary material and works. The foundations/pilings must fulfill all necessary regulations and norms and be according to calculations by static expert.	
3.5	Manufacturing, delivery, installation and calibration of structures including all necessary material and works. The structures must fulfill all necessary regulations and norms and calculations of static expert as well as requirements of manufacturer. Installation on prepared foundations/pilings (Pos. 3.3.). Minimum quality of structure: hot galvanized steel	
3.6	Installation of modules on prepared structures including all necessary material and works especially the system for clamping/fixing the modules on the structures. In case the materials of module frames and structures are different (e.g. aluminium and galvanized steel) there must be installed an intermediate layer (e.g. EPDM-rubber) which will come at extra cost.	
3.7	Reconstruction/Regeneration of site. Dispose or recycle surplus soil material and dispose waste material including all necessary material and works.	
3.8	Provide and deliver a certified/approved statistics for the structure including all fixings and fundaments according regulations and norms of the Country.	
Pos.	Description	
4	Service Station for inverters, transformers and metering/safety system	
4.1	Planning, delivery and installation of the service stations for inverters, transformers and switchboards including all installation for appropriate ventilation/climating and electrification with lights, plugs, auxiliary supply, etc. of the stations. Including all necessary material and works. The station will fulfill all necessary regulations, norms and special specifications of the utility company. (The Details have to be defined by the Customer and the utility company).	
Pos.	Description	
5	Security and protection system	
5.1	Delivery and installation of a fence around the site of the power plant including all necessary material and works. The fence will be as per the customer's specifications.	
5.2	Delivery and installation of security system for the power plant including all necessary material and works. The security system must fulfill all necessary regulations, norms and as well specifications due to insurance necessities.	

Pos.	Description
6	Earth moving works
6.1a	Installation and laying of DC-Main-Cables from connection boxes to main junction boxes and to inverters, including earth moving work due to national regulations and norms. Including all necessary material and works.
6.1b (alternatively to 6.1a)	Installation and laying of DC-Main-Cables in cable channels from connection boxes to main junction boxes and to inverters, due to national regulations and norms. Including all necessary material and works.
Pos.	Description
7	Electrical Installation of solar generator
7.1	Connection of modules to strings. Including all necessary material and works.
7.2	Installation of connection boxes at the metal structure including all necessary material and works.
7.2	Installation of main junction boxes in the service station including all necessary material and works.
7.3	Delivery, installation and connection in the connection boxes of Cables (or similar) for the module strings. Including all necessary material and works.
7.4	Delivery, installation and connection in between the connection boxes with Cables NYY (or similar) including all necessary material and works.
7.5	Delivery, installation and connection between the connection boxes and main junction boxes and the inverters of Cables NYY (or similar) including all necessary material and works. (The specification of the cables have to be defined by Subcontractor and EPC contractor)
7.6	Delivery and installation of Cable Conduits/Cable Channel with cover at metal structure including all necessary material and works.
Pos.	Description
8	Earthing/Grounding of solar generator
8.1	Delivery, installation and connection for the earthing/grounding of solar inverter (modules, structures, cable channels and connection boxes) including all necessary material and works.
Pos.	Description
9	Installation of inverters and AC-cables from inverters to transformer
9.1	Receiving and unloading of inverters (delivered by EPC Contractor) with appropriate vehicle (e.g. fork lift truck)
9.2	Check of inverters delivered with delivery note and visual inspection of delivered inverters
9.3	Transport to service station with appropriate vehicles (e.g. fork lift truck) and installation in service station.

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9.4	Delivery, installation and connection between the inverters and transformers of Cables NYY (or similar) including all necessary material and works.	
9.5	Delivery, installation and connection of remote monitoring system including all necessary material and works.	
Pos.	Description	
10	Transformers, metering and safety system and switch board medium voltage	
10.1	Delivery, installation and connection of transformers for medium voltage, metering and safety system as well as switch board for medium voltage level including all necessary material and works. The components have to accomplish all national regulations and norms.	
10.2	Delivery, installation and connection of a low voltage connection point , metering and safety system for auxiliary power (e.g. for the inverters, lights, sockets, etc.) including all necessary material and works. The components have to accomplish all national regulations and norms.	

Pos.	Description	
11	Lightning protection for service station	
11.1	Delivery, installation and connection of lightning arresters for the service stations.	
Pos.	Description	
12	Site facilities	
12.1	Delivery, installation and operation of office for project management/site management with all installation like electricity, light, telephone/fax, etc. including all necessary material and works	
12.2	Delivery, installation and operation of containers for the construction team including all necessary material and works	
12.3	Delivery, installation and operation of storage facilities for all components, material and tools, etc. including all necessary material and works	
12.2	Delivery, installation and operation of containers with bathroom/lavatory facilities including all necessary material and works	
12.4	Delivery, installation and operation of temporary power generator for electricity on site. including all necessary material and works	
12.6	Delivery, installation and operation of containers for the collection of waste. including all necessary material and works	
Pos.	Description	
13	Documentation	
13.1	Provide and deliver a complete documentation with all drawings ,plans, datasheets, statics, calculations, measurements etc.	

10 TENTATIVE PROJECT SCHEDULE

From the ‘zero’ date, we will take approximately 8-10 months to completely install and commission the 5 MWp as proposed under the project.

Zero date:

- PPA in place
- Financial Closure in place
- Mandate given to EPC contractor

10.1 Statutory approvals:

For this project, following probable statutory clearances are required,

- DPR approval from TEDA/NVVN
- NOC from village Panchayat
- Clearance from environmental department TN
- Forest clearance from Govt. of India
- NOC from District Fire Officer
- Approval from Town & Country Planning
- Clearances from National Airport Authority
- Chief Electrical Inspector etc

10.2 Project Implementation Strategy

It is envisaged that the project will have the below mentioned phase of activities. These phases are not mutually exclusive; to implement the project on fast track basis some degree of overlapping is envisaged.

Phase I	Project Development
Phase II	Finalization of the Equipment and Contracts
Phase III	Procurement and Construction
Phase IV	Plant Commissioning

10.2.1 Phase I - Project Development

In a power project, development of the project plays an important role. Almost 50 % of the work is done if one achieves power purchase agreement from the respective state utilities. The project development starts with visits to the region, understanding about the regional conditions, socio economic conditions, transportation facilities and infrastructure facilities available in the region.

Apart from the above the below listed tasks will be under project development:

Preparation of Detailed Project Report (DPR)

Submission of DPR

Power purchase agreement (PPA)

During this phase, a Project team will be formed during the execution of the project. The engineers from group will be involved from early stages of execution of the project. This would give them the opportunity to familiarize with the equipment and systems being installed. These personnel should involve with the critical team of installation and commissioning. After the plant being commissioned, these engineers and technicians would occupy key positions in the organization structure for the operation and maintenance of the plant.

The responsibilities of the project team shall be:

- Planning and programming of all the resources required for project completion
- Inspection of major fabrication items
- Organize the construction and commissioning of the plant
- Monitoring and controlling the project progress
- Execute the project within the planned budget

10.2.2 Phase II - Finalization of the Equipment and Contracts

In the power plant modules and junction boxes are the lead items and the planning schedule for the project implementation should provide adequate time period for the acquisition and installation of these equipments. The specifications for major equipment shall be drawn up at an early stage of the project. Program of design information, from the equipment suppliers, that satisfies the overall project schedule shall be drawn up.

Since, the project execution calls for closer coordination among the contractors, consultants and the company, proper contract co-ordination and monitoring procedures shall be made to plan and monitor the project progress.

10.2.3 Phase III - Procurement and Construction

The Procurement is an important function of the implementation of the project. Once the purchase order is placed, the project team follows up regularly to ensure smooth and timely execution of the contract and for obtaining technical information for the inter package engineering.

When the contracts for the equipment are awarded, detailed program in the form of network are tied up with the supplier to clearly indicate the owner's obligations and the suppliers responsibilities. And upon placement of the purchase order, the project team follows up regularly to ensure smooth and timely execution of the contract and or obtaining technical information for the inter package engineering. The procurement activity includes review of drawings, expediting, stage and final pre delivery inspection, supervision of installation and commissioning.

During Construction, the erection and commissioning phase of all the contracts proceed simultaneously. Adequate power and water shall be made available for the construction.

Construction manager takes the overall responsibility of the site.

10.2.4 Phase IV- Erection and Commissioning Phase

The commissioning phase in a project is one where design, manufacturing, erection and quality assurance expertise are put to test. The commissioning team will be from manufacturer of the equipment, consultant and the company. As discussed in the earlier section, staff identified to operate the plant will be involved in the commissioning phase of the project itself.

When construction phase is complete, the check list designed to ensure that the plant has been properly installed with appropriate safety measures. The commissioning team will follow the internal operating instructions. The plant shall be subjected to a performance test.

10.3 Probable EPC service provide

- PAN Exergy-Engineers India Ltd.
- Larsen & Tubro

11 OPERATION AND MAINTENANCE REQUIREMENTS

The proposed Organization structure for the operation and maintenance (O&M) of the power plant is presented in the exhibit. In order to ensure a high level of performance of the power plant, it is proposed to induct experienced O&M engineers from the very beginning of the project.

11.1 Basic Structure of the O&M Team

The basic structure and the broad functional area within the O&M organization would be as follows:

The Plant Manager would have the primary responsibility for the O&M of the power plant. The organization will comprise of four broad functional areas viz. Operation, Maintenance, Technical and Administration. The basic duties covered under each of these functional areas would be as follows:

11.1.1 Operation

- Operation of main generating equipment, switch yard and other auxiliary plant.
- Except for the Power Station Superintendent all other operating personnel would work one shift basis.
- The day to day operation of the power plant will be controlled by the Manager who will be assisted by the Control room operators and engineers.

11.1.2 Maintenance

- Maintenance of mechanical and electrical plant, control systems, buildings, roads, drainages and sewage systems etc.
- Operation of the plant, planning and scheduling maintenance works and deciding the requirement of spare parts
- The Plant Manager will be assisted by departmental engineers, who take care of the maintenance aspects of all mechanical, electrical and I&C requirement
- Trained technicians will be employed to assist the maintenance group in day to day maintenance of the plant.

11.1.3 Administration

The main responsibilities of this department will be as follows:

- Purchase
- Plant Security
- Liaison with local labor officers
- Stores management
- Medical Services
- Transport services

11.1.4 Facilities to Be Extended to the Employees

The number of employees required for operation of the proposed power plant will be around 10 numbers. The personnel required for administration and finance & accounts also will be provided. The following facilities will be provided in the power plant.

- Administration Building and Technical Office
- Stores
- Time and security offices
- First Aid and Fire Fighting Station
- Toilets and Changes rooms

11.2 Station Operations Philosophy

- The power generated from this plant is exported to Grid. Necessary software and hardware features are required for effective operation and maintenance management system
- Software system manages and provides the information needed to manage daily operations, improve labour productivity, reduce maintenance costs, and monitor preventive and predictive maintenance programs.
- Through more effective scheduled and preventive maintenance, the costs associated with emergency breakdowns can be greatly reduced. This includes savings from reduced payroll overtime, fewer defective products and reduced down time losses from disrupted production schedules.

11.3 Station Maintenance Philosophy

The based power plant maintenance philosophy is based on the following aspects:

11.3.1 Ordinary Maintenance

Ordinary Maintenance, which covers routine checking and minor refurbishment activities to be performed according to operation manuals of components / equipments in operating conditions

11.3.2 Emergency Maintenance

Emergency Maintenance, which is corrective maintenance to be performed when a significant failure occurs; To minimize forced outages duration, an effective Emergency Maintenance must be supported by:

- A proper stock of spare parts
- Permanent monitoring and diagnostic systems for main components.

11.3.3 Maintenance Plan and Scheduled Maintenance

Scheduled maintenance is carried out according to maintenance plan, which should be discussed and optimized according to the needs of the customer / client.

The maintenance plan is based on scheduled outages for the following components:

- Cleaning of Solar Module
- Power Processing System
- Switchyard equipment

11.4 Maintenance Management System

The maintenance of this plant will be carried out as per the above philosophy. This system aims at maximizing the availability of the plant, while ensuring minimum maintenance cost and safety of the plant and personnel.

11.5 Spare Parts Management System

The primary objective of spare part management system will be to ensure timely availability of proper spare parts for efficient maintenance of the plant without excessive build-up of non-moving and slow moving inventory.

The spare parts management system for this project will cover the following areas:

- Proper codification of all spares and consumables
- Spare parts indenting and procurement policy
- Ordering of critical mandatory and recommended spares
- Judicious fixation of inventory levels and ordering levels for spare parts based on experience.
- Development of more than one source of manufacturer / supplier whenever practicable.

11.6 Availability of O&M Manual

All contracts include provision of at least 6 sets of details O&M manuals, which will be distributed to all departments concerned well in advance from the commissioning date of the power plant to avoid problems in preparation of commissioning documents as well as proper installation and commissioning procedures of various equipments.

11.7 Special Tools & Tackles

All contracts will include the provision for supply of one set of all types of special tools and tackles, which are required for installation, commissioning and proper maintenance of plant and equipment.

11.8 Checklist & Protocol

A detailed checklist for the various equipments, supplemented with the checklist submitted by the supplier shall be drawn and logged for future reference. This will also form part of the plant's base history / datum.

Whenever an equipment is commissioned, the important parameters of that particular equipment should be observed for a period of eight hours and the readings shall be logged as per the log sheets. These activities shall be performed in the presence of the customer / consultant and a protocol shall be signed.

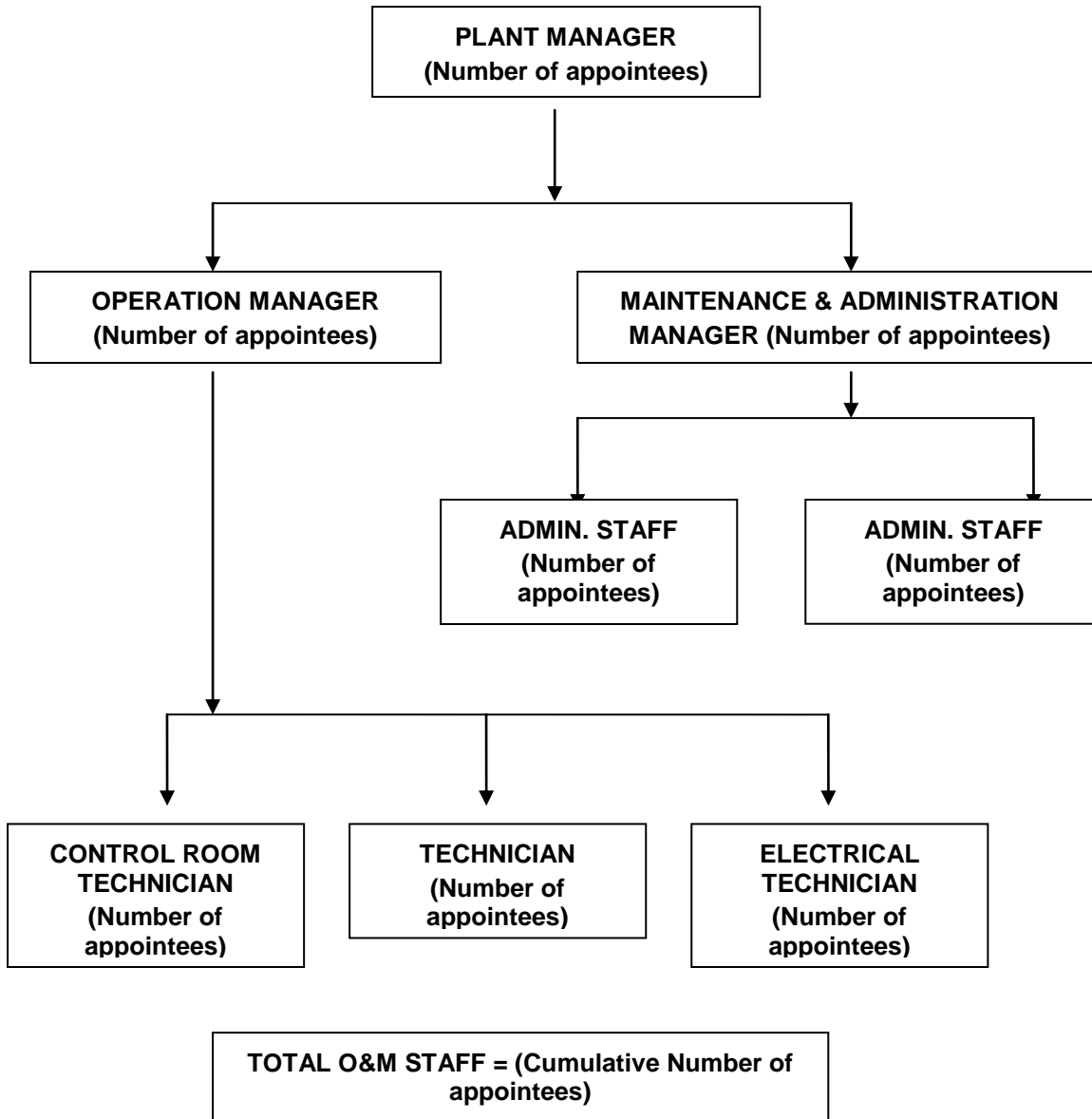
11.9 Safety & Protection

The importance of safety and the protection of personnel and equipment cannot be overemphasized. The system must be designed to minimize hazards to operation and maintenance personnel, the public, and equipment. The control subsystem must be equipped with various fuses, built-in fault detection and protection algorithms to protect the users, the loads, and the PV system equipment. The safety of an operator or technician is of the utmost importance. Personnel must be protected from electric shock by following all available safety practices. Such as displaying high voltage warning signs wherever necessary. In general, the system must adhere to the IS Codes and standards dealing with safety issues.

Some of the important safety criteria are as follows:

- Electrical components should be insulated and grounded.
- All high voltage terminations (> 50 Vdc) should be properly covered and insulated.
- All components with elevated temperatures should be insulated against contact with or exposure to personnel.
- Structures should be grounded and ground fault relays installed to give warning of ground faults in the array or other electrical components.

11.10 Organization Structure



11.11 Training

During the commissioning of the plant training will be imparted to the Engineer and supervisors.

This operational training shall cover the following:

- The nature, purpose and limitations of all plant and equipment.
- The detailed operating instructions on each section and equipment of the plant.
- Normal startup and shutdown Program for the plant.
- The emergency procedures and all related HSE issues according to the standards.
- The basis for the training shall be the plant's Operation and Maintenance Manual, Contract document and drawings provided by the manufacturer.

EPC Contractor shall conduct periodic visit to the plant to cross check the work efficiency.

12 PROJECT FINANCIALS

12.1 Project Cost

The cost of the power project is estimated, on the basis of the prevailing prices rates and the estimation is for the installation of power generation facilities described in the earlier sections of this report.

The cost of the Solar PV power plant, presented in this section of the report covers all the costs associated with the construction of the plant and included civil construction cost, cost of equipment for power generation, cost of auxiliaries and utilities. Clean Development Benefits (CDM) has been taken into consideration with an assumption that 1500 CER shall be produced per year per Mega Watt.

Project Cost per MW

PROJECT COST IN CRORE		
Equipments details	Qty	Amount (Cr)
Land Developments	LS	0.14
Equipments		
SPV Module (in KW)	1000	13.00
Installation Rs./ watt	1000	0.25
Power conditioning system	1000	1.40
Power Evacuation System	1000	0.50
Structure and fencing	1000	0.25
Earthing and cables	LS	0.20
Control Room	LS	0.70
Pre Operating Expenses	LS	0.20
Total Investments		16.64
Exclusions are land cost, grid evacuation expenses		

Note: CER distribution: yr-1, 100% to project developer (PD); yr-2, 90% to PD; yr-3, 80% to PD; yr-4, 70% to PD; yr-5, 60% to PD; year 6 onwards, 50% to PD.

12.2 Assumption

Sl No	Assumption Head	Sub-Head	Sub-Head (2)	Units	Assumptions
1	Power Generation	Capacity	Installed Capacity	MW	5
			CUF	%	14.6%
			Deration Factor	%	0.00%
			Useful Life	Years	25
2	Project Cost	Capital Cost/MW	Power Plant Cost	Rs Lakh/MW	1664.15
			Land Cost	Rs Lakh/Acre	5.169
			Land Needed	Acre/MW	5
			Total Fixed cost/PW	Rs Laks	1689.995
3	Financial Assumptions		Tariff Period	Years	25
			Tariff	Rs	17.9
		Debt-Equity	Debt	%	70%
			Equity	%	30%
			Total Debt Amount	Rs Lakh	5914.9825
			Total Equity Amount	Rs Lakh	2534.9925
		Debt Component	Loan Amount	Rs Lakh	5914.9825
			Moratorium Period	Years	0
			Repayment Period (Inc Moratorium Period)	Years	10
			Interest Rate	%	14.29%
		Equity Component	Equity Amount	Rs Lakh	2534.9925
4	Financial Assumptions (2)	Fiscal Assumptions	Income Tax	%	33.99%
			MAT Rate (for 10 years)	%	16.995%
			80 IA Benefit	Yes/No	Yes
		Depreciation	Depreciation Rate for First 10 Years	%	7%
			Depreciation Rate 11th year onwards	%	1.33%
			Years of 7% rate	Years	10
5	Operations & Maintenance		O & M	Rs Lakh/MW	9
			Total O&M escalation	%	5.72%
6	CDM Benefits	CER Produced	Expected to be generated per year for next 21 years	CER/MW/Year	1500
		CER Price	Based on ECX on 25Jan 2010,(conversion rate of 1EUR=INR65.26)	Rs/CER	764.2
7	Inverter	Inverter Replacement to be done after every 10 years	Current Price of Inverter	Rs Lakh/MW	100
			Replacement year	Year	10

12.3 Cash Flow

Units Generation	Unit	Year-->	1	2	3	4	5	6	7	8	9	10
Installed Capacity	MW		5	5	5	5	5	5	5	5	5	5
Gross Generation	MU		6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Revenue through CER	Rs Lakh		57.3	51.6	45.9	40.1	34.4	28.7	28.7	28.7	28.7	28.7
Total Revenue	Rs Lakh		1202.0	1196.3	1190.5	1184.8	1179.1	1173.3	1173.3	1173.3	1173.3	1173.3
Inverter Replacement	Rs Lakh		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
O&M Expenses	Rs Lakh		45.0	47.6	50.3	53.2	56.2	59.4	62.8	66.4	70.2	74.2
Depreciation	Rs Lakh		582.5	582.5	582.5	582.5	582.5	582.5	582.5	582.5	582.5	582.5
Loan Payment	Rs Lakh		1146.8	1146.8	1146.8	1146.8	1146.8	1146.8	1146.8	1146.8	1146.8	1003.5
Interest on Loan	Rs Lakh		845.3	802.2	752.9	696.6	632.3	474.7	474.7	378.6	268.9	143.4
Cash Flow for Equity	Rs Lakh	-2535	10.1	1.8	-6.6	-15.2	-24.0	-32.9	-36.3	-39.9	-43.7	95.6

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	0.0	0.0	0.0	0.0
1173.3	1173.3	1173.3	1173.3	1173.3	1173.3	1173.3	1173.3	1173.3	1173.3	1173.3	1144.7	1144.7	1144.7	1144.7
500.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	500.0	0.0	0.0	0.0	0.0
78.5	83.0	87.7	92.7	98.0	103.7	109.6	115.8	122.5	129.5	136.9	144.7	153.0	161.7	171.0
110.7	110.7	110.7	110.7	110.7	110.7	110.7	110.7	110.7	110.7	110.7	110.7	110.7	110.7	110.7
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1094.8	1090.4	1085.6	1080.6	1075.3	1069.7	1063.7	1057.5	1050.9	1043.8	1036.4	1000.0	991.7	982.9	973.7

Pre Tax Equity IRR

11%

12.4 Return on Investment/Return on Equity

	Year→	1	2	3	4	5	6	7	8	9	10	11	12
Profit Before Tax	Rs Lakh	-270.7	-235.9	-195.1	-147.4	-91.9	56.8	53.4	145.8	251.8	373.2	984.2	979.7
ROE (Before Tax)	%	-11%	-9%	-8%	-6%	-4%	2%	2%	6%	10%	15%	39%	39%
ROI (Before Tax)	%	-3%	-3%	-2%	-2%	-1%	1%	1%	2%	3%	4%	12%	12%
Tax	Rs Lakh	-46.0	-40.1	-33.2	-25.1	-15.6	9.6	9.1	24.8	42.8	63.4	334.5	333.0
Profit after tax	Rs Lakh	-224.7	-195.8	-162.0	-122.4	-76.3	47.1	44.3	121.0	209.0	309.8	649.7	646.7
ROE(After Tax)	%	-9%	-8%	-6%	-5%	-3%	2%	2%	5%	8%	12%	26%	26%
ROI (After Tax)	%	-1%	0%	0%	0%	0%	0%	0%	0%	1%	1%	4%	4%

13	14	15	16	17	18	19	20	21	22	23	24	25
974.9	969.9	964.6	959.0	953.1	946.8	940.2	933.2	925.8	889.3	881.0	872.3	863.0
38%	38%	38%	38%	38%	37%	37%	37%	37%	35%	35%	34%	34%
12%	11%	11%	11%	11%	11%	11%	11%	11%	11%	10%	10%	10%
331.4	329.7	327.9	326.0	324.0	321.8	319.6	317.2	314.7	302.3	299.5	296.5	293.3
643.6	640.2	636.7	633.0	629.1	625.0	620.6	616.0	611.1	587.0	581.6	575.8	569.7
25%	25%	25%	25%	25%	25%	24%	24%	24%	23%	23%	23%	22%
4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	3%

Average ROE (Before Tax)	22.05%
Average ROI (Before Tax)	6.62%

Average ROE (After Tax)	14.54%
Average ROI (After Tax)	2.25%

13 SWOT ANALYSIS

Non-Conventional Sources, which are renewable in nature, are termed as the alternate sources of energy. The Challenges of the present – energy scenario offer us a window of the opportunity in the form of renewable energy sources.

The Power from the sun is clean, silent, limitless and free. Photovoltaic (PV) process releases no CO₂, SO₂ or NO₂ gases which are normally associated with burning finite fossil fuel reserve and don't contribute to global warming. Solar power shall augment the need of peak power needs & increases the grid reliability i.e., Voltage and frequency. Solar Powered grid connect plants can act as tail end energizers, which in turn reduces the transmission and distribution losses.

- Geographically India is situated at northern hemisphere near the Equator. So India gets maximum solar irradiation and there is ample of scope to produce the power from solar PV. But till now this area is totally virgin area for producing power.
- This is true that solar PV efficiency is very low compared to other power generation systems, Lots of R&D is going on to improve the efficiency. Solar PV generates electricity only at day time, so the proposed solar PV Power plant generates power on an average only about six hours in day time.
- India is potentially one of the largest markets for solar energy in the world. The estimated potential of power generation through solar photovoltaic system is about 20 MW/Sq.km in India. It is useful for providing grid quality, reliable power in rural area where the line voltage is low and insufficient cater to connected load. Recent Government incentives and policies have been providing the momentum for PV in India. The Government of India already declared national Action plan on climate change released in mid 2008, identifies eight critical missions – one of which is the National Solar Mission.
- In comparison to other sources of power generation, the PV solar power is totally dependent in nature. The capacity utilization factor of such type of plant is only 14.6%. Because averagely in the year we get 6 hr sunlight in a day. Only this particular interval solar plant generates electricity.

In comparison to other conventional power generating units, solar power generating unit has many advantages like.

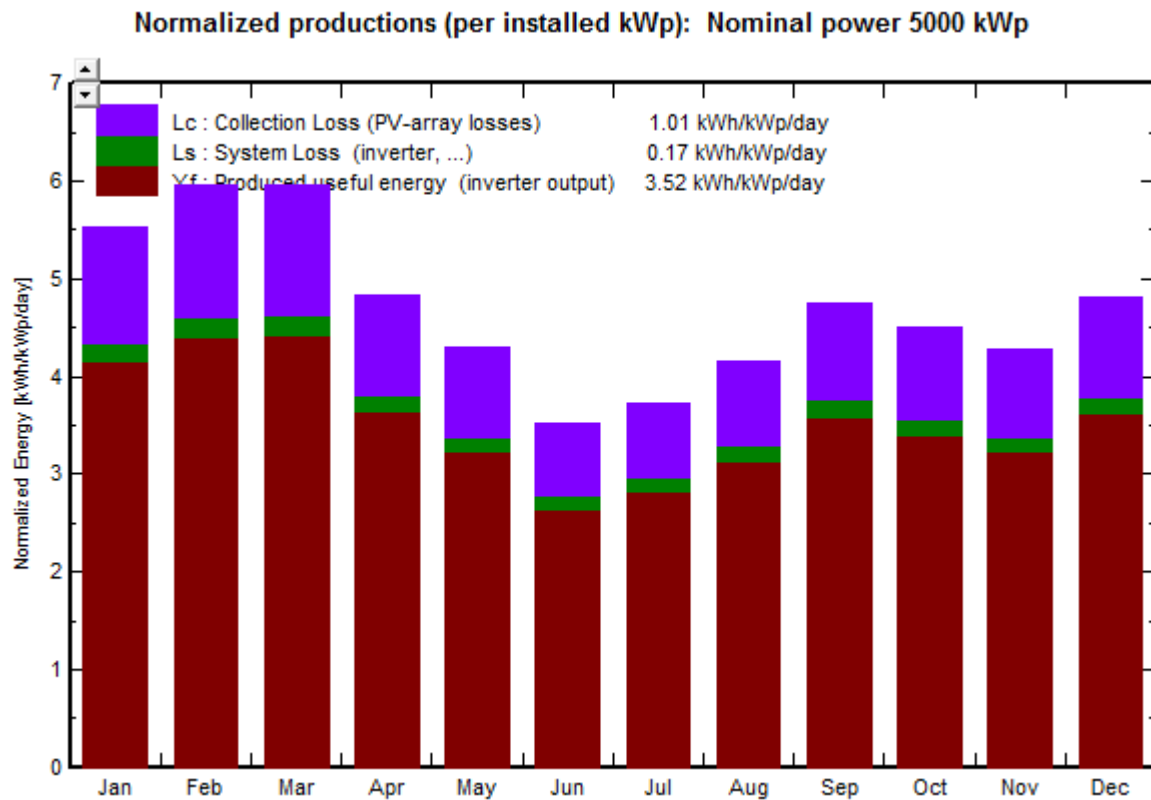
- No fuel is required for power generation.
- Operation & Maintenance Manpower required is less.

- Plant will be running smoothly for a long period as compared to other conventional power generation units.
- In environmental perspective , solar power plant generates clean energy and gets maximum clean development mechanism (CDM) benefit as compared to other conventional power generation units.
- Considering all the above points, solar power generating potential is always ahead of all other conventional power generating units in economical & Environment point of view.

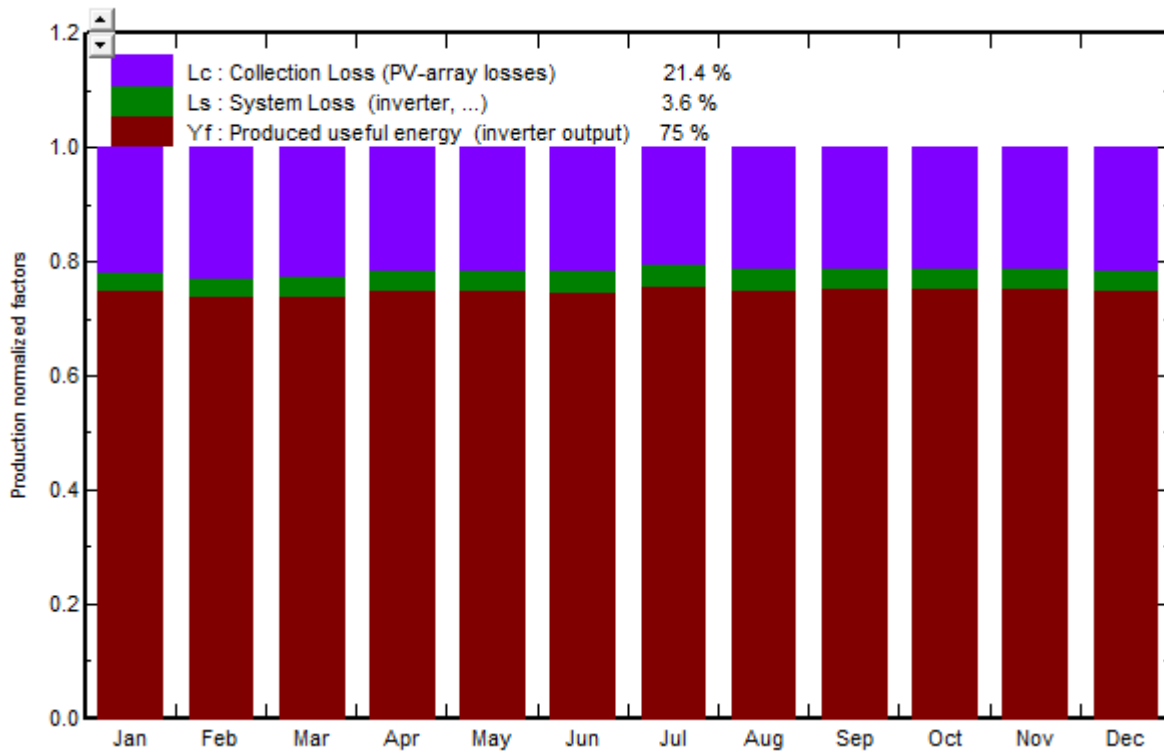
14 APPENDIX I: ENERGY YIELD CALCULATION

Output Energy has been calculated using the following formula:

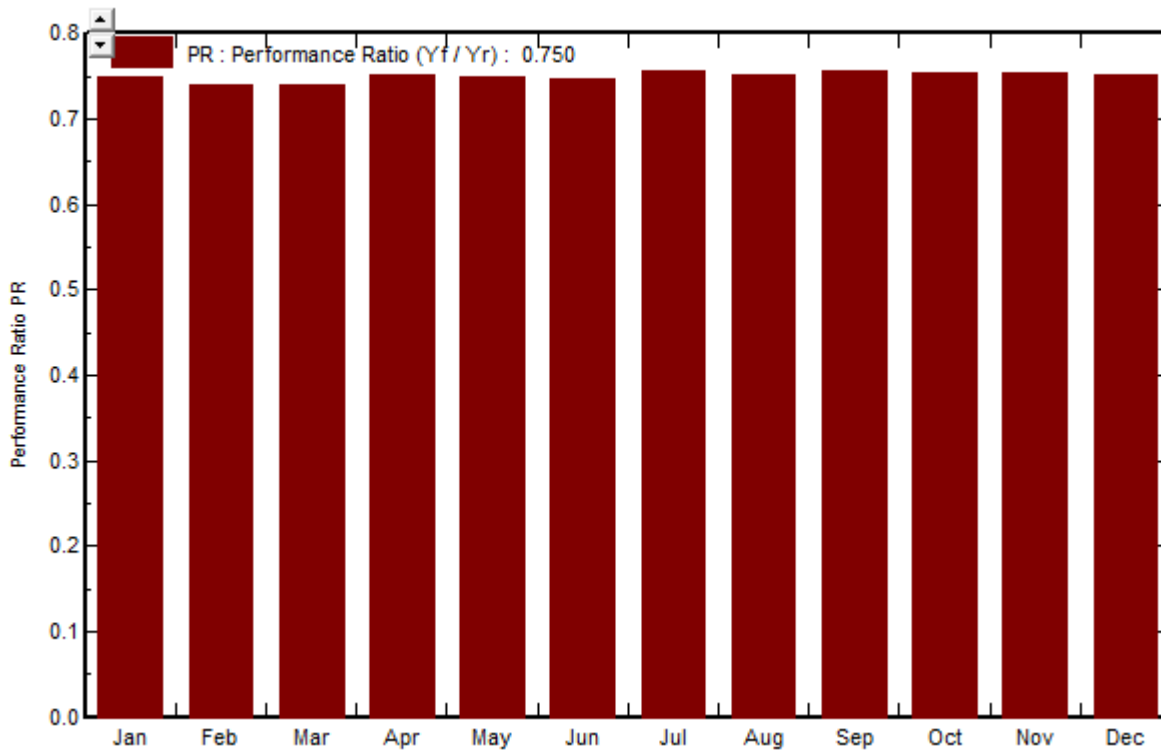
Output Energy = $\text{pcsDI} + \text{pcsBI} \times \text{IAMd} + \text{IAMb} \times \mu$ * Total Area
 pcsDI = plane clear sky diffuse irradiance (PDifCS)
 pcsBI = plane clear sky beam irradiance (PBmCS)
 IAMd = Incidence angle modifier factor for diffuse (IAMDif)
 IAMb = Incidence angle modifier factor for beam (IAMBm)
 μ = efficiency of the PV module for a particular amount of global irradiance on it.
 All the above values are hourly
 PLF/CUF= Yearly Production/365/24%



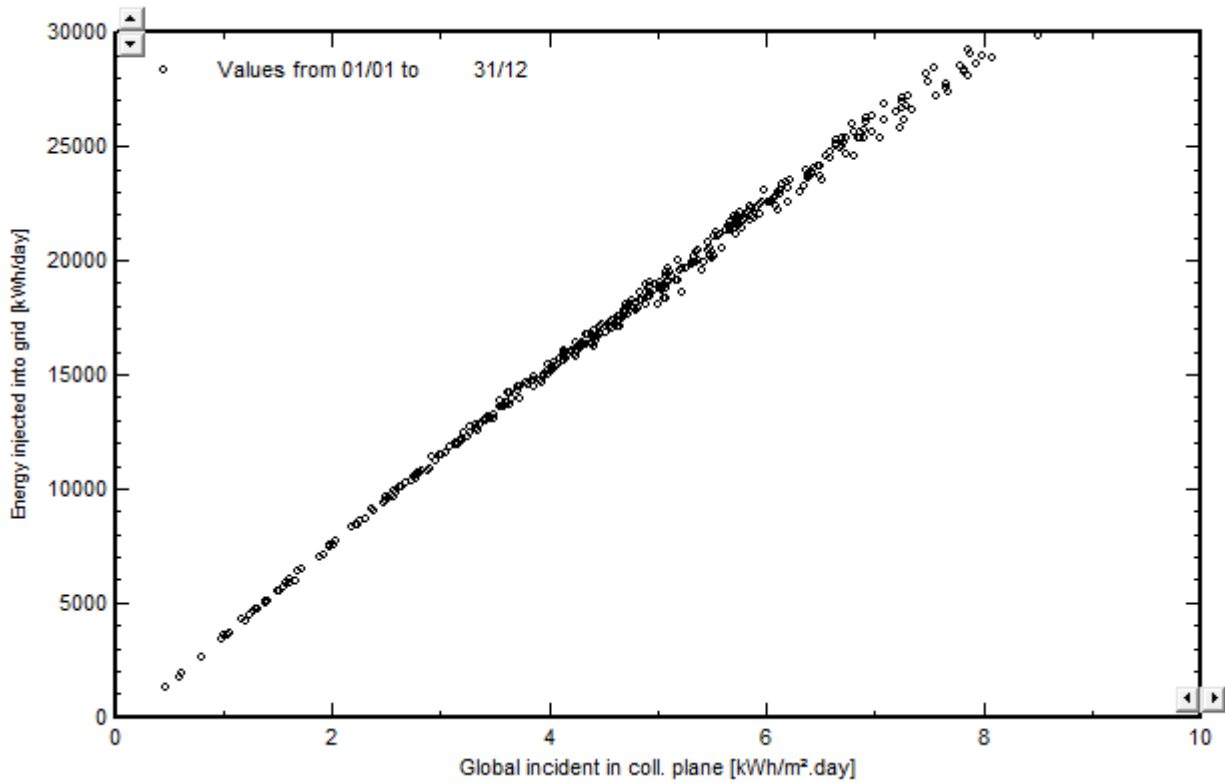
Normalized Production and Loss Factors: Nominal power 5000 kWp



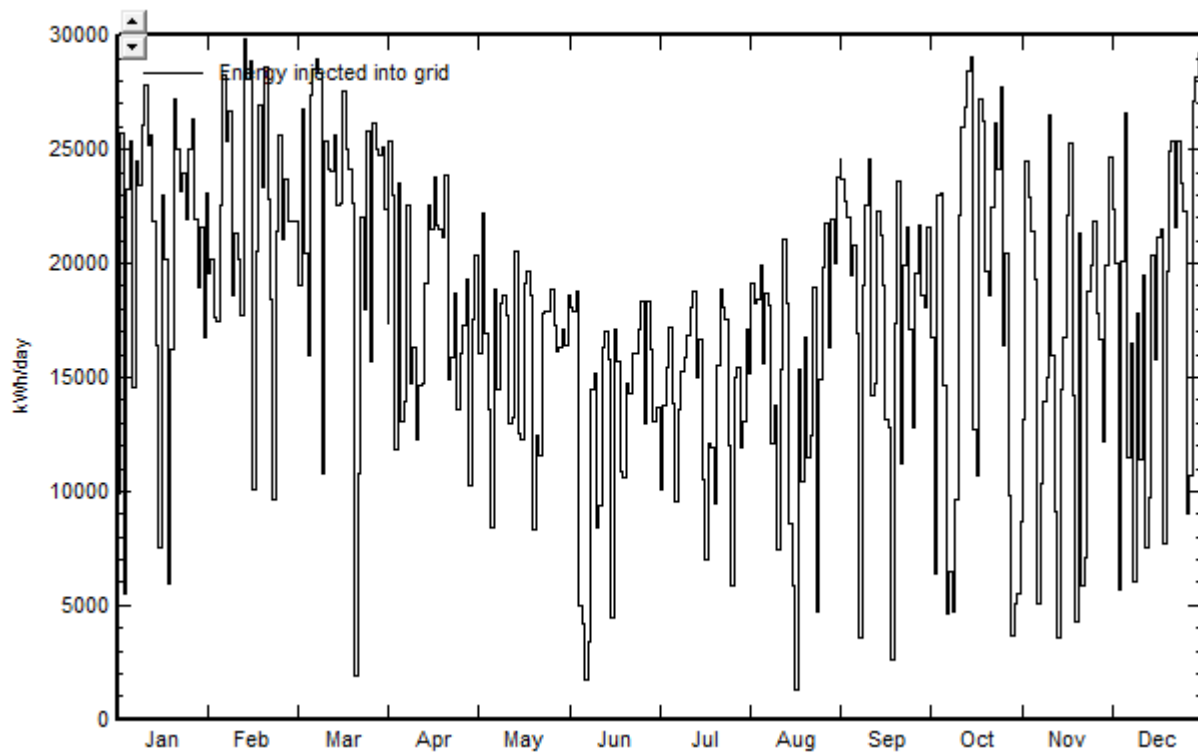
Performance Ratio PR



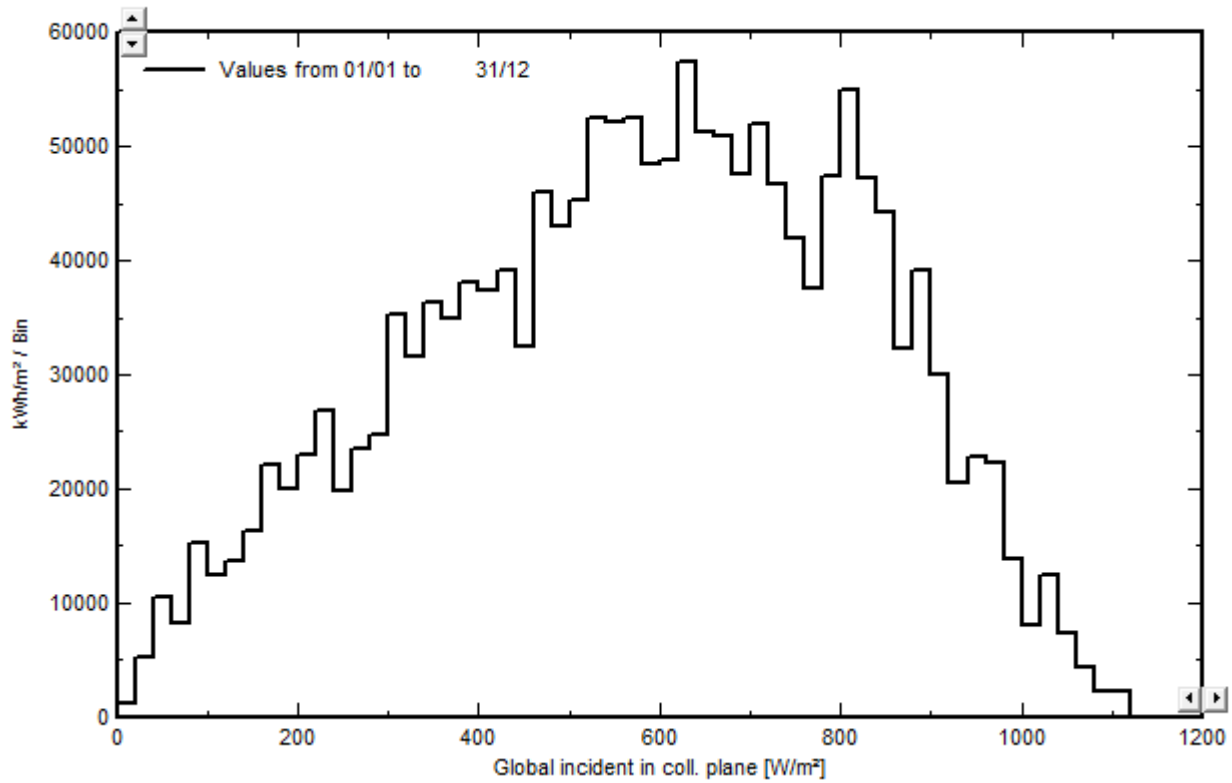
Daily Input/Output diagram



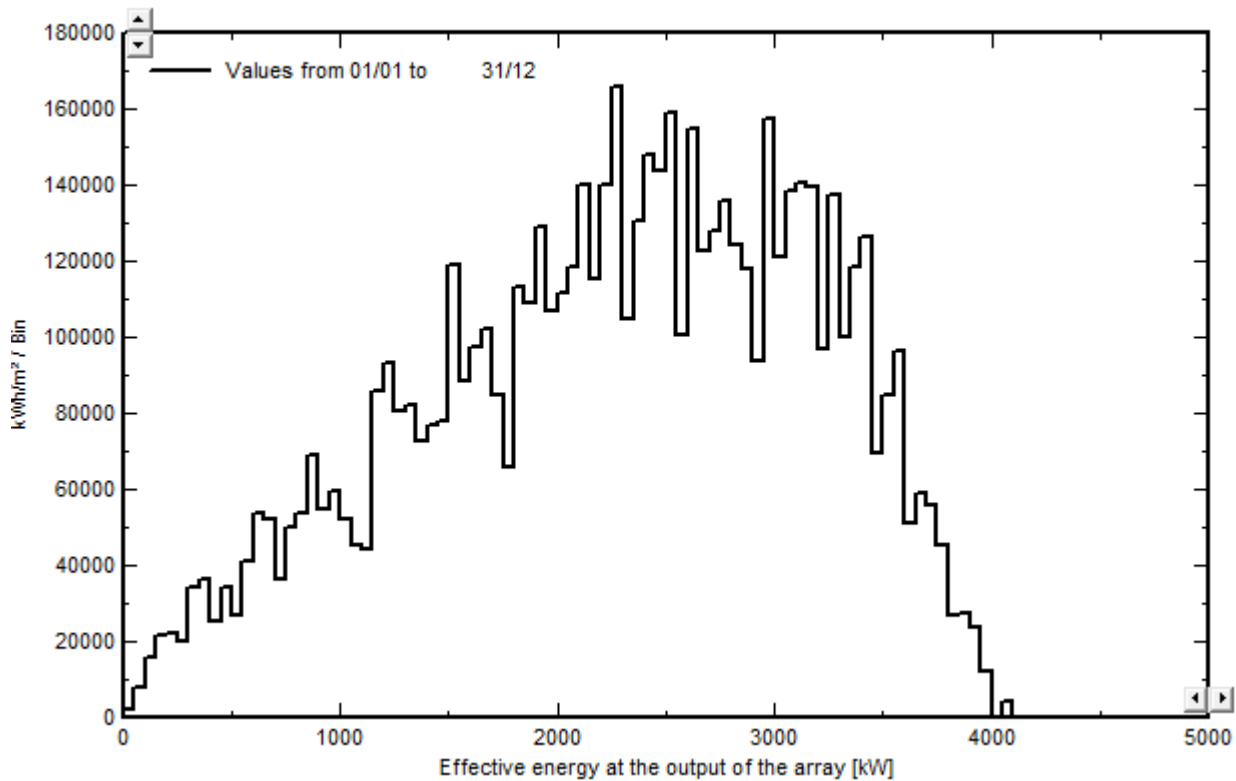
Daily System Output Energy





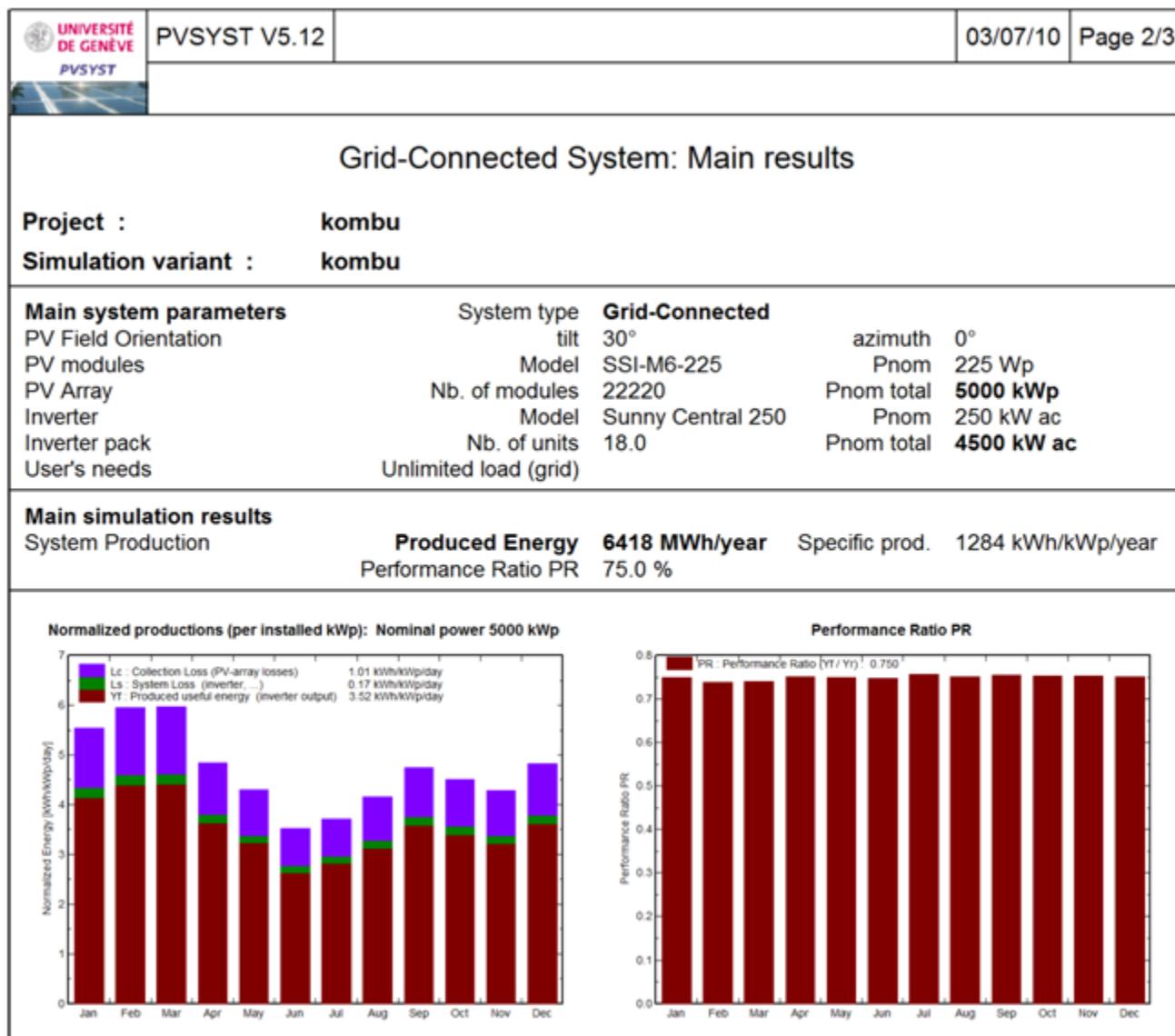
Incident Irradiation Distribution



Array Power Distribution




		PVSYST V5.12		03/07/10	Page 1/3
					
Grid-Connected System: Simulation parameters					
Project :		kombu			
Geographical Site		kombu	Country	India	
Situation		Latitude	8.8°N	Longitude	77.9°E
Time defined as		Legal Time	Time zone UT+6	Altitude	156 m
		Albedo	0.20		
Meteo data :		kombu from NASA-SSE, Synthetic Hourly data			
Simulation variant :		kombu			
		Simulation date 03/07/10 16h55			
Simulation parameters					
Collector Plane Orientation		Tilt	30°	Azimuth	0°
Horizon		Free Horizon			
Near Shadings		No Shadings			
PV Array Characteristics					
PV module		Si-poly	Model	SSI-M6-225	
		Manufacturer	Solar Semiconductor		
Number of PV modules		In series	20 modules	In parallel	1111 strings
Total number of PV modules		Nb. modules	22220	Unit Nom. Power	225 Wp
Array global power		Nominal (STC)	5000 kWp	At operating cond.	4519 kWp (50°C)
Array operating characteristics (50°C)		U mpp	540 V	I mpp	8363 A
Total area		Module area	36818 m²		
Inverter		Model	Sunny Central 250		
		Manufacturer	SMA		
Characteristics		Operating Voltage	450-820 V	Unit Nom. Power	250 kW AC
Inverter pack		Number of Inverter	18 units	Total Power	4500 kW AC
PV Array loss factors					
Thermal Loss factor		Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
=> Nominal Oper. Coll. Temp. (G=800 W/m², Tamb=20°C, Wind velocity = 1m/s.)		NOCT		56 °C	
Wiring Ohmic Loss		Global array res.	1.1 mOhm	Loss Fraction	1.5 % at STC
Module Quality Loss				Loss Fraction	2.0 %
Module Mismatch Losses				Loss Fraction	2.0 % at MPP
Incidence effect, ASHRAE parametrization		IAM =	1 - bo (1/cos i - 1)	bo Parameter	0.05
User's needs :		Unlimited load (grid)			



kombu Balances and main results

	GlobHor	T Amb	GlobInc	GlobEff	EArray	E_Grid	EffArrR	EffSysR
	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	%	%
January	150.0	26.10	171.6	167.2	673041	643020	10.65	10.18
February	156.2	26.80	166.8	162.2	645016	616477	10.51	10.04
March	190.3	27.30	185.1	179.2	716882	685039	10.52	10.05
April	165.6	26.80	145.1	139.7	570871	545011	10.68	10.20
May	164.6	26.90	133.4	127.7	524797	500563	10.68	10.19
June	133.8	26.30	105.8	101.1	416363	395529	10.69	10.15
July	140.4	25.90	115.3	110.4	458715	436584	10.81	10.28
August	151.0	25.90	129.1	124.1	509474	485275	10.72	10.21
September	153.9	26.00	142.6	137.7	564161	538538	10.74	10.26
October	137.0	25.80	140.0	135.8	552485	526922	10.72	10.22
November	119.1	25.90	128.5	124.8	507342	484027	10.73	10.23
December	131.1	26.00	149.4	145.4	587134	560691	10.68	10.19
Year	1793.0	26.31	1712.7	1655.2	6726281	6417676	10.67	10.18

Legends:	GlobHor	Horizontal global irradiation	EArray	Effective energy at the output of the array
	T Amb	Ambient Temperature	E_Grid	Energy injected into grid
	GlobInc	Global incident in coll. plane	EffArrR	Effic. Eout array / rough area
	GlobEff	Effective Global, corr. for IAM and shadings	EffSysR	Effic. Eout system / rough area

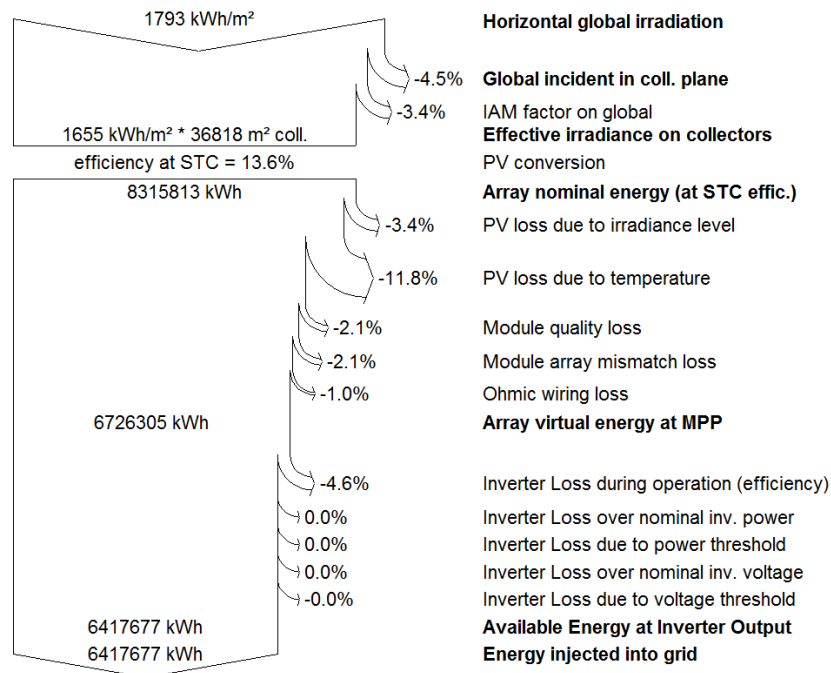
 UNIVERSITÉ DE GENÈVE PVSYS	PVSYS V5.12		03/07/10	Page 3/3
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Grid-Connected System: Loss diagram

Project : kombu
Simulation variant : kombu

Main system parameters	System type	Grid-Connected		
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	SSI-M6-225	Pnom	225 Wp
PV Array	Nb. of modules	22220	Pnom total	5000 kWp
Inverter	Model	Sunny Central 250	Pnom	250 kW ac
Inverter pack	Nb. of units	18.0	Pnom total	4500 kW ac
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



15 APPENDIX II: EPC CONTRACTOR: PAN EXERGY-ENGINEERS INDIA LTD.

PAN Exergy Private Limited

PAN Exergy is a technology agnostic and knowledge intensive niche consulting house, lead by a team of dynamic IIT & IIM graduates offering innovative services & technology solutions in the field of Renewable Energy & Energy Efficiency. Exergy was founded with the strong vision of adopting a leadership role in solving today's key issues of energy crisis and climate change.

We operate at the centroid of Energy, Environment & Finance – a niche which allows us to offer a comprehensive solution to our client for fostering sustainable development. With narrow windows of opportunity and complex regulatory requirements—all accompanied by a multitude of financial implications and options—Exergy provides the tools and expertise need to realize the technological and economic opportunities global markets present.

- ❖ Head Quartered in New Delhi, India
- ❖ Branches in Kharagpur, Ahmedabad & Hyderabad
- ❖ Leading Solar Infrastructure Service Provider with a clientele of 180MW SPV & CSP.
- ❖ Only company offering PINCH technology services (Process Optimization)
- ❖ Partners with of the largest CDM development company in the world
- ❖ Extensive network of partnership.
- ❖ Registered with Ministry of New & Renewable Energy, GoI.
- ❖ Associated with Engineers India Ltd (EIL) for Solar EPC Contracts

Exergy provide services like **Lumpsum Turn Key EPC Services** for Solar Farm development, Project Conceptualization & Documentation including Bankable Detailed Project Reports, Application Support for JNNSM Projects, Technology & Site Assessments, Project Management, Procurement, and Construction upto Commissioning & Plant Start-up Assistance and O&M services.

Backed by institutions like IIT Kharagpur, IIT Delhi, PAN-IIT Forum & IIM Bangalore, Exergy has a strong clientele & partner base, which includes GAIL, TATA Steel, ITC, LG, Indian Railways, MNRE, Air India, ACC Cement, Honeywell, Wipro EcoEnergy, Green-O-Lite, Green Brilliance etc.

Our Clients



GAIL (India) Limited

Chemtrols Industries Limited

From Monitoring to Management of Process, Environment and Utilities



Ispat Industries Limited



5 MWp Solar PV Power Generation – Detailed Project Report



5MW Manufacturing Unit at Baroda, Green Brilliance

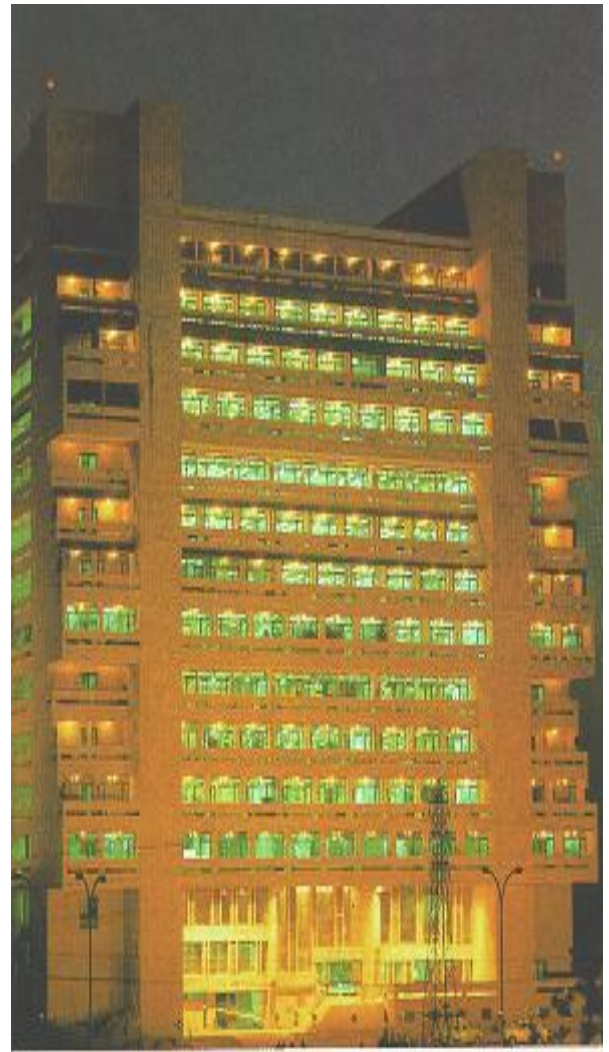


Grid Tied 10KW Crystalline Solar PV installed at Mumbai.

Engineers India Limited (EIL)

Engineers India Limited, a Govt of India Undertaking, was established in 1965 to provide engineering and related technical services for petroleum refineries and other industrial projects. In addition to petroleum refineries, with which EIL started initially, it has diversified into and excelled in other fields such as solar energy, pipelines, petrochemicals, oil and gas processing, offshore structures and platforms, fertilizers, metallurgy and power. EIL now provides a complete range of project services in these fields and has emerged as Asia's leading design and engineering Company having executed 4300 assignments. Engineers India Limited is diversifying into several new areas including Highways & Bridges, IT, Airports, Mass Rapid Transport Systems, Ports & Terminals, Power Projects, Non-conventional / Renewable Energy Sources, Specialist Materials and Maintenance Services, Intelligent Buildings, Water and Urban Development projects.

EIL provides the complete range of services needed to conceptualize, design, engineer and construct projects to meet the specific requirements of its clients. Its association with the clients extends beyond the commissioning of their plants through monitoring operation of each plant and accumulating feedback on performance. Lumpsum Turnkey Contracts from concept to commissioning is an area into which EIL has its presence in a big way. EIL's quality management systems in respect of its services have been assessed and upgraded to ISO 9001:2000 version. Besides its Head Office at New Delhi, EIL has branch office at Mumbai, zonal office at Kolkata, regional offices at Chennai and Vadodara and inspection offices at all major equipment manufacturing locations in India for smooth execution of the project. It also has overseas offices at London, Abu Dhabi, Kuwait, Qatar, Malaysia and Australia. EIL has a large number of site offices in India and abroad. EIL has two wholly owned subsidiaries, EIL Asia Pacific Sdn Bhd in Malaysia and Certification Engineers International Ltd. for undertaking independent certification & third party inspection assignments



EIL Headquarters at N-Delhi

Exergy-EIL Association

Exergy & Engineers India Ltd (EIL), have joined hands for providing Lumpsum Turnkey (LSTK) EPC services for setting up MW sized grid connected Solar Farms for Investors and Project Developers under the Jawaharlal Nehru Solar Mission Plan (JNNSM). The collaboration has already attracted large number of Project Developers (a cumulative capacity of more than **180 MW project proposals**) bidding under various State Schemes & 1st Phase of JNNSM. The Joint Association is also pursuing India's largest Grid Connected **2MW Rooftop** PV installation. Two of our DPRs, prepared for Orissa, have already been approved under migration scheme. The Alliance offers its services for Technical Feasibility Studies, Bankable Detailed Project Report (DPR), Project Management, Procurement, Construction upto Commissioning & Plant Start-up Assistance and O&M services.

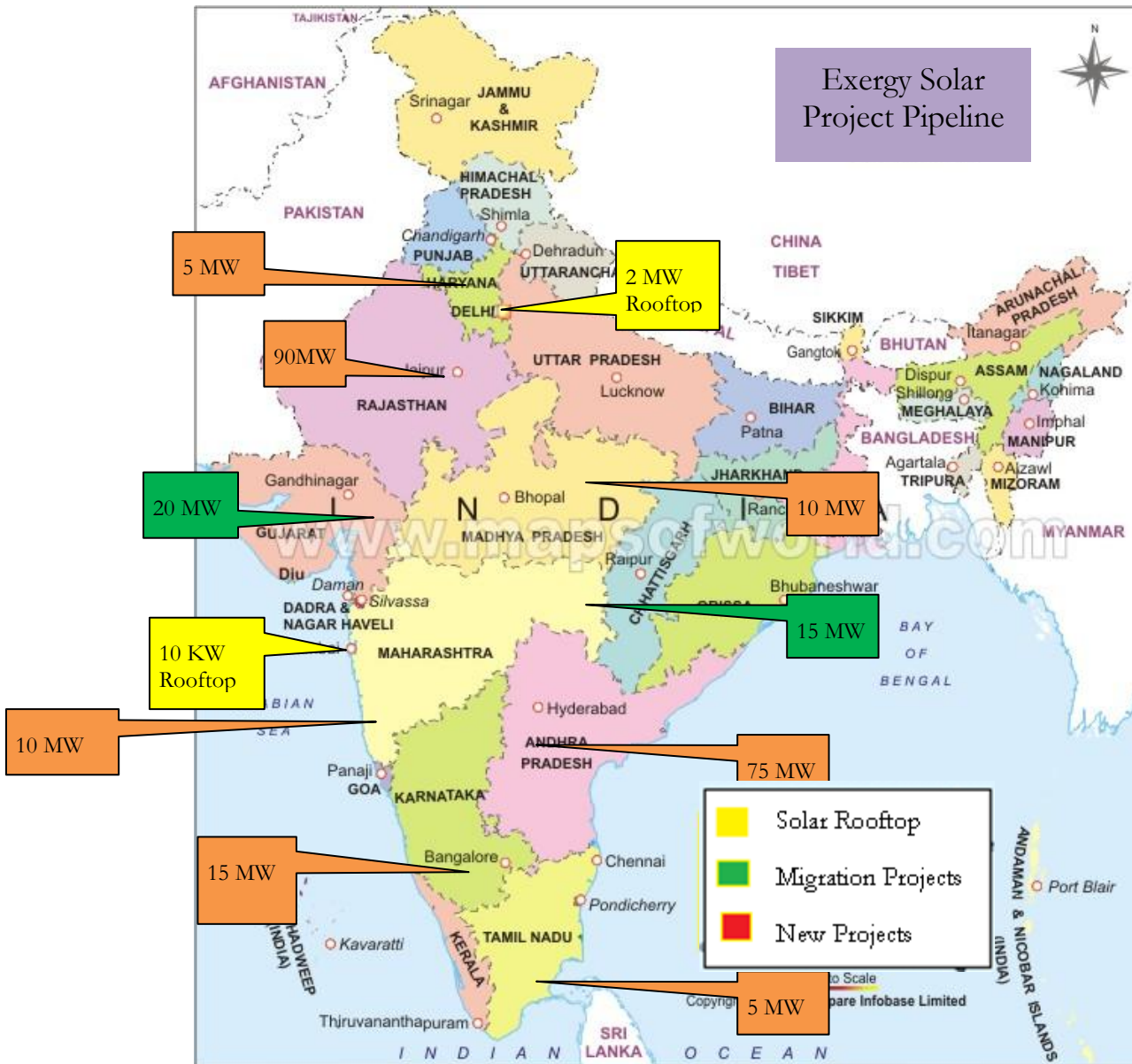
Some of the specialized services would be Cost Engineering (due to dynamic pricing model of PV modules & CSP technology) and Advanced Automation through 'Continual Production Monitoring'. This would be done through Operational Call Centers (OCC). The OCC Analysts will measure and verify the performance of all solar PV installations remotely. Quick remedial measures can be taken if the system is under-performing. Further, they will provide PV/CSP fleet performance and production on a secure, online dashboard or portal. We offer all these services in both **Solar PV & Solar Thermal** Domain

We are using all the three prevalent Solar PV Technologies based on the requirements of the client

- Crystalline Silicon (Multi/ Mono)
- Amorphous Silicon Thin Films
- Concentrated Photo Voltaic (CPV),

For solar thermal we are using Parabolic Though, Solar Tower & Dish Design technologies

Exergy-EIL Alliance is currently working with one of the largest portfolio of Project EPC Contracts, totaling to about 280MW both for Solar Thermal & Photovoltaic. Among our clientele are India's well recognized Industrial Conglomerates.



Exergy EIL EPC services (Non Exhaustive)



EXERGY

SPECIALIZING IN RENEWABLE ENERGY PROJECT DEVELOPMENT



DEFINING LEADERSHIP FOR SUSTAINABILITY