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Solar Park of 2000 MW Capacity in the State of Karnataka, India

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Detailed Project Report (DPR)

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1. Executive Summary

Solar energy is the most readily available source of non-polluting renewable energy resource. It could be utilized in two ways viz. direct conversion in to electricity through solar photovoltaic (PV) cells and indirect conversion through generating high temperatures by concentrating collectors and thereby run the steam turbine in line with a conventional thermal power plant. The uniqueness of the solar technologies is that it offers a wide range of applications in solar PV as well as solar thermal technology in which case, the generated heat could be used for domestic as well as industrial applications and power generation.

India being a tropical country is blessed with good sunshine over most parts, and the number of clear sunny days in a year also being quite high. India is located in the sunny belt of the world. As per Ministry of New and Renewable Energy (MNRE), Government of India (GoI), the country receives solar energy equivalent to more than 5,000 trillion kWh per year with a daily average solar energy incident over India which varies from 4.0 to 7.0kWh/m^2 depending upon the location. India's equivalent solar energy potential is about 6,000 million GWh of energy per year[1]. Hot and Dry climatic regions have the best solar radiations in the country with around 300 sunny days; which makes these region very appropriate locations for harnessing solar energy.

Jawaharlal Nehru National Solar Mission (JNNSM) has targeted 20000 MW by the year 2022 which has been revised up to 100 GW by the Government of India. In addition to JNNSM; there are several states in India; which are implementing their own Solar Power Policies. Karnataka is one of the states in India which is implementing multi MW capacity projects in the state under the state policy of solar power generation. In order to give more comfort to project developers the Government of India is promoting the approach of Solar Parks; which will be developed in line with the SEZ for solar project developers. In the Solar Park the required land and essential infrastructure (connectivity, water and power evacuation etc.) will be furnished by Government to the developers. In the state of Karnataka the state nodal agency Karnataka Renewable Energy Development Agency (KREDL) is taking care of its Solar Power Policy and initiative towards developing Solar Parks in the state.

There are around five Solar Parks proposed in the state of Karnataka and around 25 such parks across the country in association with the Solar Energy Corporation of India (SECI); Government of India. KSPDCL has taken the advance initiative in the Tumkur district to develop the first Solar Park of the state of the cumulative capacity of 2000 MW and the nodal agency for the development of the solar park is Karnataka Solar Power Development Corp. Ltd (KSPDCL). The power evacuation facilities from Solar Park will be furnished by Power Grid Corporation of India Limited (POWERGRID).

KSPDCL has selected the land in Pavagada Tehsil of Tumkur district of the state of Karnataka. Presently around 14000 acres of the land has been identified for which the acquisition process has been started. The selected land required less amount of civil work and well addresses the essential requirements of Solar Park. It has been noticed that the selected location satisfies most of the essential requirements towards setting up a Solar Park in the vicinity. The project is planned with multi-crystalline and CdTe based Thin Film Solar PV technologies (which are the well mature and proven technology across the globe) along with central type inverter for minimum project capacity of 50 MW. The present Detailed Project Report (DPR) contains all key aspects of a Solar Park of the capacity of 2000 MW in the Tumkur District of the state of Karnataka, India. The DPR contains covers the following major dimensions of the proposed project.

SITE ASSESSMENT

This section establishes the criteria for site assessment for establishing the Solar Park via addressing the key requirements and exhumations. The selected land (around 14000 acres at present stage) for Solar Park establishment is located in five village's namely Valluru, Rayacharlu, Balasamudra, Kyathaganacharlu and Thirumani of Pavagada Taluk of Tumkur district of the state of Karnataka. The site assessment section addresses the connectivity and accessibility (road/ rail/ air) aspects of the region. Pavagada comprises established road connectivity as the State Highway (KA SH 03) passes from the city and connect it from Madugiri to Chikkahalli. The climatic and rain fall details of the vicinity has been addresses using secondary

[1] http://www.mnre.gov.in/information/solar-rpo/

data. The region receives least rainfall across the year i.e. around 600 mm. The section also addresses the Geomorphology, Soil, Hydrogeology and Seismic aspects of the selected region based on the secondary data. The selected location of Pavagada taluk is essentially dry and contains minimum rainfall in the state; hence surface water is scarily available. There are few water bodies adjacent to state highway and connected to the selected land for Solar Park by KSPDCL which are being used for irrigation application of agro-cultivation. The construction water demand for Solar Park could be met through such water bodies after getting NoC from concern authorities. Additionally the supply leg could be met through water tankers from nearby other water sources or bore wells. No requirement of detailed shading assessment has been observed at the location.

The proposed 2000 MW Solar Power would be developed in eight blocks of 250 MW capacity. For each 250 MW Solar Power capacity block, one pooling substation of 66/ 220 kV is proposed in which 2 x 150 MVA step-up transformers are considered. 250 MW block is further subdivided into 50 MW sub blocks. Thus, these 5 X 50 MW sub blocks shall be connected to pooling substation through 66 kV underground cables. The voltage will again be stepped up to 220kV at the Solar Project Pooling Station and again stepped up to 400kV at the proposed 400kV Grid Substation by POWERGRID at Solar power. Karnataka Solar Power Development Corporation Private Limited (KSPDCL)(JV of SECI and KREDL) will establish 8 Nos. of 220/66kV pooling stations at Pavagada site to evacuate 2000MW solar power generated at the Park. The 400kV Grid substation at the Solar Project is proposed to be connected to POWERGRID's 765KV Station at Madhugiri. The entire selected land for establishment of Solar Park of 2000 MW capacity has been found technical suitable.

SOLAR RADIATION RESOURCE ASSESSMENT

The selected project location is in 'Hot and Dry' climatic zone of the country and hence experiences high solar irradiance (high DNI as well) and high ambient temperature. This feature of the location makes it well favorable locations for solar PV technologies. There is no Automatic Weather Station (AWS) of Indian Meteorological Department (IMD), Government of India at Tumkur district which could be explored for long term meteorological data. Bangalore is the nearest meteorological location of IMD; but located in different climatic zone and more than a distance of 150 km.

A detailed analysis of solar radiation resource assessment has been carried out for the location of Pavagada (Tumkur). All available static and dynamic (time series) weather databases which cover ground data, satellite data and interpolated data have been explored. National Institute of Wind Energy (NISE- initially known as C-WET); a nodal agency of MNRE has recently implemented its AWS at six districts of the state of Karnataka namely under Bellary, Belgaum, Gulbarga, Bijapur, Chitradurga and Mysore under its Solar Radiation Resource Assessment (SRRA) programme. The satellite data from National Aeronautics and Space Administration (NASA), National Renewable Energy Laboratory (NREL) and Solar and Wind Energy Resource Assessment (SWERA), RETScreen have been taken from their sources for project location. In addition to this the time series data of the sources Meteonorm 6.0, Meteonorm 7.0 and SolarGIS have also explored for the selected location. The solar radiation data from all sources has been presented on monthly average daily and monthly formats. Using ECOTECT computer software the stereographic sun-path diagram has been developed for the selected project location which gives an idea about availability of sunshine hours as well as profile of sun-earth angles at the location.

It orders to optimize the representative solar radiation database statistical analysis has been carried out. The correlation coefficient of all databases with respect to the IMD (Ground) data has been carried out in which the Meteonorm 7.0 database has been found closer to the ground data at Pavagada (Tumkur). The statistical analysis has been further followed by the intensity distribution of the solar radiation through all databases using D-VIEW computer software for which all static and dynamic databases have been converted in Typical Meteorological Year (TMY) format. It has been observed that the project location receives monthly average daily solar irradiance of 4.81 **kWh/m^2**(August) to **6.55 kWh/m^2** (March). The annual GHI is 2008 kWh/m^2 (annual average daily 5.50 kWh/m^2) which contains 826 kWh/m^2 (annual average daily 2.26 kWh/m^2) diffuse component (around 41%). The climatic study has also been carried out taking hourly profile of climatic parameters namely ambient temperature, relative humidity and prevailing wind speed. A spectral pattern of the climatic parameters has also been addressed using D-VIEW. The annual average values of ambient temperature, relative humidity and wind speed has been observed as 26.59^{o}C, 62.2% and 2.5 m/s respectively using Meteonorm 7.0 weather database.

SOLAR PV TECHNOLOGY ASSESSMENT

Solar PV Modules and Inverters are the key components of any grid connected solar PV power plant. The global overview of solar PV technologies have been presented in the DPR via addressing their technical basis, advances and limitation, market shear (global and national), manufacturing, growth and projection and status of commercialization etc. The inter-comparability of all technologies has been made qualitatively as well as quantitatively. Multi-crystalline solar PV module technology has been observed best option for Tumkur which can address all challenges of the vicinity. The global market scenario of solar PV modules has been elaborated with the present status of solar PV module manufacturing in India.

The minimum project size in the Solar Park has been selected as 50 MW. The multi-crystalline solar PV technology has been observed as optimum for the location; however the CdTe based thin film solar PV technology has also been recommended taking in to consideration the high temperature and high diffuse irradiance profile of the vicinity. In order to make the sizing of the Solar Park; two TIER-1 manufacturers of solar PV module technologies have been selected representing both categories;

- Canadian solar (multi-crystalline)
- First Solar (CdTe based thin film)

In the same line the TIER-1 inverter manufactured by SMA (the largest global inverter manufacturer) has been selected for basic designing of the Solar Park. The open type inverter has been recommended.

ENERGY YIELD ESTIMATION

The energy yield estimation has been made of the minimum project size of 50 MW capacity under both the cases of using multi-crystalline and CdTe based thin film technologies. The simulation exercise provides the base of sizing the plant and hence the Solar Park over the selected area of 14000 acres. The preliminary energy yield estimation has been carried out through RETScreen computer software while the detailed (hour to hour) analysis was made using PVSYST. Using PVSYST software (Ver. 6.2.6), the intensity of solar radiation over fixed axis inclined surface towards south (equator) has been assessed.

The tilt and orientation along with inter row spacing has been optimized. The tilt angle of 15 degree towards equator (i.e. south) has been observed optimum which augments the annual solar radiation intensity from 2008 kWh/m² to 2098 kWh/m² without any optical losses. The inter-row spacing has been finalized through ECOTECT drawings in Auto CAD environment through inter row shading analysis. The Yield assessment section addresses solar and meteorology data, orientation and tilt angle of solar PV modules, major components, namely solar PV module(s) and solar inverter, technical losses in SPV system, capacity utilization factor (CUF), annual degradation, uncertainty analysis and probability of exceedance (PoE).

Using the TIER-1 manufacturers of the key components following models and inverters have been chosen for energy yield estimation and project design.

- Solar PV Modules - CS6X-300P of Canadian Solar (multi-crystalline)
- Solar PV Modules - FS-3100 of First Solar (CdTe based Thin Film)
- Solar Inverter - Sunny Central 1000CPXT (rating of 1000 kW)

Using multi-crystalline solar PV technology the capacity utilization factor (CUF) of the 50 MW project varies from 15.31% in July to 21.72% in March; however the annual CUF has been estimated as 18.90%; which is closer to the benchmark value of 19% considered by central electricity Regulatory Commission (CERC), Government of India for annual tariff determination for grid connected solar PV power projects.

In case of Thin Film solar PV technology; the CUF of the project varies from 15.17% in July to 22.23 % in March; however the annual CUF has been estimated as 18.96%. Optimizing the DC/AC ratio the CUF of the project may increase at the project designing stage. Taking in to account the annual degradation (i.e. 0.65% for crystalline and 0.70% for thin films per annum linear) the life cycle energy generation has also been presented in the section.

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

The Solar Park is essentially being developed for Solar PV power projects which work on solar energy which is non-polluting source of energy; however there might be several dimensions of project implementation where ESIA and SIA aspects are essential to address as per the applicable acts. The initial ESIA / SIA aspects of the

Solar Park project are briefly addressed in this section. The key dimensions of the ESIA for large Solar Park have been addressed in this section with brief elaboration of the eight performance of International Finance Corporation (IFC) for project evaluation. IFC's Categorization of Projects

- Category B Projects: Projects with potential limited adverse social or environmental risks or/and impacts that are few in number, generally site-specific, largely reversible and readily addressed through mitigation measures;
- Category C Projects: Projects with minimal or no adverse social or environmental risks or/and impacts, including certain financial intermediary (FI) projects with minimal or no adverse risks;
- Category FI Projects: All FI projects excluding those that are Category C projects.

The section also elaborates the ADB's Environment Categorization of Projects. A detailed ESIA has been recommended which could be used by the various project developers at the stage of their financial closure of the projects. The possible environmental impacts over the Solar Park during the construction and commissioning phases have been elaborated. The mitigation majors have also been described with the dimensions of corporate social responsibility of KSPDCL.

CONCEPT PLAN OF SOLAR PARK

The concept of Solar Park is essentially optimizing the infrastructure cost of the solar PV power projects. In solar PV power projects the cost of infrastructure (land, connectivity, power evacuation etc.) varies from 15-25 percent. In this section the approach of the Solar Park has been developed from the point of view of Civil and Electrical aspects. The section addresses the technical aspects of land availability and acquisition, solar resource, infrastructure (Power Evacuation and Availability of water etc.), Financing and Project Implementation etc.

The overall vision of the Solar Park has been described in the section. The basis of the planning along with the factors for planning are elaborated under the dimensions of sizing of the plots in the solar park, approach of connectivity and accessibility, network, circulation, roads, water pipeline (if required), drainage and firefighting arrangements etc. The utility areas, multiple facilities at Solar Park along with the provision for the Green Belt have been addressed. Taking in to account each dimension in the design approach the estimation of the land required under each head has been made in this section. This section essentially establishes overall background of the design of Solar Park and segmentation of land for multiple aspects.

INFRASTRUCTURE PLAN OF SOLAR PARK

This section elaborates the infrastructure development over the conceptual plan of the Solar Park. There are five key dimensions of infrastructure addressed in the section viz. Site preparation (leveling, cleaning, plantation for dust deposition and wall with gates etc.), Land (survey, soil investigation and geotechnical aspects etc.), Roads & Network (major and minor roads of different width), Power Evacuation & Transmission (metering system, construction power arrangements and transmission substation etc.) and Water Supply Systems (Water Requirement for Module Washing and Other Purposes, Water Requirement for 2000 MW Solar Park, Source and storage of Water and Requirement of Water Treatment etc.).

PROJECT COST ESTIMATES

This section addresses the cost of various milestones towards developing the Solar Park. The cost section has been divided in major sun sections namely the land, side development, roads and drainage, water supply, power evacuation and other essential establishments. The basis of the cost of various above segments have been mainly taken from the latest quotation of Various Bidders for other Contemporary projects, house database of the consultant, Benchmark costs of CERC/ SERCs for solar PV power projects, Project cost of similar 50 MW Solar PV Projects in India at present and discussion with professionals of EPC companies of solar PV projects etc. In this section each segment has been elaborated with the key activities and the associated limitation. The land is proposed to purchase on the annual lease basis of Rs 23100 per acres with 5% escalation on base year lease every second year; however the current price of the private land in the vicinity has also been presented from the ongoing practices in the vicinity. Around 89 bore wells have been estimated for water supply in the field. Their costs with RO systems have been estimated from multiple market references. The length of wall, roads (two types of 8.5meter and 4.5 meter widths), 220 kV transmission line, etc. have been measured from plant layout and the cost has been estimated accordingly for the cumulative capacities. Detailed costing of 8 numbers of 220/66 kV substation, 200 kV transmission line and 400 /220 kV substation has been given with their elaborated bill of material. The cost of administrative building, warehouses, training center etc. have been estimated from best market practices in solar power projects. In addition the present cost (recently commissioned projects) of solar PV power projects with multi-crystalline and thin film technologies in India has been given with detailing from in house data.

KEY RECOMMENDATIONS

The key recommendations to KSPDCL to develop the Solar Park of 2000 MW in effective techno-commercial way have been mentioned in this section. The approach of developing the park in multiple lots of 250 or 500 MW capacities has been suggested which will reduce the project implementation duration.

Table 1 below presents the key insights of the Solar Park of the capacity of 2000 MW in Tumkur district of the state of Karnataka, India.

Table 1. Project at a glance

S. No	Particulars	Description
1.	Project site	Pavagada
2.	District Name	Tumkur
3.	Name of the State	Karnataka
4.	Geographical coordinates	Latitude 14.1°N and Longitude 77.27°E
5.	Meteorological data source for system sizing and EYA	Meteonorm 7.0
6.	Type of system	Fixed axis (inclined at latitude) facing south
7.	Tilt angle of solar PV Modules	15 degree due south
8.	Data format	Hourly in Typical Meteorological Year (TMY) format
9.	Daily average Global Solar Irradiance	5.50 kWh/m²
10.	Annual Global Solar Irradiance	2008 kWh/m²
11.	Daily average diffuse irradiance	2.26 kWh/m²
12.	Annual diffuse irradiance	825 kWh/m²
13.	Annual average ambient temperature	26.59°C
14.	Annual average relative humidity	62.2%
15.	Annual average wind speed	2.5 m/s
16.	Land availability (acres)	More than 14000 acres
17.	Land quality	Barrein and non-agricultural land
18.	Connectivity and accessibility	Well establishes and adjacent to Sate highway-03 of Karnataka
19.	Minimum plant size capacity	50 MW
20.	Minimum plot size (acres)	250 acres
21.	Nearest airport	Bangluru
22.	Nearest railway station	Hindupur Railway station (52 KM), Anantapur Railway station (101 KM) and Bellary (137 KM) are the nearest Railway Stations
23.	Solar PV Technology	Multi-crystalline solar PV /Thin Film
24.	Solar PV Module Manufacturers	Canadian Solar First Solar

25.	Solar PV Models	Canadian Solar - CS6X-300P		FS-3100	
26.	Rating of selected solar PV Modules	300 Wp		100Wp	
27.	Total number of solar PV Modules (50 MW)	166668		499995	
28.	Overall DC capacity of the project	50 MWp and for 40 units -2000MWp			
29.	Total Module Area Requirement	Multi-crystalline		Thin Film	
		12792280 m²		**14399840** m²	
30.	Inverter (Type/ Manufacturer/ Model)	Central Inverter / SMA/ Sunny Central 1000CPXT			
31.	Inverter rating and total Numbers	1000 kW / 50 in 50 MW			
32.	Total Number of Inverters in Solar Park	2000			
33.	Overall AC capacity of the project	2000 MW (40 x 50 MW)			
34.	Proposed Voltage Level	66 kV from each Plant and then step upto 220kV			
35.	Annual energy supplied to grid (Multi-crystalline)	Energy (MU)	CUF (%)		
		82.77 (MU)	18.90		
36.	Annual energy supplied to grid (Thin Film)	Energy (MU)	CUF (%)		
		83.06 (MU)	18.96		
37.	Capital Cost	**Capital Cost Components**	**Unit**	**Cost (Phase 1)**	**Cost (Phase 2)**
		Total Solar park Cost	**Rs Crores**		
		Land cost[2] 23,100 Rs per acre per year with 5% escalation on base year (Escalation in every 2nd year)	Rs Crores	32.70	33.15
		Site Development	Rs Crores	18.38	17.43
		Road and Drainage	Rs Crores	82.89	19.64
		Street lighting system	Rs Crores	3.56	0.72
		Water Supply system	Rs Crores	0.68	0.68
		Pooling[i] substations	Rs Crores	196.43	196.43
		400/220 kV substation cost[3]	Rs Crores	-	-
		220 KV Transmission line cost	Rs Crores	26.25	26.25

[2] Land lease is considered in capital cost only during construction period till Phase-1 COD and Phase-2 COD. After COD, Land cost is considered as an annual expense. For first 6 months, No land lease is considered as financial closure is attained after 6 months of project award.

[3] 400/220 KV Substation is in POWERGRID scope of work.

Admin Building	Rs Crores	11.55	-
Substation and Transmission line for Solar park use	Rs Crores	8.14	-
Expenditure towards consultancy for ESIA, LTA	Rs Crores	53.65	53.65
One time expenditure towards land lease	Rs Crores	13.92	13.92
Total Costs	Rs Crores	**448.15**	**361.87**
Total costs (P1+P2)			
IDC	Rs Crores	-	-
Total cost (Phase 1 + Phase 2)	Rs Crores	**810.02**	
Subsidy Component (Subsidy[4] on project cost+ NPV of Land lease)			
		264.57	
Project cost after subsidy (For solar park agency)			
		545.45	

Taking into account the solar radiation resource availability (>2000 $kWhm^2$/Year as per Meteonorm 7.0 database), micro-climate (lowest temperature drivel losses, moderate wind speed, low snow fall, low rain fall and low dust level etc.), site assessment (available flat area with good connectivity), technological appropriateness, financial feasibility, energy generation and environmental sustainability etc., it has been observed that proposed 2000 MW (8 x 250 MW) solar PV power project successfully satisfies all major criteria of project evaluation of Solar Park.

It is considered that 400/220 KV GRID Substation and transmission line to Devanahalli hardware park is in POWERGRID scope. 20 Lakh/MW subsidy is considered for total solar park infrastructure cost. Total subsidy of 400 crore will be distributed in proportion to capital expenditures + NPV of land lease expenditure borne by solar park owner and capex borne by POWERGRID. For subsidy calculation, Net present value of land lease is included in project cost to have benefit of subsidy on land cost. Land lease is discounted at 9% to arrive at NPV of total land lease expense. After subsidy, Total cost of the solar Park (Phase 1+ Phase2) comes out to be Rs. 545.45 Crores or Rs. 27.27 Lakh /MW.

In the above financial analysis, Project cost to solar park agency and fee charged from project developer are calculated for 2000 MW solar park. In base case, Calculations are furnished to meet returns expectation of solar park agency i.e. 16%. Sensitivity analyses are done for returns expectations of 14%,14.5%,15%.15.5%,16% In base case scenario, Per MW cost for solar park owner and Fee collection from developer are as per table below:

Table 2 : Fee collection from developer

Expected Returns by solar park agency	Annual fee paid by developer (5% Annual escalation)	Upfront payment by developer to solar park agency
%	Lakh/MW	Lakh/MW
16%	2.65	27.27

Upfront payment from project developer will be utilized in solar park development expenditure, expenditure towards consultancy for ESIA, LTA and one time expenditure towards land lease by solar park agency. Annual

[4] Subsidy has been distributed between POWERGRID and solar park owner in proportion to capital cost of POWERGRID and (Capital cost + NPV of land lease) of Solar park owner

fee will cater to recurring expenses over the project life. An annual escalation of 5% is also applicable on the annual fee.

Upfront payment and Annual fee payment from developer is 27.27 Lakh/MW and 2.65Lakh/MW at 16% returns expectation by solar park agency. NPV of annual and upfront payment is 62.36 Lakh/MW (Annual fee paid by developers is discounted at 10% for NPV calculation purpose).

For solar park implementation agency, Cost/MW for solar park infrastructure (Excluding annual land lease payment) is 27.27 lakh/MW. Additionally, advance payment from developers will contribute to 100% of the capital cost requirement after subsidy. Upfront payment and annual payment figures are subject to change as per changes in assumptions.

2. Introduction

2.1. Overview of power scenario in India

India's substantial and sustained economic growth is placing enormous demand on its energy resources. Economic growth, increasing prosperity and urbanization, rise in per capita consumption, and spread of energy access are the factors likely to substantially increase the total demand for electricity. The demand and supply imbalance in energy sources is pervasive requiring serious efforts by Government of India to augment energy supplies. In April 2002, renewable energy based power generation capacity was 3475 MW which was 2% of the total installed capacity in the country. As on May, 2015, it has reached 35,780 MW, which is about 13% of the total installed capacity. Major contribution has come from the Wind technology which is about 70% of the total capacity. Apart from the grid interactive renewable power, MNRE has ambitious programmes for deployment of off-grid/ distributed renewable power and decentralized renewable energy systems for rural applications.

India, since independence in 1947, has made a significant progress in terms of generation capacity addition, and the installed generation capacity in the country has increased from 1363 MW during the year 1947 to around 272500 MW at end of May 2015. The success graph of the Indian Power Generation Capacity addition is shown in Figure 1 below:

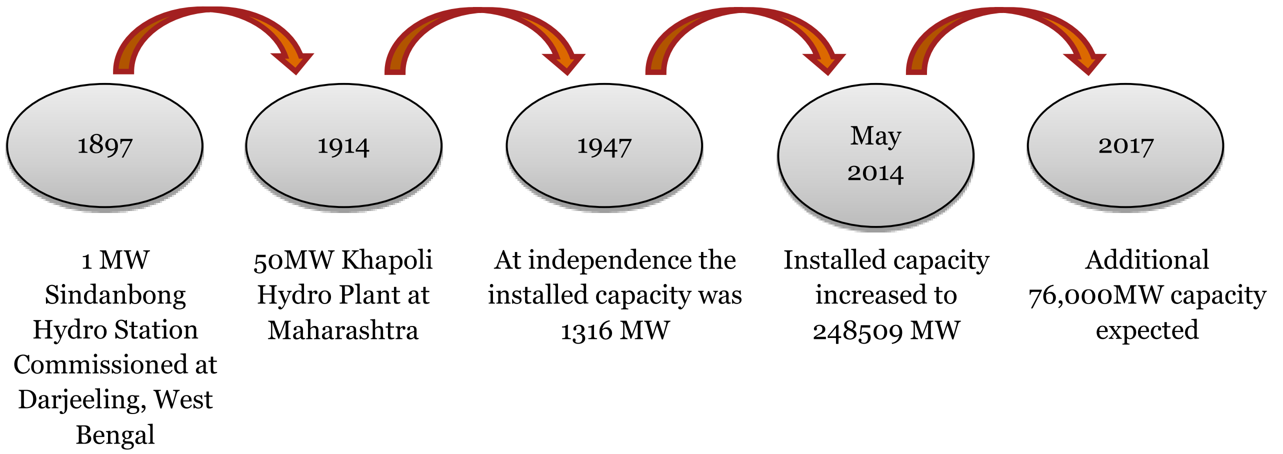


Figure 1 : Growth of Indian power sector

As on March 2015, India has an installed power capacity of **272.5 GW,** of which coal power plants are the major source and account for ~60% of the total installed capacity in the country. Indian coal reserves are dwindling and power producers face other issues related to coal linkages and supply, while Renewable energy in India has grown steadily. In April 2002, renewable energy based power generation capacity was 3475 MW – about 2% of the total installed capacity in the country. As in March 2015, it has reached approx 35.78 GW (excluding large hydro), which is about 13.2% of the total installed capacity.

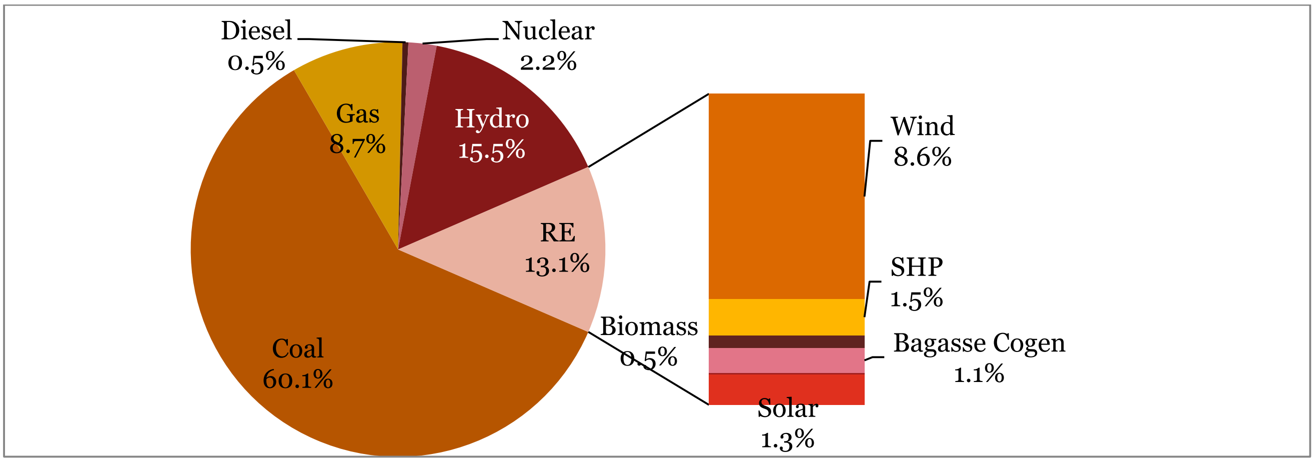


Figure 2. Installed power capacity of India

With increase in demand and volatility in prices of coal, gas and oil likely to increase, India needs to focus on renewable energy sources for enhancing the energy security. Table 3 presents the region wise and fuel-wise installed capacity at the end of May 2014:

Table 3. Region and fuel wise installed capacity

Region	Thermal			Nuclear	Hydro	Renewable	Total
	Coal	Gas	Diesel				
Northern	39843.50	5331.26	0	1620	17431.78	7156.86	71383.40
Western	66429.01	10915.41	0	1840	7447.50	12795.04	99426.96
Southern	30342.50	4962.78	917.48	2320	11398.03	15117.20	65057.99
Eastern	28582.87	190	0	0	4113.12	434.38	33320.37
N. Eastern	60	1662.70	36.00	0	1242	262.38	3263.08
Islands	0	0	40.05	0	0	11.10	51.15
All India	165257.88	23062.15	993.53	5780	41632.43	35776.96	**272502.95**

Source: CEA

2.1.1. Overview of current status of electricity demand and supply in India

Despite increase in installed capacity by more than 110 times in 62 years, India is still not in a position to meet its peak demand as well as energy requirement. The peak power deficit during FY 2001-02 was 12.2% approximately 9252 MW, however, at the end of FY 2014-15, the peak power deficit decreased to the order of 4.7% and in absolute terms peak deficit clocked at 7006 MW. Figure 3 presents the status of peak power required vis-à-vis peak power met during the various periods.

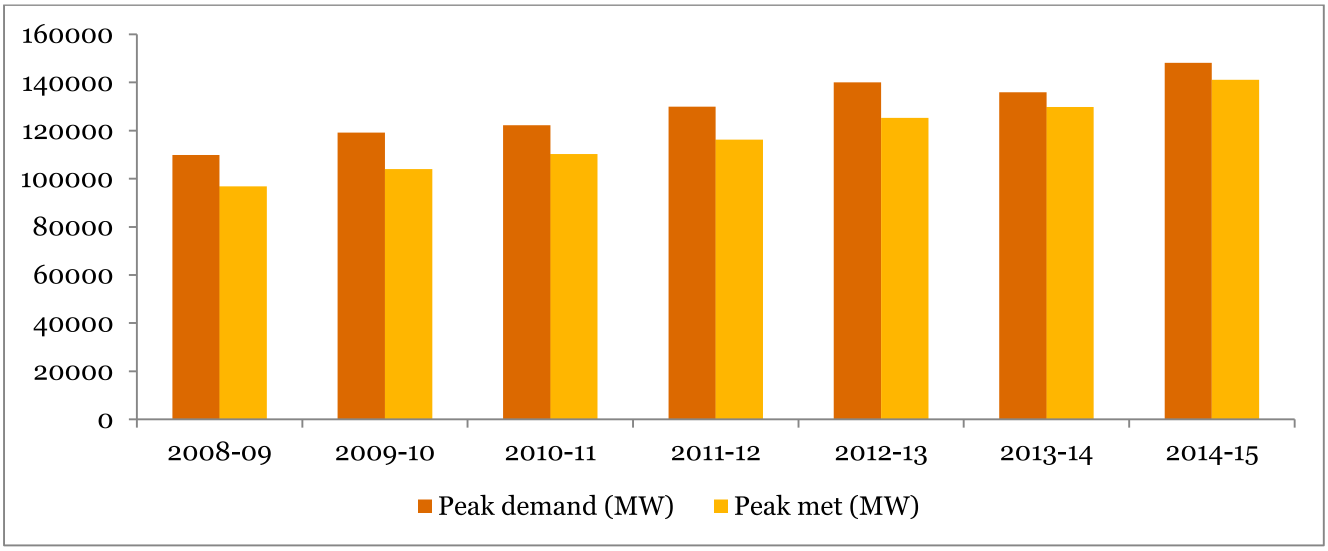


Figure 3. Peak demand status (Source: CEA)

Similarly, the shortage in terms of energy availability was around 7.5% at the end of FY 2001-02 (39,187 MU) whereas at the end of FY 2014-15 it reduced to around 3.6%. However, in absolute terms it increased to 38,138 MU. As fallout of this situation, the planned and un-planned load shedding measures were required to be undertaken by most of the Utilities to bridge this demand-supply gap. Figure 4 presents status of the year-wise variation of energy requirement and its availability-

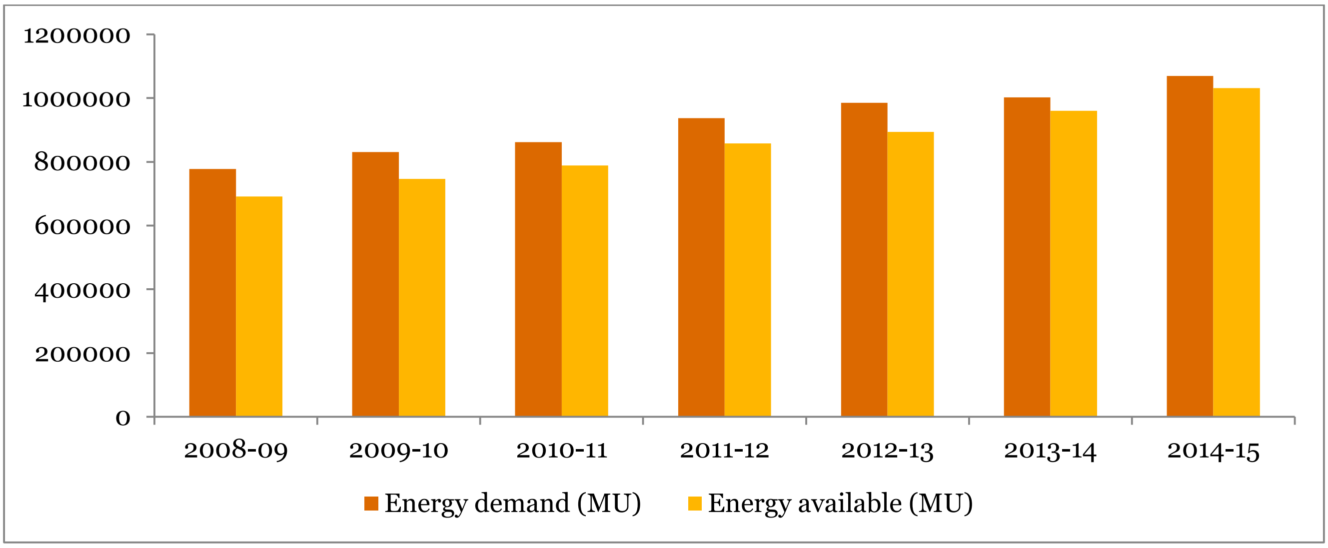


Figure 4. Energy demand status

Source: CEA

India's energy usage has been rapidly increasing as a result of economic growth in the last decade; however India still has one of the lowest per capita consumptions of energy and electricity in the world and many states face an acute power shortage. All the Regions in the Country namely Northern, Western, Southern, Eastern and North-Eastern Regions continued to experience energy as well as peak power shortage of varying magnitude on an overall basis, although there were short-term surpluses depending on the season or time of day. The surplus power was sold to deficit states or consumers either through bilateral contracts, Power Exchanges or traders. The energy shortage varied from 0.8% in the Western Region to 8.7% in the North-Eastern Region. Region-wise picture with regard to actual power supply position in the country during the year 2014-15 in terms of energy and peak is presented in Figure 5:

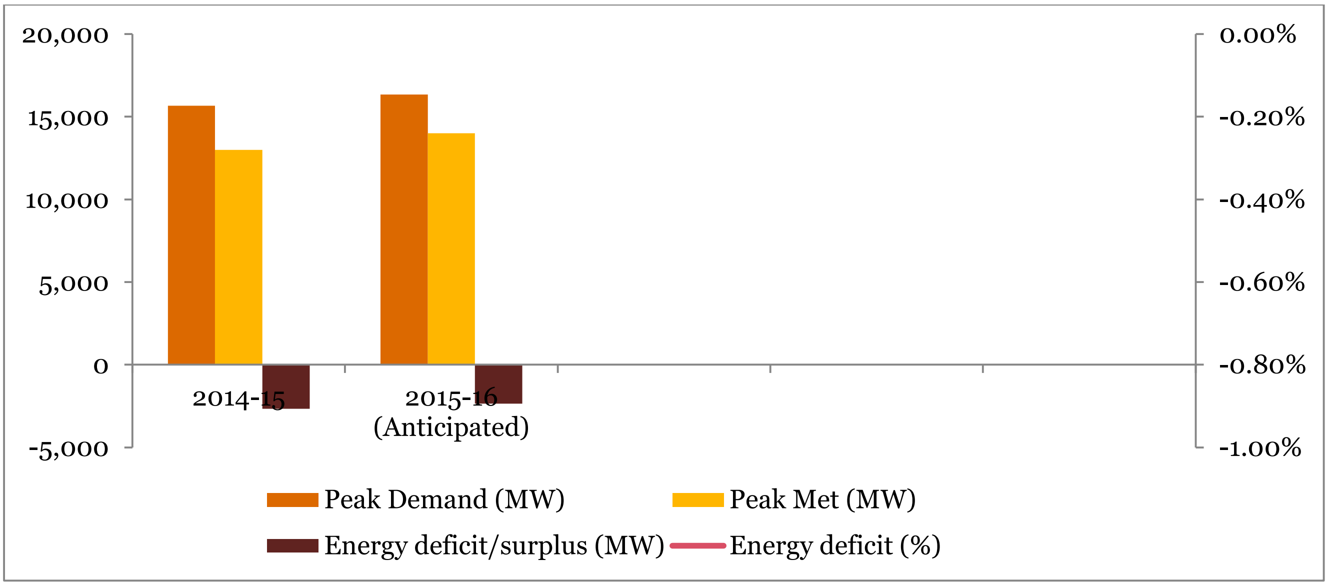


Figure 5. Power supply position

Source: CEA

It may be noted that shortage in both capacity (i.e., MW terms) as well as energy (i.e., in MU terms) is showing ascending trend. The increasing power shortage may be attributed to the following factors:

- Inadequate generation capacity addition
- Poor financial position of the distribution utilities
- High distribution losses
- Transmission capacity constraint

Therefore, there is a growing emphasis to bridge the demand supply gap by supplementing the conventional energy sources with alternate non-conventional energy sources as well as to decrease the carbon footprint in energy intensive Indian economy by providing thrust on implementation of alternate energy sources. Next section highlights major policy initiatives undertaken by the Government of India for promotion of renewable energy in India.

2.2. Current Status of Power Sector in Karnataka

The Government of Karnataka (GoK) in its notification on the State Power Sector Policy on Reforms, dated January 30, 1997 envisaged to restructure and later on privatise the distribution operations of the Karnataka Electricity Board (KEB) in order to improve the operational efficiency in distribution and to enhance customer service quality. Accordingly, under the Government resolution dated July 16, 1999 approval was accorded for incorporation of new Government companies known as the Karnataka Power Transmission Corporation Limited (KPTCL) for handling transmission and distribution functions of KEB, and Visvesvaraya Vidyuth Nigama Limited (VVNL) for handling KEB's existing generating stations with its associated units. Further, the erstwhile Karnataka Power Transmission Corporation Limited (KPTCL) was unbundled for creation of distribution companies for ensuring adequate power availability, minimum interruption and quality service to the consumers and rational tariffs to different classes of consumers. They are:

- Bangalore Electricity Supply Company (BESCOM);
- Hubli Electricity Supply Company (HESCOM);
- Mangalore Electricity Supply Company (MESCOM);
- Chamundeshwari Electricity Supply Corporation (CESC); and
- Gulbarga Electricity Supply Company (GESCOM).

As regards the generation capacity of Karnataka in concerned, the State owned electricity generating stations, with a mix of thermal, hydro and renewable, has available capacity of 7479.38 MW, while private sector has total available capacity of 5119.98 MW. Including the allocation from Central sector stations and considering resources like Nuclear and RE sources, the total capacity available to the State of Karnataka as on March 31, 2015 is around 14624.72 MW. The per capita consumption of electricity is around 934 kWh. The sector-wise and fuel-wise break-up of available capacity is summarized in Table 4:

Table 4. Fuel wise installed capacity in Karnataka

Sector	Hydro	Thermal				Nuclear	RE Sources	Total
		Coal	Gas	Diesel	Total			
State	3599.80	2720	0	127.92	2847.92	0	1031.66	7479.38
Private	0	2060	0	106.50	2166.50	0	2953.48	5119.98
Central	0	1549.51	0	0	1549.51	475.96	0	2025.37
Total	3599.80	632951	0	234.42	6563.93	475.96	3985.13	**14624.72**

2.2.1. Consumer-Category wise Consumption

The consumption mix in Karnataka is dominated by Agricultural consumers which in aggregate accounts for approximately 37% of the energy consumption in the State followed by domestic consumption in the State which accounts for nearly 19% of the total consumption. The HT Industrial consumers accounts for nearly 18% of the consumption. The category wise consumption mix of Karnataka is as shown below:

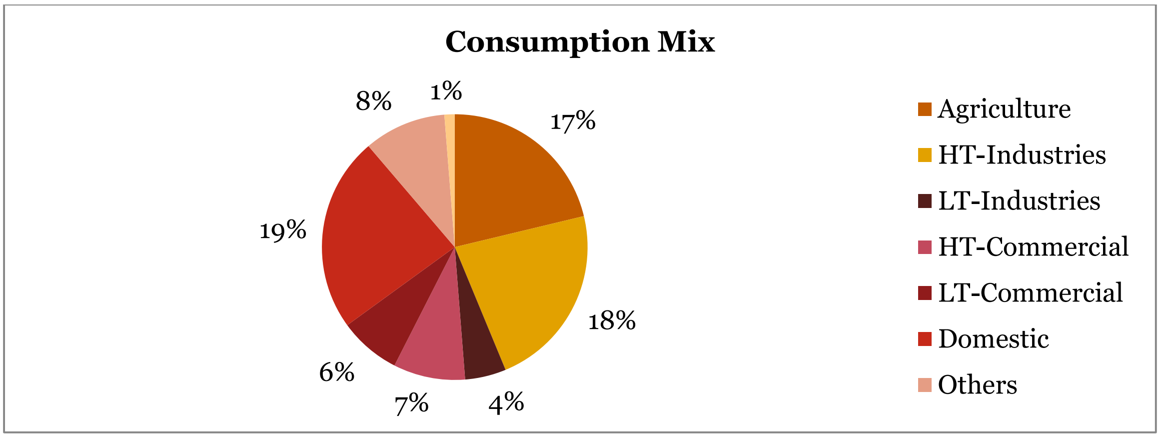


Figure 6. Category wise consumption mix in Karnataka

2.2.2. Demand Supply Assessment

The peak demand deficit in the State of Karnataka during FY 2008-09 was 344 MW which actually increased to 717 MW during FY 2013-14. The peak demand deficit has increased from 5% at the end of FY 2008-09 to 7% at the end of FY 2013-14. The summary of the year-wise peak demand and peak demand met during the period from FY 2008-09 to FY 2013-14 is shown in the figure below:

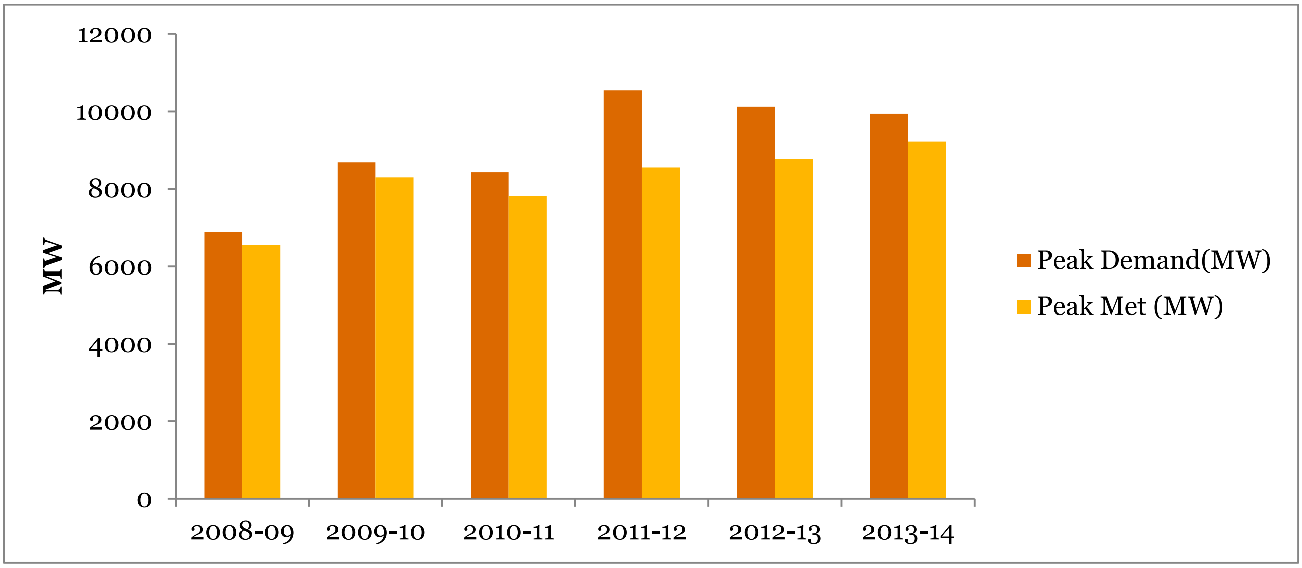


Figure 7. Peak demand and peak demand met (MW)

The gap between the energy requirement and energy availability of the region is following the increasing trend from FY 2008-09 (6%) to FY 2013-14 (10%). In absolute terms the energy gap of the region has not increased significantly from FY 2008-09 (2590 MU) to FY 2013-14 (6098 MU). The figure below shows the year-wise variation of energy requirement and its availability.

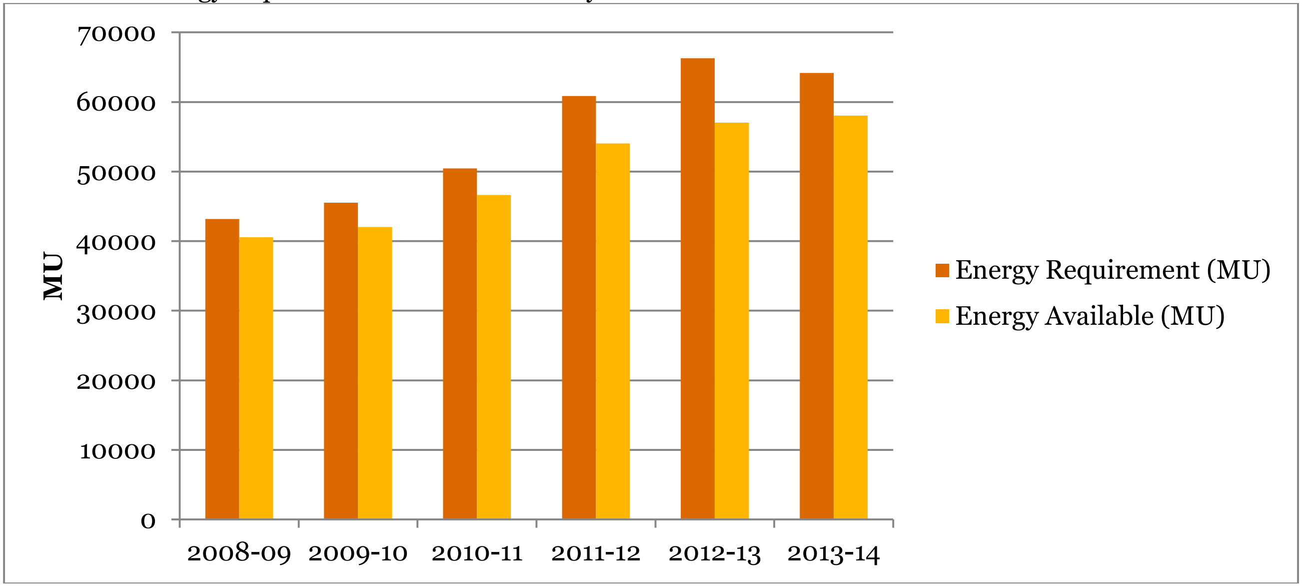


Figure 8. Year wise energy requirement and energy requirement met

2.2.3. Industry Structure

The electricity industry structure in Karnataka comprises the generating company i.e., Karnataka Power Corporation Ltd. (KPCL) which owns the State thermal and hydro power plants, the transmission company i.e., Karnataka Power Transmission Company Limited (KPTCL) and the distribution companies i.e., Bangalore

Electricity Supply Company (BESCOM), Chamundeshwari Electricity Supply Corporation (CESC), Gulbarga Electricity Supply Company (GESCOM), Hubli Electricity Supply Company (HESCOM) and Mangalore Electricity Supply Company (MESCOM). Karnataka Electricity Regulatory Commission (KERC) is the State regulatory authority which governs the electricity regulatory framework in Karnataka. Karnataka State Load Despatch Centre (KSLDC) monitors the Load despatch function in the state. Karnataka Renewable Energy Development Ltd. (KREDL) is the State Nodal Agency which monitors the development of RE sources in the State.

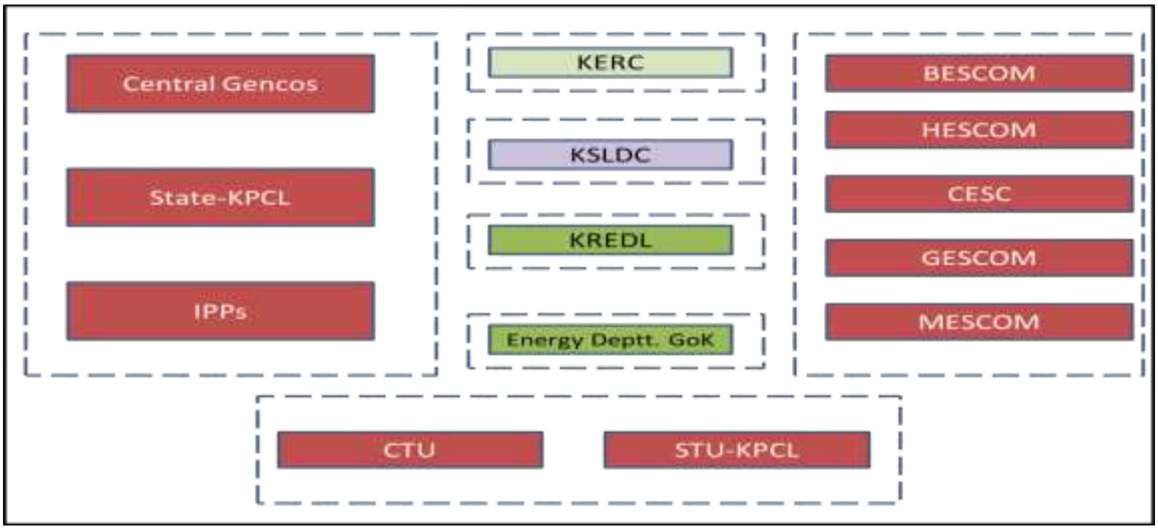


Figure 9. Electricity structure in Karnataka

2.3. Renewable Energy scenario in India

India's substantial and sustained economic growth is placing enormous demand on its energy resources. Economic growth, increasing prosperity and urbanization, rise in per capita consumption, and spread of energy access are the factors likely to substantially increase the total demand for electricity. The demand and supply imbalance in energy sources is pervasive requiring serious efforts by Government of India to augment energy supplies. Already, in the electricity sector, official peak deficits are of the order of 12.7%, which could increase over the long term. India is one of the fastest growing economies of the world. The rapid economic growth has been accompanied by commensurate growth in the demand for energy services. With its large population and rapidly growing economy, India needs access to clean, cheap and reliable sources of energy. India's energy usage has been rapidly increasing as a result of economic growth in the last decade; and energy requirement is expected to increase by 200% from FY 15 to FY 30.

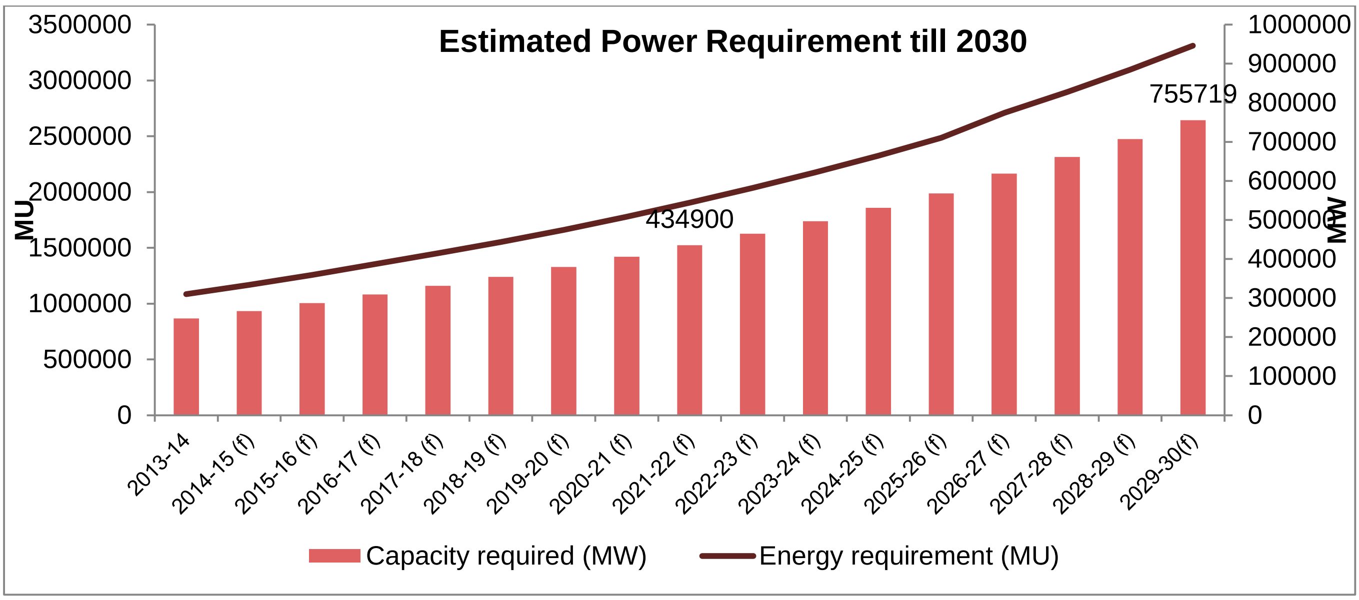


Figure 10. Power requirement projections

(Source: 18th EPS and PwC Analysis)

About half of the RE cumulative capacity addition has taken place during the first four years of the 11th five year plan period (2007-12). Renewable Energy, in India's context, is significant for enhancing energy security through diversification of fuel sources and thereby reducing dependence on fossil fuels, sustainable and environmentally efficient growth and for overcoming power shortages in the country.

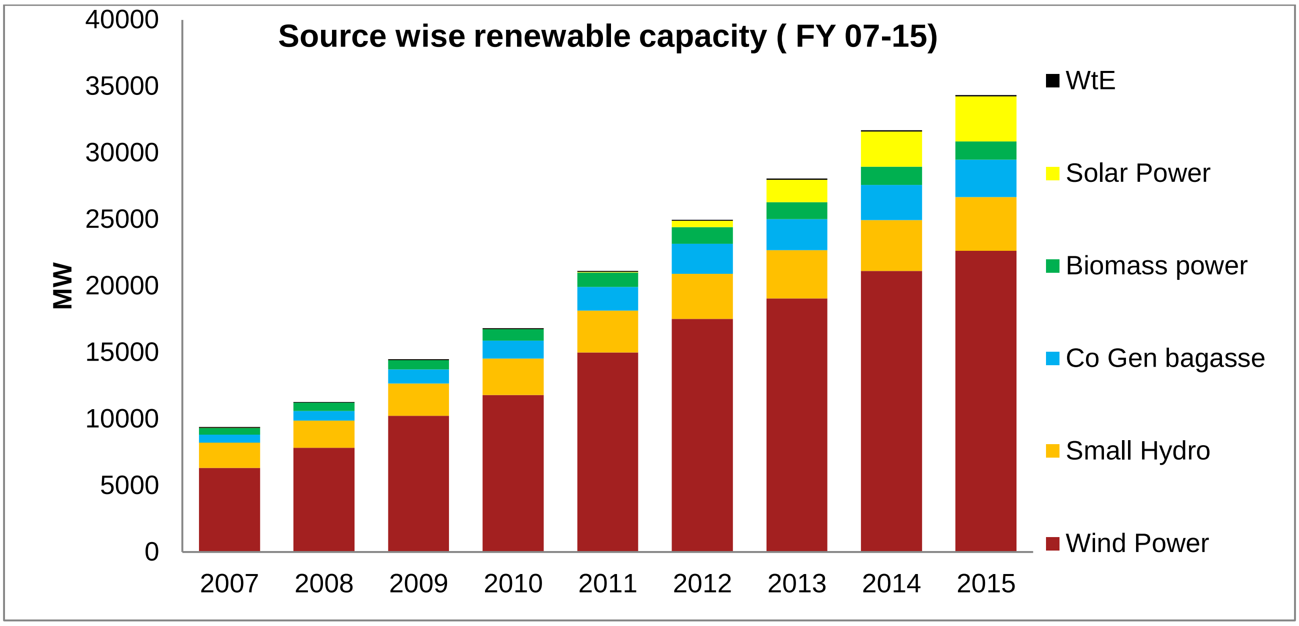


Figure 11. Year wise renewable energy capacity addition

The Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of the Government of India that deals in all matters relating to new and renewable energy. The Ministry has been facilitating the implementation of a broad spectrum of programmes including harnessing renewable power, renewable energy to rural areas for lighting, cooking and motive power, use of renewable energy in urban, industrial and commercial applications and development of alternate fuels and applications.

The current focus of electricity and energy policy is geared towards centralized and conventional grid based system with fossil fuels being the main source for generation. The Annual budget 2015-16 witnessed the announcement of 175 GW target for Renewable Energy by 2021-22.

Table 5. Current installed capacity and planned Renewable Energy targets

Source	Installed capacity by end of 11th Plan (March 2012)	Current installed Capacity (March 2015)	Target as per 12th Plan (March 2017)	**Revised Targets till 2022**
Solar Power	941	3,383	10,941	**1,00,000**
Wind power	17,352	22,645	32,352	**60,000**
Biomass Power	3,225	4,183	6,125	**10,000**
Small Hydro	3,395	4,025	5,495	**5,000**
TOTAL	**24,914**	**34351**	**54,914**	**1,75,000**

Renewable energy solutions promise to be one of the most viable interventions to answer the problems faced by the use of conventional energy sources for rural needs. Apart from the obvious benefits associated with access to reliable energy, RE sources are clean, with minimal emissions of harmful gases. This is likely to reduce both global and local GHG emissions, as well as cut down on the harmful health effects associated with these fumes. Improved health in turn is likely to improve productivity, as well as make the relatively scarce financial resources available for other uses. RE sources are also likely to reduce the recurring household expenditure on conventional fuels, thereby also contributing to overall prosperity of households and communities. Finally, on account of being location specific, harnessing RE sources is likely to promote local employment and skills development, further empowering the community and making it more self-sufficient.

2.4. Solar Energy development in India

India meets close to 65% of its electricity needs from fossil fuels and is expected to continue doing so in the foreseeable future. This poses questions on cost of electricity supply in future, environmental impacts and energy security. At this juncture, Renewable Energy (RE) is being seen as one of the important means to meet the growing power needs of the economy while enhancing energy security through diversification of fuel sources and providing opportunities for mitigating greenhouse gas emissions. India has vast renewable energy potential through wind, solar, biomass, small hydro etc.

India lies in the high solar insolation region, endowed with huge solar energy potential with most of the country having about 300 sunny days per year with annual mean daily global solar radiation in the range of 5-7 kWh/m^2/day. With the quest to suffice growing power demand and support in the form of enabling government policy initiatives, a paradigm shift has been experienced in the growth of solar PV for power generation in the country. As per Wasteland Atlas of India over 4,70,770 Sq. km of wasteland (viz. upland with or without scrub, under-utilized/ degraded notified forest land, sand/ inland/ coastal, barren/rocky/stony-waste/ sheet rock area) is available in the country which can support installation of solar power projects. The total estimated solar power potential of the country, including that of rooftop, is approximately 748.98 GW as estimated by National Institute of Solar Energy (NISE) which may further go up with more investigation.

The grid interactive solar power as of December 2010 was merely 10 MW. However, most of the capacity addition in India has happened in last three years, driven by series of incentives and support extended by state and federal governments. Realising the presence of abundant solar potential in the country, slew of policy and enabling regulatory measures were promulgated and therefore, till date almost 3744 MW of grid interactive solar capacity is commissioned in country.

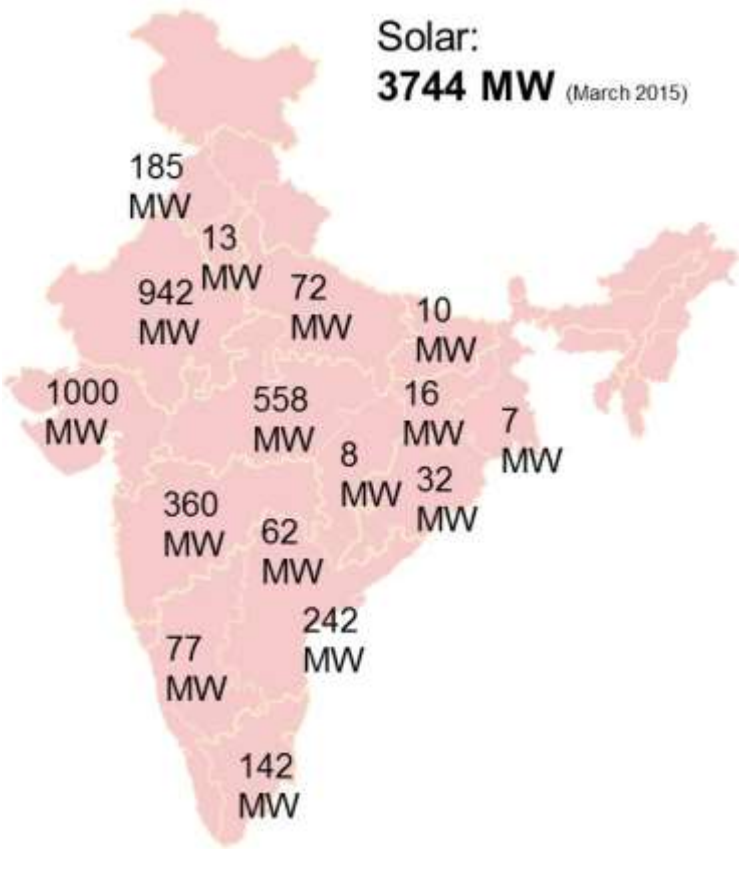


Figure 12. State wise installed solar energy capacity

Despite our huge potential, government will and incentive mechanisms, large scale deployment of solar will be feasible only if solar generation costs achieve the grid parity. The generation cost has been brought down from the initial high of approximately INR 17/unit to about INR 6.5 /unit. The Government plans to scale up solar to a cumulative 100GW by 2022. MNRE has already prepared a way forward for achieving the targets envisaged and has listed out the immediate actions required by the Government and interventions from various stakeholders including regulators, distribution companies and financial institutions. With the trend of falling PV prices and availability of high solar potential as mentioned above, it is possible to reach grid parity.

Government of India has proposed to scale up the existing target of 20,000 MW in the next 7 years to 100 GW of solar installed capacity by 2021-22. An enhanced target of 100 GW will bring India on the global solar power map. For achieving the significantly higher capacity addition target, it is proposed to have capacity addition under 2 categories of solar projects: Rooftop Solar Projects and Large Scale Solar as under:

Table 6. Capacity addition targets under 100 GW solar scale up plan

Category-I	Proposed Capacity (MW)	Category-II	Proposed Capacity (MW)
Rooftop Solar	40,000	Projects by Unemployed graduates, Village Panchayats, Small Scale Industries (SSI) Units	20,000
		Public Sector Undertakings	10,000
		Large Private Sector	5,000
		SECI	5,000
		Under State Policies	10,000
		Ongoing programmes	10,000
Total	**40,000**		**60,000**

There is a strong rationale for supporting rooftop projects in India, as the national average AT&C losses hover around 27%. The target of 40,000 MW of grid-connected rooftop is being proposed for the next 7 years. This capacity will come up through the institutional sector (hospitals, educational institutions, etc.), industrial & commercial sector and the housing sector. The target for this category is proposed to be kept at 60,000MW. Large Scale Grid Connected Solar Power projects can include projects in Solar Parks, small projects on spare capacity with sub stations, small stations connected to the distribution network at 66KV and below by unemployed graduates and village panchayats, medium size projects on land outside the solar parks, Ultra Mega Solar Power Projects which require huge investment and can be developed by companies which are into the power sector business and have proven experience in developing and operating large power projects. The expected categories of developers would be (i) private sector companies with surplus funds; (ii) PSUs and (iii) international companies.

Recognizing the immense potential and taking measures for scaling up solar has eventually lead to identification of viable business opportunities that can be tapped by both public and private sector in the near and medium term future.

2.5. Policy and Regulatory landscape for Solar in India

Various policies and regulations have been notified by Government of India in the energy sector. Some of the important regulations and policies related to renewable energy are Electricity Act, 2003, Integrated Energy Policy (IEP), National Tariff Policy, 2006 and National Action Plan for Climate Change (NAPCC). In this section, these regulations and policies are discussed in brief.

2.5.1. Electricity Act 2003 (EA 2003)

The Electricity Act 2003 has radically changed legal and regulatory framework for the RE sector. EA 2003 was passed by both houses of Parliament and made effective from June 10, 2003, making it the single most important piece of legislation for the sector and effectively nullifying all earlier enactments that governed the electricity businesses. EA 2003 provides for policy formulation by the Government of India and mandates SERCs to take steps to promote renewable and non-conventional sources of energy within their area of jurisdiction. Further, EA 2003 has explicitly stated the formulation of National Electricity Policy (NEP), National Tariff Policy and plan thereof for development of power systems to ensure optimal utilization of all resources including renewable sources of energy.

Extract of relevant sections of EA 2003

Section 3	***The Central Government shall, from time to time, prepare the National Electricity Policy and tariff policy, in consultation with the State Governments and the Authority for development of the power system based on optimal utilization of resources such as coal, natural gas, nuclear substances or materials, hydro and renewable sources of energy.***
Section 4	*The Central Government shall, after consultation with the State Governments,prepare and notify a national policy, permitting stand alone systems (including those based on renewable sources of energy and non-conventional sources of energy) for rural areas.*
Section 61(h)	*The Appropriate Commission shall, subject to the provisions of this Act, specify the terms and conditions for the determination of tariff, and in doing so, shall be guided by the following, namely:-* … *(h) the promotion of co-generation and generation of electricity from renewable sources of energy;* …
Section 86(1)(e)	*The State Commission shall discharge following functions, namely –* … *(e) promote cogeneration and generation of electricity from renewable sources of energy by providing suitable measures for connectivity with grid and sale of electricity to any person, and also specify, for purchase of electricity from such sources, a percentage of total consumption of electricity in the area of distribution licensee* …

2.5.2. National Electricity Policy 2005

Significant regulatory developments have taken place since the notification of national electricity policy by the central Government. Various provisions of these policies reemphasise the need for harnessing RE generation.

Provisions of the National Electricity Policy

5.2.20	***Feasible potential of non-conventional energy resources, mainly small hydro, wind and bio-mass would also need to be exploited fully to create additional power generation capacity. With a view to increase the overall share of nonconventional energy sources in the electricity mix, efforts will be made to encourage private sector participation through suitable promotional measures.***
5.12.1	*Non-conventional sources of energy being the most environment friendly there is an urgent need to promote generation of electricity based on such sources of energy. For this purpose, efforts need to be made to reduce the capital cost of projects based on nonconventional and renewable sources of energy. Cost of energy can also be reduced by promoting competition within such projects. At the same time, adequate promotional measures would also have to be taken for development of technologies and a sustained growth of these sources.*
5.12.2	*The Electricity Act 2003 provides that co-generation and generation of electricity from non-conventional sources would be promoted by the SERCs by providing suitable measures for connectivity with grid and sale of electricity to any person and also by specifying, for purchase of electricity from such sources, a percentage of the total consumption of electricity in the area of a distribution licensee. Such percentage for purchase of power from non-conventional sources should be made applicable for the tariffs to be determined by the SERCs at the earliest. Progressively the share of electricity from non-conventional sources would need to be increased as prescribed by State Electricity Regulatory Commissions. Such purchase by distribution companies shall be through competitive bidding process. Considering the fact that it will take some time before nonconventional technologies compete, in terms of cost, with conventional sources, the Commission may determine an appropriate differential in prices to promote these technologies.*

2.5.3. National Tariff Policy, 2006

As per national tariff policy, it will take some time before non-conventional technologies can compete with conventional sources in terms of cost of electricity. Therefore, procurement by distribution companies may be done at preferential tariffs determined by the appropriate state commission.

Provisions of the National Tariff Policy

6.4 (1)	***the Appropriate Commission shall fix a minimum percentage for purchase of energy from such sources taking into account availability of such resources in the region and its impact on retail tariffs....***
6.4 (2)	*.... Such procurement by Distribution Licensees for future requirement shall be done as far as possible through competitive bidding process under section 63 of the Act within the suppliers offering energy from same type of non conventional sources*

2.5.4. National Action Plan for Climate Change (NAPCC)

The National Action Plan for Climate Change (NAPCC), announced by the prime minister of India on June 30, 2008, envisages several measures to address global warming. One of the important measures identified involves increasing the share of RE in total electricity consumption. NAPCC has set the target of 5% RE purchase for FY 2009-10, with increase of 1% in target each year for the next 10 years.

Provisions of NAPCC

4.2.2	***The Electricity Act 2003 and the National Tariff Policy, 2006 provide for both the Central Electricity Regulatory Commission (CERC) and the State Electricity Regulatory Commission (SERC) to prescribe a certain percentage of total power purchase by the grid from renewable based sources. It also prescribes that a preferential tariff may be followed for renewables based power.***
	A dynamic minimum renewable purchase standard (DMRPS) may be set, with escalation each year till a pre-defined level is reached, at which time the requirements may be revisited. It is suggested that starting 2009-10, the national renewables standard (excluding hydropower with storage capacity in excess of daily peaking capacity, or based on agriculture based renewables sources that are used for human food) may be set at 5% of total grids purchase, to increase by 1% each year for 10 years. SERCs may set at higher percentages than this minimum at each point in time.

2.5.5. Renewable Energy Certificate (REC) Mechanism

Existing legal framework under EA 2003 puts responsibility for promotion of renewable energy on SERCs. As a result, the SERCs set targets for distribution companies to purchase certain percentage of their total power requirement from renewable energy sources knownas Renewable Purchase Obligation (RPO). But the requirement of scheduling and prohibitivelong term open access charges poses major barrier for RE abundant States to undertake inter-State sale of their surplus RE based power to the States which do not have sufficient RE based power. Consequently, the States with lower RE potential have to keep their RPO target at lower level. In addition, the unit cost of the RE based non-firm power is higher than the conventional power sources.

As a result, while RE abundant States have no motivation to produce RE based power more than that required to satisfy the RPO mandate within the State. On the other hand, RE scarce States are not able to procure RE generation from other States. Therefore, a mechanism which will enable and recognize the inter-State RE transactions is critically required for further promotion and development of RE sources.

The REC mechanism seeks to address the mismatch between availability of RE sources and the requirement of the obligated entities to meet their RPO across States. So far inter-State exchange of renewable energy was constrained due to the fact that such transactions are governed by inter-State open access Regulations and the regional energy accounting framework, which necessitates scheduling of power. Some of the RE sources such as biomass power or bagasse based cogeneration can be scheduled and inter-State open access transactions based on such firm RE sources have taken place in the past, however, inter-State exchange of power based on non-firm RE sources such as wind energy, solar power, small hydro power, etc., was constrained. Besides, the cost of open access wheeling under long term arrangement was prohibitive for such non-firm RE sources due to their inherent lower capacity utilisation factors. The REC mechanism addresses these constraining factors as the Certificate is issued for the energy generated at the point of injection into the Grid. It is envisaged that the REC mechanism shall facilitate emergence of large number of cross-border RE transactions based on non-firm RE sources, while at the same time, enhancing the volume of cross-border RE transactions based on firm RE sources as well.

2.5.6. FOR policies on renewable energy

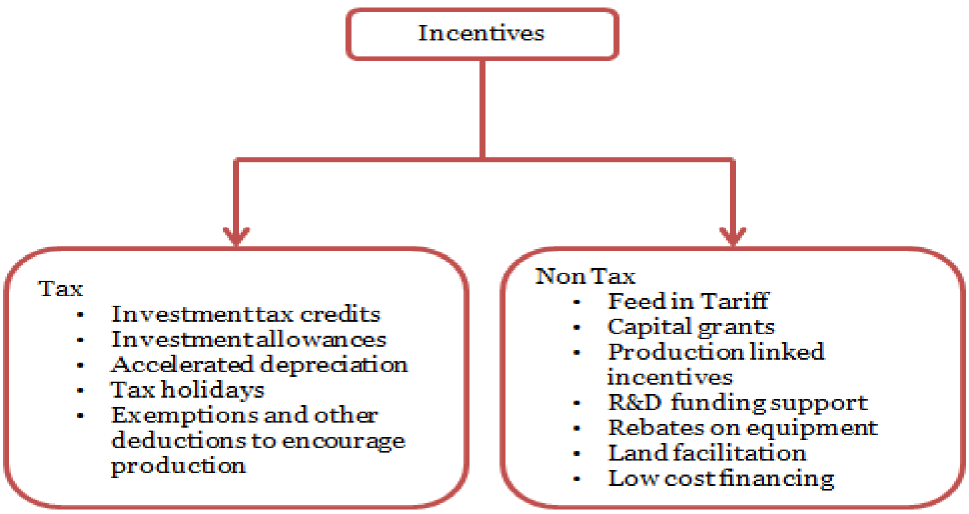
The Forum of Regulators (FOR) constituted under Section 166 of EA 2003, for harmonising the policies across the regulatory commissions, has published a report 'Policies on Renewables' with the objective of evolving a common approach to the promotion of renewable sources of energy in the country as a whole.

Excerpts from FOR renewable energy policies

1. **Each State Commission may specify a minimum RPO of 5% in line with the NAPCC. RPO should be calibrated with regard to the energy input in the system, after adjustment of losses and not on energy billed.**
2. **Need for a facilitative framework for grid connectivity and inter-State exchange of power generated from RE sources.**
3. **Need to develop Renewable Energy Certificate (REC) mechanism for achieving the RPO targets.**
4. **Preferential tariff for renewable sources should be specified at least during their loan tenure, subsequent to which, they should be encouraged to compete amongst themselves.**
5. **Generation Based Incentive (GBI) should be declared upfront to enable the Regulatory Commission to factor it in the tariff determination process.**
6. **Each State Commission may specify a minimum RPO of 5% in line with the NAPCC. RPO should be calibrated with regard to the energy input in the system, after adjustment of losses and not on energy billed.**

2.6. Incentives available to Solar Projects in India

Government of India provides a mix of tax and non-tax benefits to promote solar, so as to create an enabling investment climate where these projects are taken up by market forces. The different incentives offered by central and state governments can be broadly illustrated as under:



Tax Incentives	Details
Income tax Holiday	100% for 10 consecutive years - MAT @ 20% to apply
Accelerated depreciation	Accelerated depreciation @ 80% on solar & wind assets Additional depreciation @ 20% on new plant/machinery in the 1st year
Deemed export benefits	Available to specified goods manufactured and not actually exported • Advance authorization from Directorate General of Foreign Trade • Deemed export drawbacks • Exemption/return of Terminal Excise Duty
Service tax based on negative list	Certain services are exempted from service tax • Services of transmission or distribution of electricity by an electricity utility
Customs and Excise Laws	Various duty concessions and exemptions to RE Sector
Reduced VAT	Certain States allow reduced VAT rates (5%) on RE projects
Additional one-time allowance	Available @15% in Budget 2014 on new plant and machinery
Tax-free Grants	Grants received from the holding company engaged in generation, distribution or transmission of power
Non-Tax Incentives	**Details**
Feed-in-tariffs	• When renewable generators sell to state utilities under the MoU route • Rates decided by the CERC and the SERC
Rebates	• Available on the manufacturing of solar and wind components • Targeted at specific types of renewable energy technology • Include subsidies and rebates on capital expenditures
Favorable land policies	• By various state governments for renewable development • Reduce capital costs and favours ease of land allocation
Government R&D programs	• Improve renewable energy technologies • Lead to growing performance, importance and reducing costs

2.6.1. Jawaharlal Nehru National Solar Mission (JNNSM)

Launched by the Government of India in January 2010, JNNSM is one of the major global initiatives in promotion of solar energy technologies. The mission has a twin objective - to contribute to India's long term energy security as well as its ecological security. The JNNSM would be implemented in 3 stages and aims to have an installed capacity of 20,000 MW by the end of the 13th Five Year Plan in 2022. It is envisaged that as a result of rapid scale up as well as technological developments, the price of solar power will attain parity with grid power at the end of the Mission, enabling accelerated and large-scale expansion thereafter. The mission includes a major initiative for promoting solar photovoltaic (PV) applications. Under Phase - I of JNNSM to be implemented between 1st April 2010 and 31st March 2013; 200MW capacity equivalent off grid solar PV systems area to be installed in the country. The National Solar Mission is a thus a major initiative of the Government of India and State Governments to promote ecologically sustainable growth while addressing India's energy security challenge.

The Union Cabinet in an ambitious push for solar energy has revised the cumulative target of grid Connected Solar Projects under Jawaharlal Nehru National Solar Mission (JNNSM) from 20,000 MW by 2021-22 to 100,000 MW solar capacity by 2021-22.

The target of 100,000 MW will be met through 40,000 MW of rooftop solar projects and 60,000 MW of large- and medium-scale grid-connected projects. The capacity addition envisaged under the 2 categories shall be as under:

Table 7. Category wise capacity addition plan under 100 GW solar scale up plan

Category	Year-wise Targets (in MW)							
	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	Total
Rooftop Solar	1,000	4,000	5,000	6,000	7,000	8,000	9,000	**40,000**
Large Scale Solar Power Projects	3,000	6,000	10,000	10,000	10,000	9,500	8,500	**57,000**
Total	**4,000**	**10,000**	**15,000**	**16,000**	**17,000**	**17,500**	**17,500**	**97,000***

*3,000 MW commissioned upto 2014-15.

NSM (Phase I)

In order to facilitate grid connected solar power generation in the first phase, a mechanism of "bundling" relatively expensive solar power with power from the unallocated quota of power generated at NTPC coal based stations, which is relatively cheaper, was proposed by the Mission. This "bundled power" would be sold to the Distribution Utilities to reduce the cost of procuring solar power. The Bidding process under the first phase of the National Solar Mission was split into two batches with the understanding that this circumspect approach would leave enough room for rectification if some flaws or shortcomings that may emerge in the first batch of bidding. The following table gives a snapshot of the bidding outcome of both the batches of Phase-I:

Bidding outcome of Phase-I of JNNSM

Capacity Allocated	Benchmark Tariff	Tariff Range	Average Tariff
Batch I			
Solar PV- 140 MW	Rs. 17.91/kWh	Rs. 10.95-12.76/kWh	Rs. 12.12/kWh
Solar Thermal- 470 MW	Rs. 15.31/kWh	Rs. 10.49-12.24/kWh	Rs. 11.48/kWh
Batch II			
Solar PV- 340 MW	Rs. 15.39/kWh	Rs. 7.49-9.44/kWh	Rs. 8.77/kWh

The commissioning status of different projects under JNNSM Phase - I is as follows:

1. Migration Projects

Under Migration scheme, a total of 16 Solar Power Developers have been selected for 84 MW Solar Projects (54 MW for Solar PV and 30 MW solar thermal. The Scheduled Commission Date

- Solar PV – 12 months from signing of PPA, i.e. mid October, 2011.
- Solar Thermal – 28 months from signing of PPA, i.e. mid February, 2013.

The commissioning status of Migration Solar PV projects (as on January 2013) is tabulated below:

Status of projects under migration scheme

State	Solar PV capacity to be commissioned (MW)	PV Capacity actually commissioned (MW)
Rajasthan	36	35
Punjab	7	2
Maharashtra	11	11
Total	**54**	**48**

2. NSM Batch- I

The commissioning status of new grid connected PV projects allotted under Batch I of NSM-Phase 1(as on January 2014) is tabulated below:

Status of solar PV projects under JNNSM Phase I Batch-I

State	Solar PV Capacity to be commissioned as per PPA (MW)	Solar PV Capacity actually commissioned (MW)
Rajasthan	100	100
Uttar Pradesh	5	5

Maharashtra	5	-
Andhra Pradesh	15	10
Karnataka	10	5
Tamil Nadu	5	5
Orissa	5	5
Total	**145**	**130**

The commissioning status of new grid connected solar thermal projects allotted under Batch I of NSM-Phase 1 (as on January 2014) is tabulated below:

Status of solar thermal projects under JNNSM Phase I Batch-I

State	Solar Thermal Capacity to be commissioned as per PPA (MW)	Solar Thermal Capacity actually commissioned (MW)
Rajasthan	400	50
Andhra Pradesh	50	
Gujarat	20	
Total	**470**	**50**

There is general consensus that the Phase-I have been successful and efforts should be made to build on this success. The lessons learnt from Phase-I of the Mission should be imbibed for further fine tuning the mission implementation. Key learning from Phase-I are as under:

- Grid connected solar PV power is now fairly established in terms of availability of required expertise for designing, construction and site preparation etc.
- Grid connected solar thermal power is still to prove its operational powers as the Phase I projects are yet to be commissioned.
- In general, experienced companies are more interested in large size projects. Price reduction is possible if the tender size is big.
- Most of the projects so far have come up in a few States, like, Rajasthan, Gujarat where high solar energy potential combined with cheap land and favorable State Government policies are in place. Other States need to follow and reap the benefits of solar power.
- Transmission remains a major issue.
- Some assurance regarding regular payments is very important particularly for banks / financial institutions, which have to finance these projects.
- Generation from PV projects so far has been in accordance with the estimates, and higher in many cases.
- Better system designing and construction is required to meet challenges of the local conditions.
- Solar radiation data is an important issue, especially with regard to Direct Normal Irradiance (DNI) data. MNRE has setup Solar Radiation Measure Stations through C-WET and data on various sites for the limited period can be obtained from C-WET or SEC (Solar Energy Centre).
- Provision of requirement of domestic content for setting up solar power projects was kept in the guidelines for Phase-I with a view to develop indigenous capacities and generate employment. It was noted that the production capacities for solar PV cells and modules have expanded in the country.

3. NSM Batch II

The commissioning status of new grid connected PV projects allotted under Batch II of NSM-Phase 1 (as on January 2014) is tabulated below:

Status of solar PV projects under JNNSM Phase I Batch-II

State	Solar PV Capacity to be commissioned as per PPA (MW)	Solar PV Capacity actually commissioned (MW)
Rajasthan	280	270
Maharashtra	40	40
Andhra Pradesh	20	20

Tamil Nadu	10	
Total	**350**	**330**

NSM Phase II

Solar Energy Corporation of India (SECI), the nodal agency for Phase – II Batch 1 of the National Solar Mission, released the details of shortlisted project developers on February 25, 2014, after opening the financial bids on February 21, 2014. The total capacity targeted under this phase was 750 MW and all of the projects will use PV technology. The winners were the project developers who sought the minimum possible funds to make their projects viable to sell power to SECI at a tariff of INR 5.45/kWh (INR 4.75/kWh for projects claiming accelerated depreciation) for 25 years. With an objective to promote local manufacturing, SECI invited bids in two separate categories, reserving half of the projects under domestic content requirement (DCR) restrictions. INR 18.75 billion was earlier approved for viability gap funding (VGF) of all the projects under National Solar Mission Phase2 Batch1.

Bidding results and mechanism of NSM Phase II Batch I

Particulars	Resolution
Managed by	SECI
Capacity Allocation	PV-750 MW; CSP-Nil
Minimum and Maximum project capacity	Min-10MW, Max-100MW
Domestic content requirement	Separate bids for 375 MW capacity under DCR category and remaining 375 MW under open category
Policy mechanism	Funding support by the government (VGF) to make projects viable at INR 5.45/kWh tariff (INR 4.75/kWh for projects claiming accelerated depreciation)
Allocation method	Reverse bidding for viability gap funding demand. Maximum VGF: INR 25 million/MW
Commissioning period	13 months
No. of bids submitted	122
Total capacity of bids submitted	2170MW
No of projects selected	47
Range of winning bids	DCR: INR 13.5 million/MW - INR 24.56 million/MW. Open: INR 1.7 million/MW - INR 13.5 million/MW
Weighted average of the winning bid	DCR: INR 20.19 million/MW, Open: INR 10.67 million/MW

2.6.2. Preferential tariff for inter -state renewable projects

The Central Electricity Regulatory Commission (CERC) exercising its power conferred under Section 61 and section 178(2) of the Electricity Act, 2003 had notified the CERC (Terms and Conditions for Tariff determination from Renewable Energy Sources), Regulations, 2012. Applicability of these regulations shall be confined to Central Sector and Inter State Generation projects, however, under Section 61 of EA 2003; these regulations would be guiding principles for State Electricity Regulatory Commissions while dealing with the matters related to energy generation from RE sources. The salient features of the Tariff Regulations applicable for the Solar Projects are as follows:

Salient Features of Tariff Regulations for Solar Energy Projects

Solar PV and Solar Thermal Projects – Based on technologies approved by MNRE	
General Principles	
Resolution	**Provisions in Regulation**
Control Period	Five (5) years
Tariff Period	Solar PV and Solar Thermal Projects – 25 years
Tariff Structure	Single Part Tariff- Fixed components shall be: • Return on Equity • Interest on loan capital

	• Depreciation • Interest on working capital • Operation and maintenance expense
Tariff Design	The generic tariff shall be on levellised basis for the Tariff Period
Dispatch Principles	a. All plant with installed capacity of 10MW and above shall be treated as 'MUST RUN' power plants and shall not be subjected to 'MOD'
Financial Principles	
Discounting Factor	Weighted Average of Cost of Capital
Debt Equity Ratio	70:30
Loan and Finance Charges	Loan Tenure – 12 years
Interest Rate	a. Average long term prime lending rate (LTPLR) of SBI prevalent during the first six months previous year plus 300 basis points. b. Repayment of loan shall be considered from the first year of COD
Return on Equity	Pre - Tax 20% for first ten years and Pre - Tax24% from eleventh year onward till useful life
Depreciation	1. Value base shall be Capital cost of the asset 2. 5.83% for the first 12 years and the rate of depreciation from the 11^{th} year onwards has been spread over useful life
Interest on Working Capital	a. O&M for 1 month b. Receivables for 2 months of energy charge on normative CUF c. Maintenance spare @ 15% of O&M expense
Operation and Maintenance Expense	R&M expense + A&G expense + Employee expense Escalated at 5.72% per annum over first year of control period
Rebate	For payment of bills through letter of credit, a rebate of 2% shall be allowed Payments made other than through letter of credit within 1 month of presentation of bills by the generating company, a rebate of 1% will be allowed
Late payment surcharge	Delay beyond the period of 60 days from the date of billing attracts late payment surcharge of 1.25% per month
Sharing of CDM benefits	100% of the gross proceeds to be retained by the developer in the first year In second year, the share of beneficiaries shall be 10% which shall be progressively increased by 10% every year until it reaches 50%, where after the proceeds shall be shared in equal proportion, by generating company and the beneficiaries
Subsidy or incentive	Accelerated depreciation or generation based incentive shall be factored in while determining the tariff
Taxes and duties	Taxes and duties shall be passing through on actual incurred basis.

2.6.2.1. CERC Tariff Order of Solar Power for 2015-16

Following the stipulation of the CERC RE Tariff Regulation 2012, CERC under its dispensation mandated the RE Tariff Order 2015-16 which defined the financial, operational and other technology specific norms for determining the tariff of solar power projects commissioned during 2015-16. The defining parameters for solar PV power projects under the aforementioned tariff order are tabulated in Table 8:

Table 8. Assumptions of CERC Tariff Order of Solar PV for 2015-16

Assumption Head	Specification	
	Solar PV	**Solar Thermal**
Useful Life	25 years	25 years
Tariff Period	25 years	25 years
Capital Cost	Rs.605.85 lakhs/MW	Rs. 1200 lakhs/MW
Debt: Equity	70:30	70:30
Interest Rate	13%	13%
Return on Equity (pre-tax)	Return on Equity for first 10 years: 20% Return on Equity 11th year onwards: 24%	Return on Equity for first 10 years: 20% Return on Equity 11th year onwards: 24%
Depreciation	Depreciation Rate for first 12 years: 5.83% Depreciation Rate 13th year onwards: 1.54%	Depreciation Rate for first 12 years: 5.83% Depreciation Rate 13th year onwards: 1.54%
O&M Cost (Base year- FY 15)	Rs.13 lakh/MW; Escalation: 5.72% YoY	Rs.17.72 lakh/MW; Escalation: 5.72% YoY
CUF	19%	23%
Applicable Tariff	Without AD: Rs. 7.04/ kWh With AD: Rs. 6.35/ kWh	Without AD: Rs. 12.05/ kWh With AD: Rs. 10.80/ kWh

2.6.2.2. CERC IEGC Regulations, 2010 - Analysis of the specific provision

The Central Electricity Regulatory Commission (CERC) exercising its power conferred under Section 79(1) (h) and section 178(2) (g) of the Electricity Act, 2003 had notified the CERC (Indian Electricity Grid Code), Regulations, 2010. This code will be applicable to NLDC, RLDC/SLDCs, ISGS, and Distribution Licensees/SEBs/STUs/regional entities, Power Exchanges and Wind and Solar Generating Stations.

In order to encourage the solar based generation into the electricity grid, the IEGC has given due consideration for such segment. The Grid Code provides that in case the generation from solar power project deviates from the schedule the financial burden shall be borne by all the users of the Inter-State Grid, instead of the concerned solar project developer. The IEGC provides the methodology for rescheduling of solar energy on three (3) hours and the methodology of compensating the solar energy rich state for dealing with variable generation through Renewable Regulatory Charge. In pursuance of this, appropriate meters and data acquisition systems facility shall be provided for accounting of UI charges and transfer of information to SLDC and RLDC. The provisions of the IEGC shall be applicable from January 1, 2011, for new solar generating plants with capacity of 5MW and above connected to 33kV and above who have not signed any PPA with States or others. Some of the key and enabling provisions for solar energy in IEGC are tabulated in Table 9.

Table 9. Provision for Solar Energy under IEGC

Provisions in IEGC,2010	Description
Special conditions for solar (Reg 5.2(u):System security Aspects	• System Operator (SLDC/RLDC) shall make all efforts to evaluate the solar and wind power and treat as a '**Must Run**' Plant. • System Operator may instruct the solar generator to back down generation on consideration of grid security or safety of any

	equipment or personnel is endangered and solar generator shall comply with same. • For this, data acquisition system facility shall be provided for transfer of information to concerned SLDC and RLDC.
Scheduling of Solar Power (Reg. 6.5(23)(i))	• Schedule of the Solar generation shall be given by generator based on the availability of the generator, weather forecasting, solar insolation, season and normal generation curve and shall be vetted by RLDC and incorporated in inter-state schedule. • If the RLDC is of opinion that the schedule is not realistic, it may ask the solar generator to modify the schedule
Implications of Scheduling	• In case of solar generation no UI shall be payable/receivable by the generator for any deviation in actual generation from schedule. • The host state shall bear the UI charges for deviation in the actual generation from schedule. • The net UI charges borne by the host state due to solar generation, shall be shared among all the states of the country in ration of their peak demands in previous month based on the data published by CEA, in form of regulatory charge known as Renewable Regulatory Charge operated through the Renewable Regulatory Fund. • The provision shall be applicable, with effect from 1.1.2011 for new solar generating plants with capacity of 5MW and above and connected at 33Kv level and above and who have not signed PPA with states or others as on date of coming into force of this IEGC.

2.6.2.3. CERC Initiative for Transmission/Evacuation of Solar Power

Under the mandate of statutory provisions of Section 61 of the Electricity Act, 2003 inter-alia para 5.3.4 and para 7.2(1) of the National Electricity Policy and Tariff Policy respectively, Central Electricity Regulatory Commission (CERC) has undertaken the exercise to frame regulations on sharing of transmission charges and losses among the users.

The regulations facilitate the solar based generation by allowing zero transmission access charges for the use of the Inter State Transmission System and allocating no transmission loss to the solar based generation. Solar power generators shall be benefited in event of use of the ISTS. Since such generation would normally be connected at 66KV, the power generated by such generators would most likely be absorbed locally. This would cause no / minimal use of 400 kV ISTS network and might also lead to reduction of losses in the 400 kV network by doing away the need for power from distant generators. The cost of energy from solar based generation is perceived to be costly as compared to other sources, including renewable energy sources, and further application of ISTS charges and losses would further reduce the acceptability of power generated from solar sources. This regulation thus encourages solar based generation and inter-state transactions based on solar energy.

2.7. Solar Potential in state of Karnataka

Blessed with significant solar power potential, of which nearly more than 95 per cent remaining still untapped, the State of Karnataka in India portrays itself as a geography which allures all serious solar energy investors to venture into. Karnataka as a State has witnessed significant growth in Solar power capacity addition in the past. As per the estimates of Ministry of New and Renewable Energy (MNRE), the solar power potential stands at 24.70GW.

2.7.1. Policy Initiative for Solar Promotion

The Government of Karnataka (GoK) on 22nd May 2014 revised its existing state solar power policy. Karnataka previously had a five year solar policy in place for the period 2011 to 2016. The new solar policy is a seven year policy spanning 2014 to 2021. With the release of a new comprehensive solar policy, GoK aims to develop Karnataka as a solar hub of India.

Under the Karnataka Renewable Energy Policy, it is envisaged that the State will have a target for achieving 2000MW MW of solar power up to 2020-21. In the allignment of the aforementioned target, the policy envisages for procurement of 3% of total power consumed from solar resources in 2021-22 from the prescribed levels of 1.75% in 2015-16.The targets promotion of solar power under different mechanisms is detailed in the figure.

Grid Connected Projects-1600MW

- Projects by land owning farmers- 300MW
- Projects under REC mechansim & 3rd party sale- No limit
- Projects under bundled power- Not defined
- Projects selected under competitive bidding (>3MW)-Not defined

Grid connected rooftop projects- 400MW by 2018

The Karnataka Renewable Energy Development Ltd. (KREDL) has already taken the initiative in line with the Solar Policy and has selected project developers by conducting tariff based competitive bidding for allocation of 500 MW of solar project capacity. The lowest winning bid was submitted at a tariff of INR 6.71/kWh.

2.7.2. Rationale for Solar Park

It is being felt that developing a solar energy project is still a complex process and for the successful development of a solar project, many fundamental blocks under the development process must come together. The development of solar projects face a number of issues related to land availability, financing, project development, approval & clearances. Some of these key issues are detailed below:

- Power Evacuation: The availability & capacity of power evacuation infrastructure in the remote areas is a major impediment for development of solar projects, as it results in putting additional burden on solar project developer on grid connectivity infrastructure.
- Water Availability: The water supply network at the proposed site for solar projects needs to be assessed from the perspective of cleaning of solar panels with perspective from improved performance of solar PV projects
- Land Availability: Availability of land is a major issue faced for the development of solar power projects.
- Financing: Legal arrangements like PPA, Transmission agreement and land acquisition etc are pre-requisites to the financing and developers are supposed to utilize equity (for payment of charges/fees etc) till debt disbursements are available. Absence of the aforementioned arrangements effects the solar project financing
- Project Development: Development of projects needs to go through various administrative steps which are under various departments.

Development of Solar Park provides an integrated approach for addressing some of the key issues related to the development of solar projects. This is also results in reduced cost related to power evacuation, water availability owing the large scale solar project development in the solar park.

2.8. MNRE Scheme for solar parks and UMPPs

To achieve the ambitious target of 20GW grid connected solar power by 2022 set under the Jawaharlal Nehru National Solar Mission (JNNSM), the major thrust area continue to be large scale grid connected projects. Solar UMPP projects get their motivation from coal based Ultra Mega Power Projects with capacity of more than 4000 MW each, at both the coal pitheads and coastal locations aimed at delivering power at competitive cost to consumers by achieving economies of the scale.

The solar parks in Gujarat and Rajasthan not only enable the states to meet their policy targets for solar power and renewable purchase obligations, they also contribute towards the ambitious targets put in place by the JNNSM. In addition, the clean power generated by these solar projects play a role for reducing India's carbon footprint, promote high end technical investments and empower local communities.

MNRE recently declared a draft Scheme for development of Solar Parks and Ultra Mega Solar power projects in India with its implementation agency being Solar Energy Corporation of India (SECI). MNRE through this scheme plans setting up 25 solar parks, each with a capacity of 500 to 1000 MW; thereby targeting around 20000 MW of solar power installed capacity. These solar parks will be put in place in a span of 5 years and the solar projects may then come up as per demand and interest shown by developers.

At the state level, the solar park will enable the states to bring in significant investment from project developers, meet its Renewable Purchase Obligation (RPO) mandates and provide employment opportunities to local population. The state will also reduce its carbon footprint by avoiding emissions equivalent to the solar park's installed capacity. Further, the state will also avoid procuring expensive fossil fuels to power conventional power plants of equivalent installed capacity.

The solar park will provide a huge impetus to solar energy generation by acting as a flagship demonstration facility to encourage project developers and investors, prompting additional projects of similar nature, triggering economies of scale for cost-reductions, technical improvements and achieving large scale reductions in GHG emissions. Some Ultra Mega projects may be set up in these Parks or entire parts may be an Ultra Mega Power Projects. Salient features of the scheme are as follows:

Applicability: All the states and Union territories are eligible for benefits under the scheme.

Capacity: Park to be taken up for development should be of capacity of 500 MW and above. Smaller parks of 100 MW and above may be considered in NE, HP, Uttarakhand and J&K.

Implementation agency: The solar parks will be developed in collaboration with the State Governments. The MNRE Nodal Agency would be Solar Energy Corporation of India (SECI) on behalf of Government of India (GOI). SECI will handle funds to be made available under the scheme on behalf of GOI.

The states applying under the scheme will have to designate an agency for the development of solar park. Solar parks are envisaged to be developed in the following four modes.

Implementation modes

- **Mode 1:** The State designated nodal agency undertakes development & management of solar park. This agency could be a State Govt. Public Sector Undertaking (PSU) or a Special Purpose Vehicle (SPV) of the State Government.
- **Mode 2:** A JV is set up between State designated nodal agency and SECI for development & management of solar park with 50% equity from SECI and 50% equity from the State Agency (more than one agency allowed).
- **Mode 3:** The State designates SECI as the nodal agency and SECI undertakes the development and management of solar park on behalf of State Government on mutually agreed terms.
- **Mode 4:** Private entrepreneurs promote solar parks without any equity participation from SECI, but may have equity participation from the State Government or its agencies.

Any of the above four alternatives with a private sector partner with a condition that at least 51% of the equity will remain with SECI+ State designated agency. There will be an implementation agency setup as above.

The Implementation Agency or Special Purpose Vehicle (SPV), as identified under provisions at (i) to (iv) above, shall undertake following activities to achieve the objective of speedy establishment and implementation of Solar Power Parks in the State.

i. Develop, plan, execute, implement, finance, operate and maintain the Solar Power Park
ii. Identify potential site and to acquire/possess land at potential sites for Solar Power Park
iii. Carry out site related studies/investigations
iv. Obtain statutory & non statutory clearances and to make area development plan within Solar Power Park.
v. Design a plan for sharing development cost between the developers and the park
vi. Create necessary infrastructure like water, transmission lines, roads, drainage etc. to facilitate Solar Power Project developer for faster implementation of Solar Power Projects
vii. Frame out transparent plot allotment policy and specify procedures pursuant to the relevant State policies and their amendments thereof.

viii. Provide directives for technology-specific land requirements
ix. Engage the services of national/global experts/consultants to promote Solar Power Park related activities
x. Facilitate the State Government to establish educational institutions/training facilities within Solar Power Park for development of manpower skill related to Solar Power
xi. Any other activities related to Solar Power Park as per the directives from MNRE and the State Government.
xii. Conduct the necessary evaluation and pre-permitting of the environmental and social impacts of utility scale solar deployment before allocating the land to prospective developers.

All infrastructural requirements outside the park such as connecting road, provision of water supply, construction electricity, etc. to make the park functional, will be the sole responsibility of the concerned State Government.

Land acquisition / site selection: Land for the setting up of the solar park will be identified by the State Government. It will be the responsibility of the State Government to make the land available. States are encouraged to identify sites receiving good solar radiation and sites which are closer to CTU (i.e. Power Grid Corporation of India Limited), preferably locations with spare transmission capacities and water availability. The park must have at least 5 Acres per MW towards installation of solar projects.

In order to provide for such a large tract of contiguous land with appropriate insolation levels, the state government may prioritize the use of government waste/non-agricultural land in order to speed up the acquisition process. It will be preferred if most of the required land is Government owned and very little private land is to be acquired. The price of the land is to be kept as low as possible in order to attract the developers and, therefore, the site should be selected in such a manner so that inexpensive land can be made available. If land cannot be made available in one location, then land in few locations in close vicinity may be taken.

Facilities to be provided: The solar park will provide specialized services to incentivize private developers to invest in solar energy in the park. These services while not being unique to the park, are provided in a central, one-stop-shop, single window format, making it easier for investors to implement their projects within the park in a significantly shorter period of time, as compared to projects outside the park which would have to obtain these services individually.

The implementing agency is tasked with acquiring the land for the Park, cleaning it, levelling it and allocating the plots for individual projects. Apart from this, the agency will also be entrusted with providing the following facilities to the solar project developers for the development of the solar park:

i. Land approved for installation of solar power plants and necessary permissions including change of land use etc.
ii. Road connectivity to each plot of land
iii. Water availability for construction as well as running of power plants and demineralization plant
iv. Flood mitigation measures like flood discharge, internal drainage etc.
v. Construction power
vi. Telecommunication facilities
vii. Transmission facility consisting pooling station (with 400/220, 220/66 KV switchyard and respective transformers) to allow connection of individual projects with pooling station through a network of underground cables or overhead lines.
viii. Housing facility for basic manpower wherever possible
ix. Parking, Warehouse etc.

The solar park will be a large contiguous stretch of land with high insolation levels, saving the private developer from making the effort of identifying the ideal site for the plant. In addition, the site within the park is already levelled and developed reducing these costs for the project developer.

In addition, the Park will provide road access (both approach roads and smaller access roads to individual plots), water (via a dedicated reservoir located within the premises), boundary wall and security, each of which would have entailed additional costs for the developer outside the park.

Each of these specialized services offer significant benefits to the developers but come at a premium. Land plots within the solar park are more expensive than outside. But this premium is easily justifiable by these services, which are bundled into the land cost. However, the most important benefit from the park for the private developer is the significant time saved. The centralized, single window nature of the services within the park reduces the time between project conceptualization and operations, translating into economic and real monetary gains for the private developers and the state. Centralised Weather Monitoring Station would be set-up so as to provide weather data to the projects in the solar parks.

Financial model: The implementation agency, entrusted with implementing the programme will get the land developed and provide necessary infrastructure like road connectivity, transmission infrastructure etc. Significant investments will also be made in the operation & maintenance of the solar park, employing staff and other activities like marketing etc. The entire cost of development including cost involved in acquisition of land will form the total cost for the project for which an estimate will be prepared beforehand by the nodal agency. Based on this estimate the implementing agency will formulate a recovery model to ensure the sustainability of the park. The implementing agency may raise the funds as follows:

- The implementation agency may sell/lease out the plots to prospective project developers. Lease period shall be of 30 years or as per State land policy. The Allotment Price per metre square (inclusive of all applicable taxes, duties, cess etc.) payable by the plot applicant for the applications must be specified in a transparent manner. The allotment price may be reviewed annually and an annual increment may also be specified. The maximum stretch of plot to be allotted will be decided as per the benchmarks finalized by the implementing agency.
- A one-time registration fee (per project or per MW) may be collected by inviting applications from the prospective buyers when the scheme is finalized, land identified and marked. An advance may be collected from the prospective buyers when 50% of the land is acquired. This advance will be 10% of the sale price or lease amount. Another instalment of 25% of the price of land or lease amount may be taken when full land is acquired. Further instalments may be collected while plot are being developed. Final 15% of the price of land or lease amount may be collected at the time of allotment of the plot to the buyer.
- The implementation agency may put in some of its own equity and can raise loans, depending on the availability of funds and requirement. The subsidy of MNRE under the scheme would bring down the cost of the project to that extent. The SPV will also create a small corpus for working capital to ensure upkeep and maintenance in the future, which may be supplemented with some annual charges. The implementation agency may change the above plan if it is in the interest of the solar park.

MNRE support: The State Government will first identify the nodal agency for the solar park and will also identify the land for proposed solar park. Thereafter, it will send a proposal to MNRE for approval. After the solar park is approved by MNRE, the implementing agency may apply for a grant of Rs. 25 lakhs for preparing DPR of the solar park, conducting surveys etc. Thereafter application may be made for the grant of up to Rs.20 lakhs/MW or 30% of the project cost including grid connectivity cost whichever is lower, which will be released as per the following:

S. No.	Milestone	% of subsidy disbursed
1	Date of issue of administrative approval	5%
2	Land acquisition (50% land acquired)	20%
3	Financial Closure	20%
4	Construction of Pooling Substation, Land Development and other Common facilities as per DPR	25%
5	Construction of transmission line and Grid Connectivity	20%
6	Final instalment on completion	10%

The grant will be managed and released by SECI on behalf of MNRE for which SECI will be given a fund handling fee of 1%. If the park is developed in phases, grant will also be phased out in proportion to expenditure in each phase.

Transmission and evacuation of power from solar park: Interconnection of each plot with pooling stations through 66 KV other suitable voltage underground or overhead cable will be the responsibility of the solar project developer.

The designated nodal agency will set up the pooling stations (with 400/220, 220/66 KV or as may be suitable switchyard and respective transformers) inside the solar park and will also draw transmission to transmit power to 220 KV/400 KV sub-station.

The responsibility of setting up a sub-station nearby the solar park to take power from one or more pooling stations will lie with the central transmission utility (CTU) or the State transmission utility (STU), after following necessary technical and commercial procedures as stipulated in the various regulations notified by the Central/State Commission.

If the state government is willing to buy substantial part of the power generated in the solar park, preference will be given to STU, which will ensure setting up of sub-station and development of necessary infrastructure for transmission of power from substation to load centres.

The designated implementing agency will intimate POWERGRID and CEA well in advance so that the planning and execution can be carried out in time.

If the state is not willing to buy substantial power generated in the solar park, then CTU may be entrusted with the responsibility of setting up 400 KV sub-station right next to the solar park and its connectivity with the CTU. For setting up of this transmission & evacuation infrastructure, Power Grid may prepare a separate project to be funded from NCEF / external funds / Green Corridor project, if the cost is very high. The system would be planned in such a manner so that there is no wheeling charge applicable on solar power in accordance with the CERC Regulation or they are very low.

To build this infrastructure using the highest possible standards, the whole solar power evacuation network scheme may be designed using latest technologies like SCADA, GIS, Bay controller, online monitoring equipment for dissolved gas analysis, OPGW, PLCC etc.

Power sale arrangement: Acceptance for development of solar park under the scheme does not guarantee Power purchase agreement (PPA) or a tariff for the power to be produced. The project developers need to have their own arrangements for a PPA or get selected in any Government of India or State Government scheme. The developer will be free to set up projects under any scheme or for third party sale.

Loan: MNRE will also put in efforts to tie up with multilateral/ bilateral funding agencies to finance the entire or a part of the cost of the solar parks. The MNRE grant will be treated as the developers' contribution to get this loan. The loan tenure and the moratorium period will be set in accordance with the banks' terms and conditions while the annual interest will be set in accordance with banks' LIBOR-based lending facility.

Fund for power evacuation: The connectivity with grid i.e. 220/400 KV substation and transmission line to connect with CTU / STU's, existing network is a very important component. For power evacuation network, MNRE grant may be used. Loan from multilateral or bilateral agencies may also be used to the power evacuation network. If the expenditure is high then a separate proposal may also be considered for funding from NCEF, Green Corridor Programme or any other source.

Equity Contribution: Minimum up front equity will be required to setup from the implementing agency as most of the costs will be covered through MNRE grant and loan. Most of the land is expected to be Government Land. The expenses on land can be recovered and paid from sale proceeds gradually from developers.

The surplus money that will accrue from sale may be converted into equity of promoters so that the implementing agency gets a financial strength for long term sustenance.

Ultra Mega Solar Power Projects: Ultra Mega Solar Power Project is defined as a single power project with capacity of over 500 MW. These projects may be set up in some of these solar parks. The projects may be bid out after developing the park or simultaneously with park developments. In some cases the entire solar park may be set up as a single Ultra Mega Solar Power Project. In such cases the J.V. set up to develop the Ultra Mega Solar Power Project may become the implementing agency also.

Hybrid Projects: Some other forms of RE like wind, biomass etc. may also be allowed to come up in the park wherever feasible.

Timelines: Scheduled timelines for setting up of Solar Power Park is as under:

S. No.	Milestone	Timelines
1	Date of issue of administrative approval	Zero Date
2	Land acquisition and Financial Closure	6 months from zero date
3	Construction of Pooling Substation, Land Development and other Common facilities as per DPR	15 months from zero date
4	Transmission line and Grid Connectivity	18 months from zero date
5	Final instalment on completion	18 months from zero date

Manufacturing: Manufacturing of solar products and components may also be allowed in the parks.

Interpretation: In case of any ambiguity in interpretation of any of the provisions of the Scheme, the decision of the Ministry shall be final.

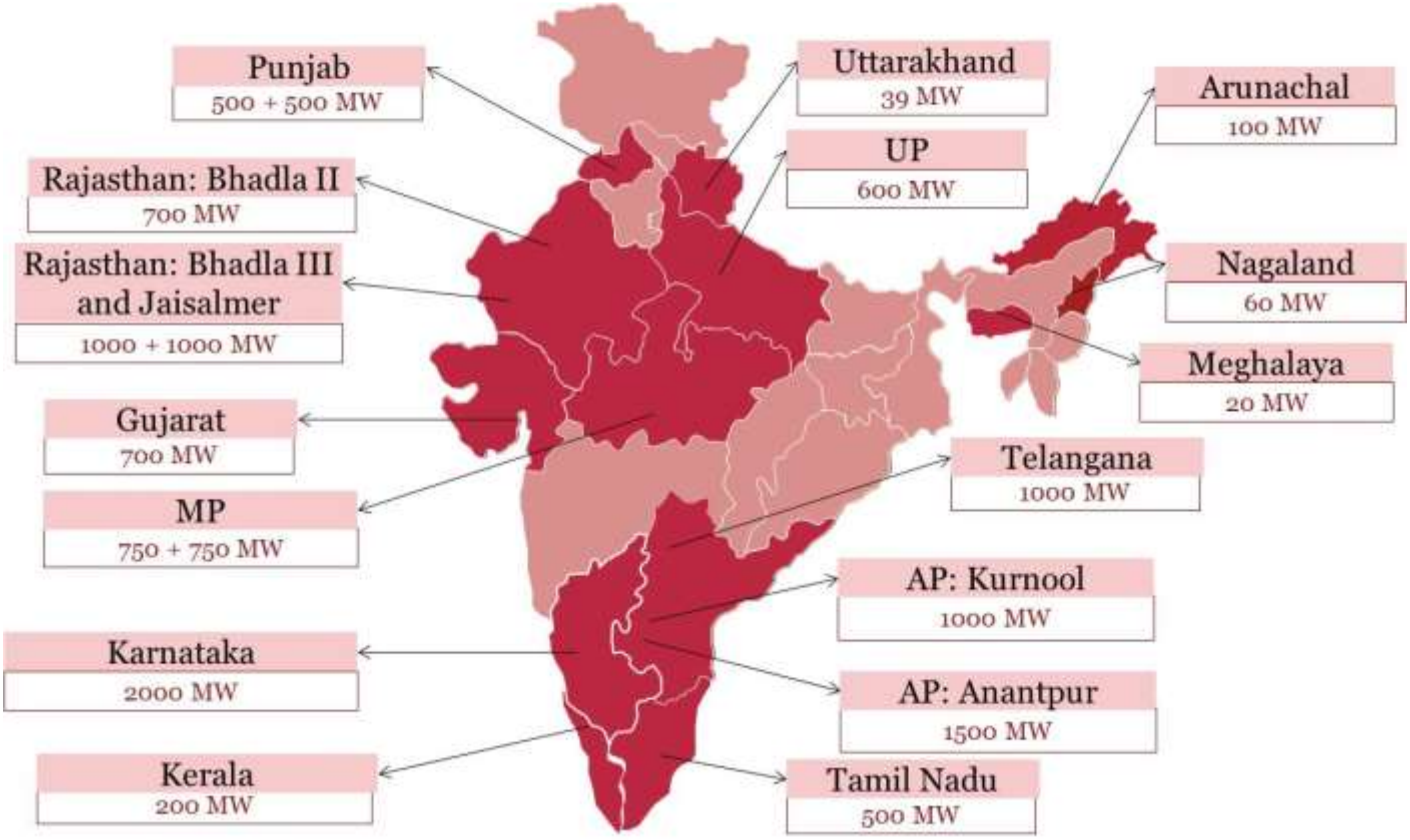
Arbitration: Any dispute that arises out of any provision of the scheme shall be settled by an Arbitrator appointed by this Ministry for the purpose and his decision shall be final and binding.

Power to remove difficulties: If there is need for any amendment to this Scheme for better implementation or any relaxation is required in the norms for Solar Parks due to operational problems, MNRE will be competent to make such amendments with the approval of Minister-in-charge.

State Government's obligation to purchase power: The State Government in which the solar park is developed must agree to buy atleast 20% of the power produced in the park through its Discom. The States which agree to buy higher percentage of power will be given preference. In case the State refuses to buy power then connectivity with CTU systems has to be ensured. If connectivity with CTU system is through STU system then State will agree to waive wheeling charges failing which affordable arrangement will be considered.

Monitoring progress of Scheme: MNRE will appoint a Nodal Officer in the Ministry to closely monitor progress of the scheme to ensure that timeliness as envisaged for completion of various activities are adhered to for development of solar parks.

As on April 2015, 20 Parks (15 states) with capacity 12,999 MW approved and requests were received for 5 more parks. An overview of the solar parks is presented herewith:



The grant will be managed and released by SECI on behalf of MNRE for which SECI will be given a fund handling fee of 1%. If the park is developed in phases, grant will also be phased out in proportion to expenditure in each phase.

3. Site Assessment

Renewable energy resources (solar, wind etc.) are intermittent in nature and change with change of the location. Solar radiation is essentially a macroscopic energy resource which depends upon the location, day of the year (season), time of the day etc. The site assessment of solar PV power projects comprises three major dimensions namely Land, Meteorology and Infrastructure availability. Out of three key dimensions the maximum weightage is given to land which is explored under several dimensions of engineering.

Development of Solar Park is a new approach in India towards rapid growth of solar power generation; where large scale multiple solar power projects could be implemented at a common location. The approach will enhance the techno-commercial viability of solar power projects due to sharing of the common infrastructure. There is no specified mechanism of site selection of Solar Parks defined in any policy in India; however in the present exercise the globally adopted site assessment / selection approach developed under Empower Program has been taken as benchmark. Figure 13 presents the basics approach of site selection approach of Empower[5] toolkit for implementation of large scale solar power projects.

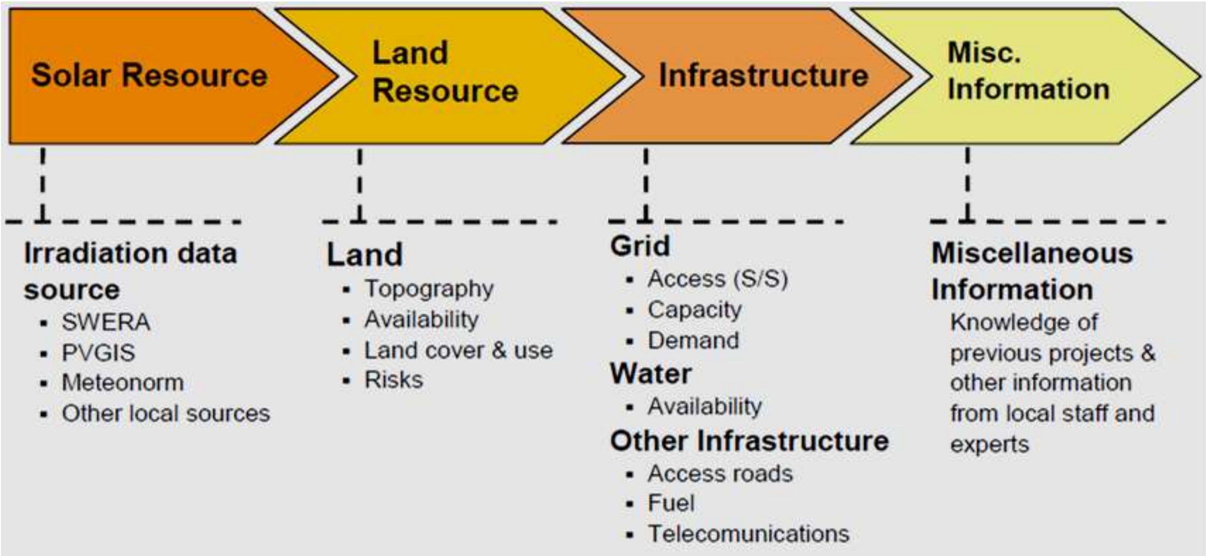


Figure 13. Approach adopted for site assessment

Based on the best industrial practices, PwC has undertaken visits of the selected location for developing Solar Park of 2000 MW capacity in the district of Tumkur, Karnataka. The location has essential been identified by Karnataka Renewable Energy Development Ltd. (KREDL) which is the state nodal agency (SNA) of Ministry of New and Renewable Energy (MNRE); Government of India. The site assessment has been carried out from the point of view of solar PV technologies (most commercial technology options) and no consideration has been made for solar thermal power generation (i.e. concentrating solar power).

The suitability of the sites for developing the Solar park of 2000 MW has been addressed on the basis of connectivity and accessibility, meteorological features, GHI availability (satellite data at site selection stage), water availability, power evacuation facilities, accessibility of construction power and water etc. Topographically the site will be addressed from the point of view of slope, free of obstacles for shadow, free from underground structure (pipes, cables, channels, tunnels etc.).

The overall approach of site assessment for solar PV power projects has been presented below:

[5] http://www.empower-ph2.com/

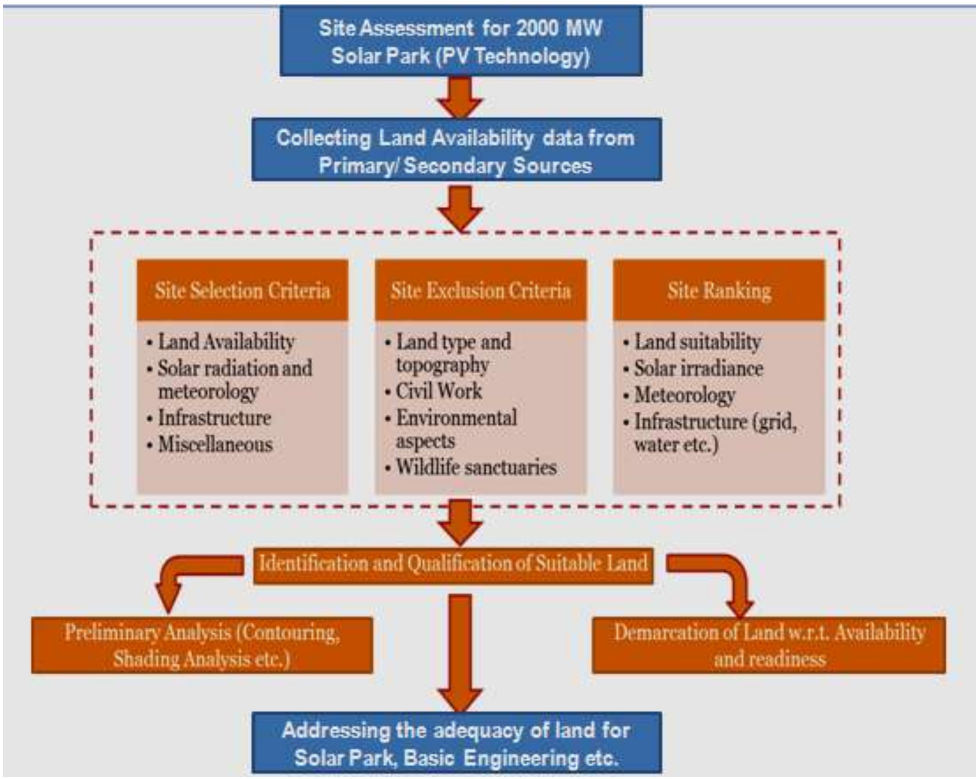
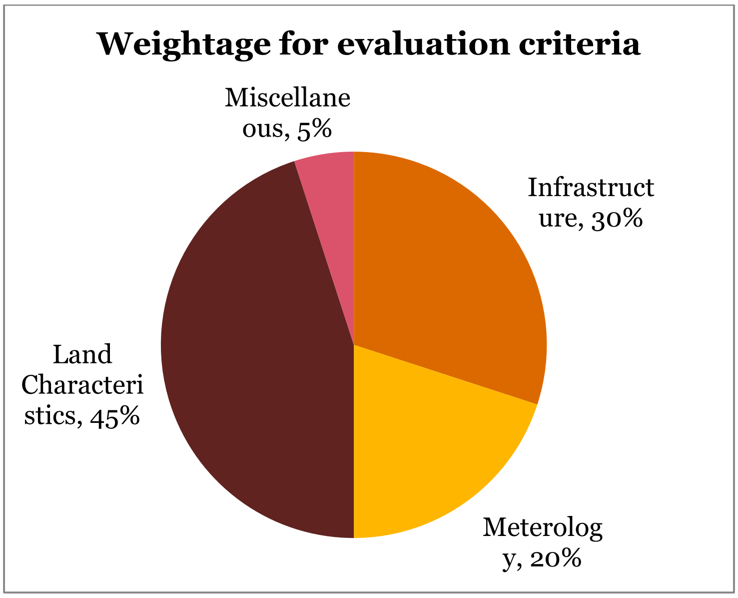


Figure 14: Step wise methodology for site assessment for Solar Park

3.1. Site Assessment Criteria

Due to the dilute nature of solar energy (solar irradiance), solar PV power projects require higher area (foot print) as compared with the conventional power projects. In order to implement large scale solar PV projects, site selection is required to be done from the point of view of high solar radiation availability, connectivity and accessibility, shadow free area, water availability and arrangements of power evacuation. The power evacuation needs to be especially address for large capacity solar park. Figure 15 presents the approach of site selection for large solar PV power projects.



Meteorology

- Micro-Climate
- Solar Radiation

Land Characteristics

- Size, shape, orientation
- Shading, land use
- Seismic activities, flooding etc.
- Ownership

Infrastructure

- Grid availability
- Accessibility
- Connectivity (Road, Rail, air)
- Water availability
- Electrical situation

Figure 15. Evaluation criteria for Site Assessment of PV Power Plant

3.1.1. Introduction

The Site Selection Process aims at identifying sites suitable for the Solar Park and solar projects inside the park from the point of view of suitable solar PV technology, appropriate design approach and effective project implementation. Following issues are essential to addressed during this phase in order to achieve the expected result:

- Definition of exclusion criteria and areas *(Environmental restrictions, military facilities, etc.)*
- Assessment of Site Conditions (*Meteorology, land characteristics, land use*)
- Infrastructure (*Power for construction, roads, power evacuation, water, other off site facilities etc.)*
- Electricity price, production, and demand (*For the projects not under any specific policy*)

All above points have influence in the evaluation of potential sites with different weightages and these will have to be incorporated in evaluating potential sites by means of an exclusion matrix. In doing so, sites can be evaluated and ranked to find out the best suited location. In the present case; KSPDCL has plan to develop 2000 MW capacity Solar Park in Tumkur district of the state where land has been preliminarily identified. As per KSPDCL the provisional external evacuation plan for the solar park has already been drawn up. The 400 kV works would be implemented by Power Grid Corporation of India (POWERGRID) and 220 kV Works up to 66KV pooling stations would be carried out by Transmission Corporation of Karnataka (KPTCL). The proposed site for 400/220kV grid substation to be established by POWERGRID falls in Pavagada taluk, Tumkur district. The nearest proposed grid substation of POWERGRID is 765KV station at Madhugiri, Karnataka.

In order to optimize the sites according to their suitability for the installation, it is a common practice to organize and evaluate them through a selection matrix. A selection matrix sets out the characteristics of a site which are relevant for installation of a particular facility while assigning each of these characteristics a grade for each site. Since not all characteristics have the same importance for the final overall grade, each one of the characteristic is allocated a corresponding weight depending on the evaluation criterion and particular conditions of the project.

3.1.2. Exclusion Criteria and Areas

Before evaluation potential areas seeking for optimum sites it is necessary to rule out ineligible areas applying the exclusion criteria such as:

- Environmental restrictions (*Natural Park, protected habitat, etc.*)
- Military facilities
- Areas affected by armed conflicts
- Existing human settlements
- Archaeological restrictions
- Livestock

This research is generally carried out as desktop study prior to the actual selection of a site and can be coupled to a contact with the local authorities.

3.1.3. Assessment of site conditions

Once the potential areas have been identified through the Site Identification stage, the next foremost important task to be performed is the visits to sites. Visits to the areas identified allow determining the optimum sites suitable for installation of PV Power plants within the area by analyzing the following key associated factors:

- Meteorology
- Land characteristics
- Infrastructure

3.1.3.1. Meteorology

The solar energy, i.e. solar irradiation, is the first criteria for the selection of a site since it is the resource which will determine how much electricity can be produced. The amount of solar radiation available on a site depends on three main factors:

- Latitude
- Altitude and
- Local climate and atmosphere

The Solar Irradiance comprises of direct irradiation reaching the ground without clouds and diffused radiation which is reaching the ground through the clouds. The sum of direct and diffuse radiation is referred to as Global Horizontal Irradiation (GHI) and is given in kWh/m². In order to keep the electricity generation costs for a PV power plant as low as possible, the mean annual GHI should be at least around **1600** kWh/m². Additionally, site selection is influenced by

- Wind speed (*standard withstand capacity of 150 km/h*)
- Extreme weathers (*e.g. heavy snow, temperature, fog*)
- Pollution (*e.g. dust, sand, salty air*), and
- Relative Humidity

As construction of the plant has to fit the relevant guiding standards related to these site characteristics, corresponding design values for these parameters have to be obtained for the respective region.

3.1.3.2. Land characteristics

Having the meteorological circumstances analyzed and solar irradiation found sufficient, the next step is to assess the land characteristics.

- ***Size, shape, and orientation -*** Essentially for a site located between the 35° N and 35°S latitude, an area of around **2 ha (20,000 m²)** is required for a **1 MW** PV Power plant with crystalline based technology. When locating fixed Photovoltaic Power Plants, near-rectangular shapes of appropriate size must be sought. Rectangular shapes allow for simple plant geometry, and thus facilitate both the plant design and its installation. For the best energy harvest by using the technology of a fixed PV Power plant, rectangular shaped areas facing the equator is preferred. The area should be reasonably flat or with a modest hilly slope without shadow effects by obstacles. The slopes preferably should be between 0 - 10° in North-South orientation. Figure 16 presents few solar PV power projects with non-uniform land.

Figure 16. Large solar PV power projects over inclined land due equator

- ***Distance to shading Objects-*** For a best use of the solar irradiation the PV power plant design should be optimized to minimize shading losses. Hence it is important to consider during the site visit the little shading from outside the PV Plant which can reach the modules (*Trees, lines, buildings, mountains*). Trees, buildings which are near or on site have to be documented properly, such that a desktop assessment can be done later. To have a clear understanding of the site during simulation and to identify possible near or far shading obstacles, photos spanning around 360° should be taken at site with the directions North, South, East and West clearly labeled. By means of a 360° view, a horizon of the site can be prepared (Figure 17 and Figure 18).

Figure 17. Shading aspects and 360° view of horizon
(Source: http://www.solarpowerportal.co.uk)

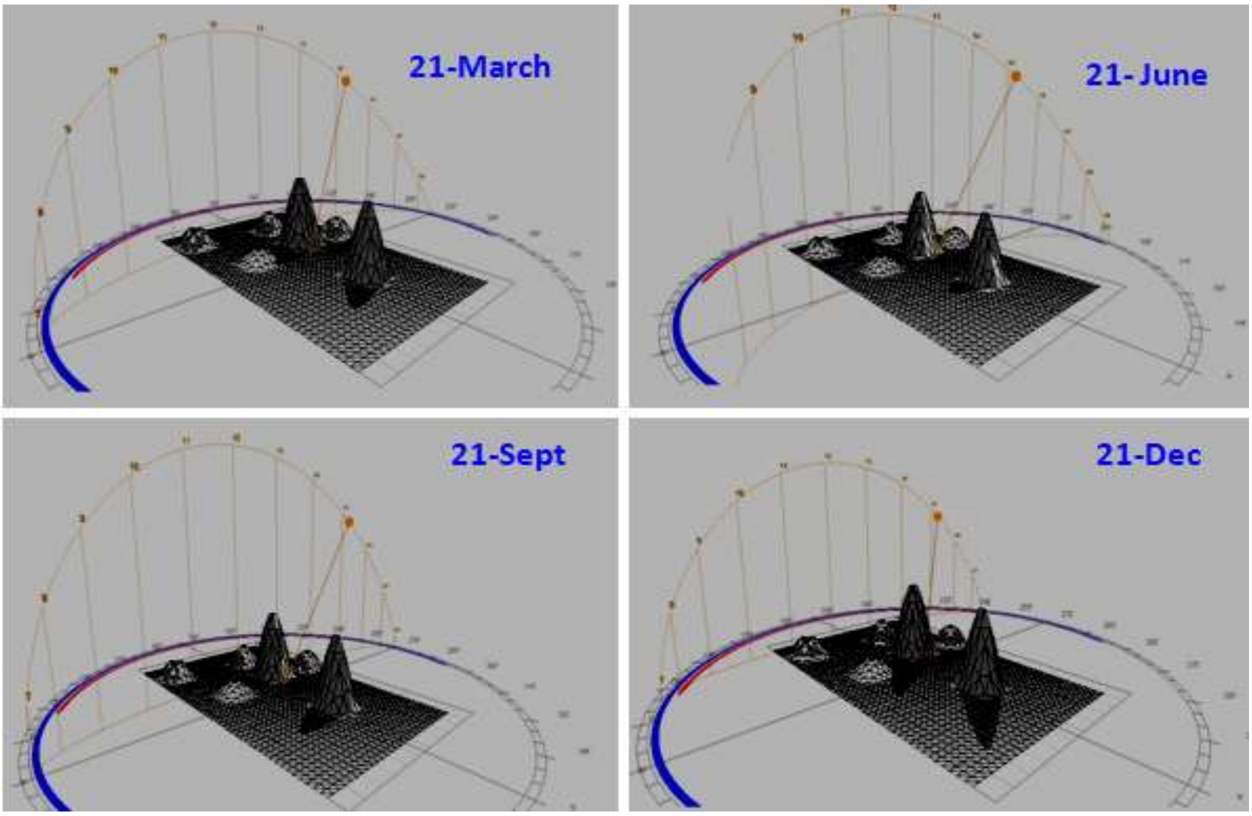


Figure 18. The topographical shading (indicative) at four representative days of the year
(Source: ECOTECT Software)

- ***Use of Land and effects of Soiling-*** Ideally, the foreseen site should be not covered by prior agriculture or ulterior use. Keeping in mind the existing restrictions regarding plant operation (e.g. dust) or facts which could influence the authorisation to proceed, the condition of the site has to be documented during site visit. Care needs to be taken by recognising protected trees, agricultural use, livestock pathways, or alike, which might represent future constraints for the project. Soiling depends on the occurrence of airborne pollutants (dust etc.) along with frequency and quality of rainfalls. Soiling will lead to increased losses in energy generation due to reduction in amount of solar energy used or require more frequent module cleaning increasing the operational costs (Figure 19). To prevent soiling by, e.g. sand/dust or salty air, and consequent energy losses, PV plants should be placed
  - At a certain distance from sea coast (important from the point of view of corrosion)
  - In areas with low dust concentration (sand, harvest etc.)

Figure 19. Soiling on PV modules

- ***Soil Characteristics -*** For almost every soil type, solutions for construction of foundation for Solar Module supporting structures as well as the BoS of plant do exist. When a site is selected, a geotechnical soil study for the specific selected site has to be conducted. Usually, the geotechnical soil study forms part of the EPC contract in turn-key projects.

- ***Geomorphology -*** Site visits intend to visually verify whether the morphology of the area available is suitable for the project. Geomorphology of the terrain is of high relevance for solar power projects since they occupy much larger areas of flat terrain as compared to other forms of power plants. The site visit shall give a firsthand knowledge of the earth works (excavation/back-filling) required to install the plant based on observation of the existing topography and slopes.

- ***Ownership -*** The land ownership and therefore the availability and costs of land can be crucial for long term availability and expenses for land lease. Contracts for land lease and purchase of land respectively should be negotiated in the early stage of a project.

3.1.3.3. Infrastructure

Availability of suitable infrastructure at the site is an essential criterion for site selection which mainly takes in to account the connectivity/ accessibility, water availability, arrangements of construction water and power, and power evacuation facilities.

- ***Grid availability -*** Usually, PV plants in range of 1 MW and above will be connected directly to the HV public grid through Step-up Transformers. Ideally, an HV terminal point of the utility should be available nearby to prevent losses due to interconnections between utility and feed-in-point of the Solar PV Power plant. A preliminary investigation of the HV power network infrastructure within a few kilometers around the area of interest should be complemented with the visual review of the particular infrastructure to primarily verify that:
    - Enough capacity is available at the existing facility to evacuate the generated power.
    - Voltage levels of the existing infrastructure with reference to the capacity foreseen for PV plants.
    - Installation of overhead or underground interconnections will not face major obstacles which might jeopardize successful completion and commissioning of the project.
    - Pre-existing projects in the pipeline with allocated capacity for interconnections at the Utility's infrastructure.

- ***Access to the site-*** During construction, the access for heavy vehicles must be possible to ensure smooth delivery of equipment/materials to site. Subsequent to commissioning, operation and maintenance (O&M) requirements need to be addressed. Assessment of access road for construction as well as for O&M phases of the plant has to be done during site visit.

- ***Proximity to roads, railways, ports, cities, or airports -*** Major components of the power plant shall reach the site through ports, railways, main roads, or airports. Therefore proximity of the foreseen area to these facilities has to be preliminarily investigated. Assessment of suitability and cost involved using different combinations of transport options is a matter of further analyses.

- ***Water availability -*** In case of dusty areas, regular cleaning of the modules is necessary to prevent losses on account of soiling. This would require permanent water supply either on site or adjacent to site. Alternatively new water supply proximities by way of bore wells etc. can also be planned for.

- ***Electrical situation in the region -*** Once the technical viability of a PV plant has been assessed, a study of the integration in the local/ regional energy mix is important. The daily/seasonal production patterns have to match with those of local/ regional demand, and the costs of generation have to be compatible with local/ regional strategy.

- ***Overview of Demand – Supply -*** Experience in planning and running PV Power plants shows that certain characteristics of the demand supply system of the utility benefit installation of PV Power plants. As per the KERC order, KERC shall plan for evacuation of power from the solar projects. Solar projects will get highest priority in the merit order and hence absorption of the electricity generated from solar power projects in to grid is assured.

Large scale solar PV power sector is a Policy Driven Sector in India and the techno-commercial viability of the project varies with the policies. The infrastructural requirements also changes with the policies. The concept of

Solar Park is well established from the point of view to give relax to project developers from time taking procedure of land acquisition, power evacuation and water approvals and several permit and licenses required from various Government departments. Additionally this is one way to attract the project developers of solar PV power in the state.

3.2. The Location – District Tumkur (Karnataka)

The overall objective of setting up the Solar Park in the district of Tumkur in the State of Karnataka is to promote the development of the solar power projects for electricity generation. The overall aim is to install a capacity of around 2000 MW in the Solar Park. It is proposed that one or more blocks of land identified in the solar park will be allocated to different project developers in order to have a concentrated zone for solar development. KSPDCL has targeted acquisition of around 25000 acres (14000 acres for the 2000 MW solar park) of the land in Tumkur district of the state of Karnataka where annual GHI is high (>1900 kWh/m^2) and climate is favorable for large scale deployment of solar PV based power projects.

Tumkur district is located in the eastern belt in the southern half of the Slate. Spanning an area of 10598 km^2 the district lies between the latitudinal parallels of 12° 45' N and 14° 22' N and the longitudinal parallels of 76° 24' E and 77° 30' E. The shape of the district is somewhat irregular and has a peculiar feature in that the north-eastern portion is totally detached from the remaining areas of the district. This portion constituting Pavagada taluk is almost surrounded on all sides by territories belonging to Andhra Pradesh, But for the fact that on its; western border for a very short stretch it touches Chitradurga district, Pavagada would have been an enclave territory. Tumkur district is bounded on the north by Anantpur district of Andhra Pradesh; on the east by the districts of Kolar and Bangalore; on the south by Mandya district and on the west and north-west by the districts of Hassan and Chitradurga. In the mid-west, Chikmagalur district too touches this district and shares a common border though only for a very short distance.

The climate of the district is quite agreeable and free from extremes; however, amongst the taluks, Pavagada which is located in the north-cast is noted for its relatively hot climate. The day temperature reaches a maximum of 41°C at times. April is the hottest month, During April as well as May there would be thunderstorms followed by heavy pre-monsoon showers, in almost all parts of the district. With the onset of the monsoon, the temperature drops' appreciably and throughout the monsoon period the weather remains pleasant. After October the night temperature dips further. December is usually the coldest month, during which the minimum temperature would be as low as 9°C on certain days. Relative humidity is high during the monsoon period, moderate during the other months and comparatively low during the summer afternoons, Winds arc generally moderate with some increase in strength during the monsoon months, especially June and July. The average annual rainfall in the district is 687.9 mm. This amount of rainfall is subject to considerable fluctuations from year to year. Within the district itself the northern and the eastern regions receive comparatively lesser amounts of rainfall than their southern and south-western counterparts. Figure 20 presents the map of the Tumkur district showing the location of Pavagada Taluk where Solar Park of 2000 MW is proposed by KSPDCL.

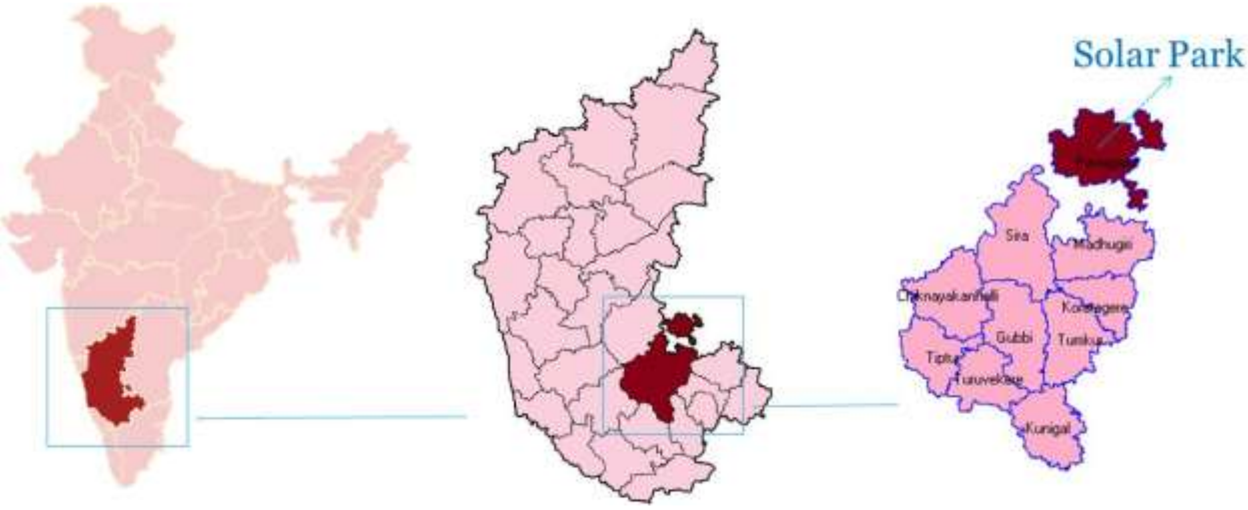


Figure 20. District map of Tumkur, Karnataka showing Pavagada Taluk

3.2.1. Pavagada

Pavagada is a town in Tumkur district in the Indian state of Karnataka. Though it is geographically connected to Chitradurga district inside state of Karnataka, it comes under Tumkur district. It is 150km from state capital of Bangalore and Uttara Pinakini river flows in this Taluk. Pavagada is located at 14.1°N 77.27°E and has an average elevation of 646 metres.

The 2000 MW Solar Park is proposed to be located in Taluka- Pavagada, District-Tumkur. The proposed site is spread across five villages in the same taluka of the Tumkur district. The total land availability for the proposed site is around 15000 Acres. The spread of the project site across the villages (which have been taken over on lease basis till date) along-with its coordinates for setting the Solar Park project have been provided in Table 10 below.

Table 10. Geographic coordinates and details of the land taken for Solar Park in Pavagada (Tumkur), Karnataka

S. No.	Name of the village	Extent of area (Acres)	Coordinate spread	
			Latitude	Longitude
1	Valluru,	2846.61	14°16’10.94°N to14°14’32.68°N	77°23’18.17°E to 77°24’33.07°E
2	Rayacharlu	1745.21	14°16’57.05°N to14°16’45.24°N	77°26’54.79°E to 77°26’51.37°E
3	Balasamudra	1309.27	14°14’32.68°N to14°14’59.27°N	77°24’33.07°E to 77°25’42.52°E
4	Kyathaganacharlu	5135.05	14°18’33.18°N to14°17’33.35°N	77°22’42.38°E to 77°23’5.88°E
5	Thirumani	3208.15	14°13’54.48°N to14°13’31.82°N	77°24’33.14°E to 77°25’2.71°E
	Total	**14244.29**		

(Source: KSPDCL)

The satellite mapping (with plots) of the land over these five villages is presented in Annexure 1: . It has been noticed that solar PV technologies requires 5-6 acres of land per MW; however it depends upon the type of technology used. In order to develop a Solar Park of 2000 MW a total of around 10-12 thousand acres of land is essential. KSPDCL has selected the land in the Pavagada Talur of Tumkur district which is mostly un-irrigated land and belongs to multiple farmers (i.e. private land).

3.2.2. Connectivity and Accessibility

Pavagada comprises established road connectivity as the State Highway (KA SH 03) passes from the city and connect it from Madugiri to Chikkahalli. The selected land for Solar Park is adjacent to the SH-3. There is no railway station near to Pavagada Taluk in less than 10 km. Malugur Rail Way Station (near to Hindupur), Hindupur Rail Way Station (near to Hindupur) are the Rail way stations reachable from nearby towns. Anantapur railway station is at a distance of 101 KM from Pavagada. Bellary Jn Rail Way Station is another major railway station 137 KM near to Pavagada. Figure 21 presents the connectivity mat of the Tumkur district.

Figure 21. Connectivity map of District Tumkur, Karnataka
(Source: www.mapsofindia.com)

3.2.3. Climate and Rainfall

Tumkur district falls in the eastern dry agro climatic zone. The temperatures start rising from January to peak in May, around 40° C is common. Annual rainfall in the district varies from over 900mm in Tumkur to around 600mm in Pavagada. Figure 22 presents the rainfall pattern over Pavagada (Tumkur), Karnataka.

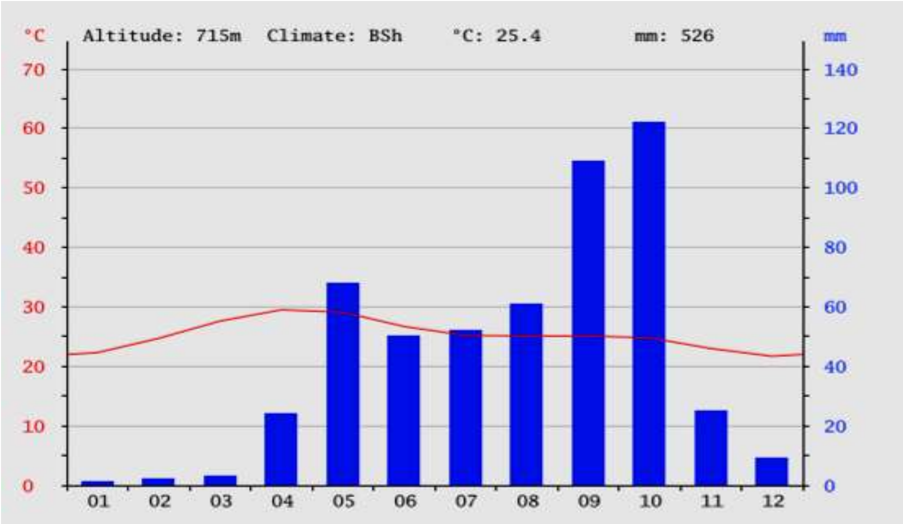


Figure 22. Rainfall over Pavagada (Tumkur), Karnataka
(Source: www. http://en.climate-data.org/location/24126)

3.2.4. Geomorphology and Soil Type

Tumkur district is generally, an open tract except in the south of Kunigal taluk, where the area is covered with intensive thick forests with hills. A narrow range of granitic hills grouped under closepet granites occupies the eastern part. These hills pass through the taluks of Pavagada, Madhugiri, Koratagere and northern parts of Tumkur. The landmass in the plains ranges between 450 to 840 m above msl; while hilly areas range between 840 to 1500 m above msl.

Major types of soils occurring in the district are 1) Red loamy soil, 2) Red sandy soil and 3) Mixed red and black soils. Red loamy soil occurs in eastern central part of the district covering Koratgere, Tumkur, and eastern parts of Madhugiri and Kunigal Taluks. Red soils have good drainage but poor in lime and bases.

3.2.5. Hydrogeology

The district is underlain by meta sediments (limestone) and meta volcanic (quartzite and schists) of Dharwar Group, Peninsular gneisses and Closet granites of Pre Cambrian age, which are intruded by pegmatite and dolerite dykes. Ground water occurs in weathered and jointed zones of gneisses, granites and schists and alluvium in unconfined or water table conditions where as it occurs in semi confined to confined conditions in fractured formations[6].

Net annual groundwater availability of the district is 92262.71 ham, draft for all uses is 102247.26 ham, available resource for future irrigation development is 15408.83 ham which can create an irrigation potential of 22632 hectares. 55% area of the district is overexploited, 8% critical, 11% semicritical and only 26% of the area is safe.

High concentration of nitrates (>45 mg/lit) is observed in major parts of Pavagada, Sira, Madhugiri, Koratagere and central part of Chiknayakanahalli and western parts of Gubbi taluks. This may be attributed to more use of fertilizers. High chloride concentrations are observed in central part of Pavagada and Madhugiri taluks and in northwestern parts of Chiknayakanahalli taluk. Electrical conductivity is in permissible range in general.

[6] http://cgwb.gov.in/District_Profile/karnataka/2012/Tumkur%20brouchure%202012.pdf

3.2.6. Seismic

As per the seismic zone map of India; the selection location for Solar Park in the state of Karnataka falls under Zone-II (Least Active) seismic zone of the country.

3.2.7. Water

The selected location of Pavagada taluk is essentially dry and contains minimum rainfall in the state; hence surface water is scarily available. There are few water bodies adjacent to state highway and connected to the selected land for Solar Park by KSPDCL which are being used for irrigation application of agro-cultivation. The construction water demand for Solar Park could be met through such water bodies after getting NoC and clearances from Village Panchayats. Additionally the supply leg could be met through water tankers from nearby other water sources or bore wells.

There will be sufficient water requirement for operation of the solar PV power projects of 2000 MW capacity in the Solar Park; mainly for module cleaning application. As per KSPDCL the water needs to be arranging through bore wells (i.e. ground water) after treatment. The drainage system of the park needs to be designed in such a way that it should address the rain water harvesting in the premises.

3.2.8. Power Evacuation

The proposed 2000 MW Solar Power would be developed in eight blocks of 250 MW capacity. For each 250 MW Solar Power capacity block, one pooling substation of 66/ 220 kV is proposed in which 2 x 150 MVA step-up transformers are considered. 250 MW block is further subdivided into 50 MW sub blocks. Thus, these 5 X 50 MW sub blocks shall be connected to pooling substation through 66KV underground cables. The voltage will again be stepped up to 220kV at the Solar Project Pooling Station and again stepped up to 400kV at the proposed 400kV Grid Substation by POWERGRID at Solar power.

Karnataka Solar Power Development Corporation Private Limited (KSPDCL)(JV of SECI and KREDL) will establish 8 Nos. of 220/66kV pooling stations at Pavagada site to evacuate 2000MW solar power generated at the Park. The 400kV Grid substation at the Solar Project is proposed to be connected to POWERGRID's 765KV Station at Madhugiri.

Based on the site survey, site visit, review of information furnished by KSPDCL on the site selected for implementation of 2000 MW solar PV power projects it has been observed that selected land suitable meets the key requirements of Solar Park. The location well addresses the significant land availability, connectivity and accessibility, meteorology and favorable global solar irradiance, shadow free area and required infrastructure. Table 11 presents the photographs of selected location of KDERL.

Table 11. Different photographs of the land selected for Solar Park

4. Solar Radiation Resource Assessment

4.1. Background

Resource assessment is one of the most important aspects towards realising the large scale renewable energy projects; mainly due to their intermittent nature and non-uniform availability across the globe. The performance of solar energy systems (*Thermal or Photovoltaic*) is mainly governed by the incident solar radiation it receives. The intensity pattern of solar radiation over any location critically depends upon the Earth-Sun geometry of any place which is essentially decided by the season, time and geographical position of the place.

Outside the Earth's atmosphere, on a surface normal to the solar beam, the power density is 1,365W/m² which is known as 'Solar Constant'[7]. As the solar radiation passes through the atmosphere, depending on the length of the atmospheric path traversed by the solar radiation and the quantity of dust, water vapour, ozone, CO_2 and other aerosols/gases present, some amount of the radiation is scattered and absorbed (i.e. *attenuation of radiation*). The diffused irradiance plus the direct irradiance from the sun are together termed as Global (or Total) Irradiance[8]. The component of global solar radiation of minimal attenuation by the Earth's atmosphere or other obstacles is known as direct radiation. The diffused sunlight can vary from about 20% on a clear day to 100% in heavily overcast conditions.

Site selection and planning of PV power plants requires reliable solar resource data as the electrical output of a PV plant is directly dependent on the solar irradiance it receives, which is the power incident on a surface per unit area (measured in W/m²). However, the total solar energy received in a day over a specific area is more important than the instantaneous solar irradiance from a power generation perspective, and as such the solar resource of a location is usually defined by the values of the global horizontal irradiation, direct normal irradiation and diffuse horizontal irradiation as follows:

- Global Horizontal Irradiation (GHI) – GHI is the total solar energy received on a unit area of a horizontal surface. It includes energy from the sun that is received in a direct beam as well as that received from all other directions when radiation is scattered by molecules and particles in the atmosphere
- Direct Normal Irradiation (DNI) – DNI is the total solar energy received on a unit area of a surface directly facing the sun at all times. For this reason, the DNI is of particular interest in solar installations which employ trackers
- Diffuse Horizontal Irradiation (DHI) – DHI is the energy received on a unit area of a horizontal surface from all directions (except normal) when radiation is scattered by molecules and particles in the atmosphere

Solar irradiation (also known as insolation) is measured in kWh/m², and values are often given for a period of a day, a month or a year. A high long term average annual GHI is the single most important condition contributing to the power generation potential of a solar installation.

All stationary solar thermal and solar PV systems are designed on GHI over the respective project location which comprises flat collector surfaces. However, in order to achieve higher temperatures through solar energy; special type of solar collectors called concentrating collectors are used which focuses the incident solar radiation either on a line (single-axis) or point (two-axis). The concentrating collectors could achieve temperature to the tune of 2000°C and therefore have a major role to play in electricity generation. The philosophy of concentrating collector depends on direct component of solar radiation which could be treated optically for focusing. The BHI is treated in a specific manner and estimated over single-axis and double-axis

[7] The solar constant is defined as the quantity of solar energy (W/m²) at normal incidence outside the atmosphere (extraterrestrial) at the mean sun-earth distance. Its mean value is 1367.7 W/m².

[8] Irradiance: The rate at which radiant energy is incident on a surface per unit area of surface.

system in line with the mechanism of concentrating collectors; which is known as Direct Normal Irradiance[9] (DNI). Therefore for techno-commercial feasibility of solar energy system based on concentrating collectors, resource assessment is one of the most key areas. Proper resource assessment is of paramount importance towards realising large-scale renewable energy projects; mainly due to its intermittent nature and non-uniform availability across the globe.

It is well established that the solar resource is not equally available in all regions of the world as it is governed by the earth-sun geometry. On a clear day in the tropics, when the sun is overhead, the global irradiance can exceed 1000 W/m² but in high latitude it rarely exceeds 850 W/m². Similarly, daily solar insolation may be 5-7 kWh/m²/day in the tropics but could be less than 0.5 kWh/ m²/ day in high latitudes.

In order to design any solar system, the long term measured ground data of GHI, DI and DNI are recommended in time series or Typical Meteorological Year (TMY) format; which could express the time dependent (dynamic or transient) performance of solar system. In India, Indian Meteorology Department (IMD), Ministry of Earth Sciences, Government of India is responsible for weather measurement and climatic prediction related activities. IMD has a wide network across the country for measurement of GHI, DHI and other climatic parameters and caries out large scale measurements 45 radiation observatories with data logger. There are 21 principal and 18 ordinary locations in the radiation network of IMD. Figure 23 presents the map of the network of weather stations implemented by IMD in India towards measurement of solar radiation and meteorological parameters; which also provides the information of the solar radiation measured at different stations indicating the Tumkur, Karnataka region of India.

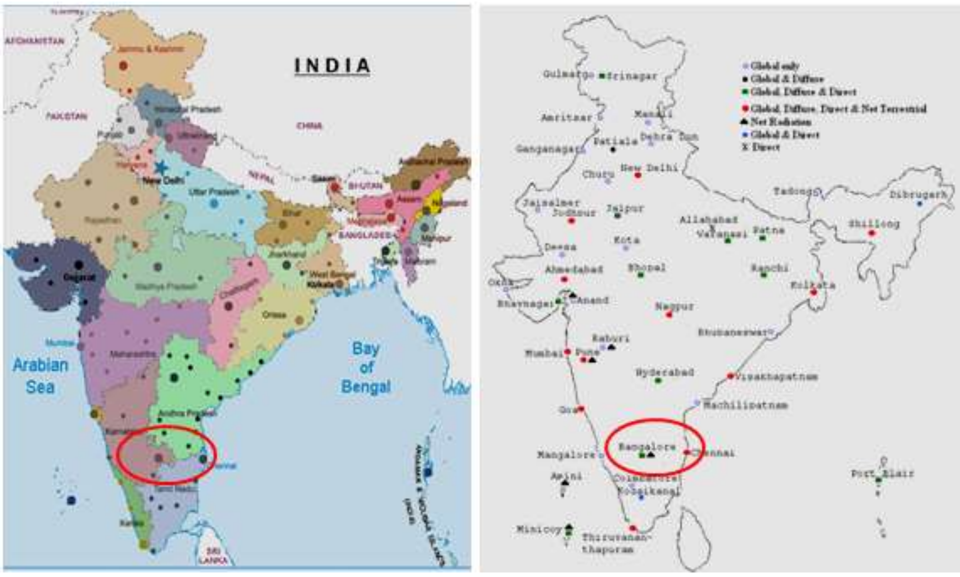


Figure 23. Weather measurement network of Indian Meteorological Department in India
(Source: http://www.imd.gov.in, http://www.indiaenvironmentportal.org.in/files/srd-sec.pdf)

4.2. Solar Radiation over India

India being a tropical country receives good sunshine over most parts of the country, and the number of clear sunny days in a year is also quite high. It receives solar energy equivalent of more than 5,000 trillion kWh per year; however the equivalent solar energy potential is about 6,000 million GWh of energy per year. In India, the daily GHI is around 5 .0 kWh/m² in north-eastern and hilly areas to about 7.0 kWh/m² in western regions and cold desert areas with the sunshine hours ranging between 2300 and 3200 per year. In most parts of India, clear sunny weather is experienced for 250 to 300 days a year. The annual GHI varies from 1600 to 2200 kWh/m². Around 25-30 percent annual diffuse irradiance (DHI) component has been indicated by IMD in most of the Indian locations. A GHI map for India, developed by The Energy and Resources institute (TERI) based on the data of IMD (1980, 1982) is presented in Figure 24.

[9] DNI is the amount of direct beam solar radiation per unit area that is intercepted by a flat surface that is at all times pointed in the direction of the sun.

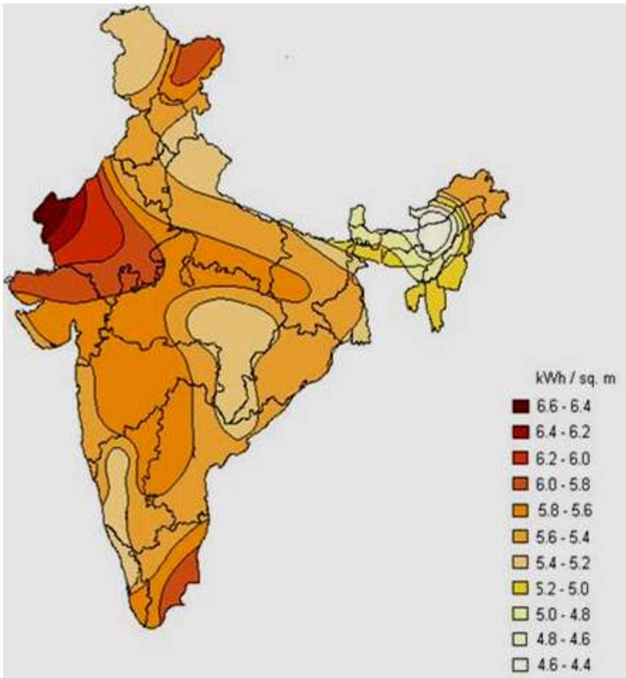


Figure 24. Global solar radiation (GHI) map of India
(Source: TERI, IMD)

GHI is essential for stationary type of solar energy collectors/PV modules; however DNI is required for concentrating collectors (CSP and CPV systems). It is well established that one year of measurements could be more than 15% above or below the long-term average whereas averaging five years still could lead to deviations larger than 10%. Therefore, at least 10 years of data should be taken into account to gather reliable information on solar resources[10].

4.3. Solar Radiation Databases

Availability of long term ground solar radiation (GHI and DNI) data over the potential locations (where waste land is available) is one of the major barriers towards rapid deployment of solar energy projects in India. Hence the dependence of the project developers and lenders is mainly towards the satellite data or interpolated data. Figure 25 presents the overview of the all types of solar radiation databases available in context of India. The available data sets are available in static (monthly average daily) and dynamic (hourly time series) formats.

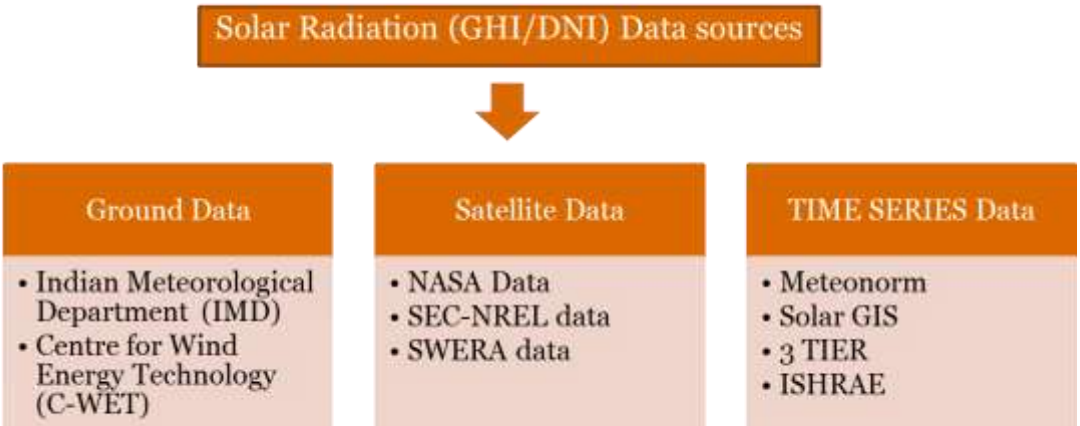


Figure 25. Solar Radiation databases in context of India

[10] Lohmann, S., Schillings, C., Mayer, B. Mayer, R. 2006. Long-term variability of solar direct and global radiation derived from ISCCP data and comparison with reanalysis data. Solar Energy, 80 (11), pp. 1390-1401.

4.3.1. Ground (measured) data

These are the databases which are sourced from ground station measurements. The measuring station consists of radiation measuring instruments installed as per standard guideline and such instruments record data round the year which are stored in data logger. In India, IMD databases are based on ground stations.

Recently the Centre for Wind Energy Technology (C-WET[11]) of MNRE has implemented around 51 weather stations across the country for GHI, DI and DNI measurement under solar radiation resource assessment (SRRA) programme of MNRE under Phase-I; however 60 AWS are under implementation under Phase-II. Although these data are considered best for any analysis, but unavailability of ground stations at all the potential locations limits their usefulness. The accuracy of the measured data is challenged by the accuracy of instruments and maintenance practices including cleaning, calibration, and quality check procedures. Long term solar radiation data is available only for a few locations of the country. ISHRAE weather database is based on the ground measurements of IMD and statistical approach.

4.3.2. Databases based on satellite images

These are the databases which are sourced from the satellite measurements. These databases measure the Albedo[12] and calculate the radiation at any reference location. The accuracy depends upon the spatial and temporal resolution[13] along with other factors. Databases like NASA, NREL, 3TIER, DLR, SolarGIS belong to this category and can provide solar radiation in context of India. In case of unavailability of ground data, these data are the first point of reference to judge the solar potential at any location. Although the values are often too optimistic, these data do help in estimating an overall potential with a certain uncertainty. The key benefits of satellite data are spatial–continuous and time-continuous data with invariant uncertainty.

4.3.3. Derived databases and system integrating data

These are the databases which are based on reanalysis of the collected data. The basic idea of reanalysis is to use a frozen state of the art analysis system and assimilate data using historical data. The databases namely Meteonorm (6.0, 7.0), PVGIS etc. belongs to this category. These databases uses software and statistical tools to process the data collected from satellite and ground measurement to minimize the error in reporting the actual radiation potential at any location.

4.4. Solar Radiation Databases in context of India

The ground data for solar radiation and other climatic parameters for India are available with IMD and C-WET. The long-term GHI and DI data of IMD is available for 23 locations of the country. Out of the above categories of solar radiation (GHI/DNI) data, a review of the solar radiation databases available in context of India is appended below.

4.4.1. IMD Database (Ground Data)

Indian Meteorological department (IMD) has a wide weather monitoring network across the country. There are 23 locations in India for which long term GHI and DHI have been published by IMD; but long term measured DNI is not available. The solar data collected from these 23 stations is available in the "**Solar handbook of Solar Radiant Energy over India, 2009**", published by the IMD and MNRE. Till date this is assumed to be most potential resource of solar radiation resource assessment in context of India. Following additional databases are available for several Indian locations based on the IMD data;

- **Solar Radiation over India**, (1980), A Mani, Allied Publishers, New Delhi
- **Handbook of Solar Radiation**, (1982), A Mani and S. Rangrajan, Allied Publishers, New Delhi

[11] Known as National Institute of Wind Energy (NIEW) now.
[12] Albedo is the fraction of solar energy (shortwave radiation) reflected from the Earth back into space. It is a measure of the reflectivity of the earth's surface.
[13] Temporal resolution is how frequently a satellite observes the same area on Earth. It depends primarily on the orbit of the satellite.

- High temporal resolution (e.g., 30 minutes): nearly continuous observations
- Low temporal resolution (e.g., 1 day): only one observation per day

- **Solar Radiation Handbook**, (2008), MNRE, **Government** of India
- **Handbook of Solar Radiant Energy over India**, (2009), MNRE and IMD, Government of India

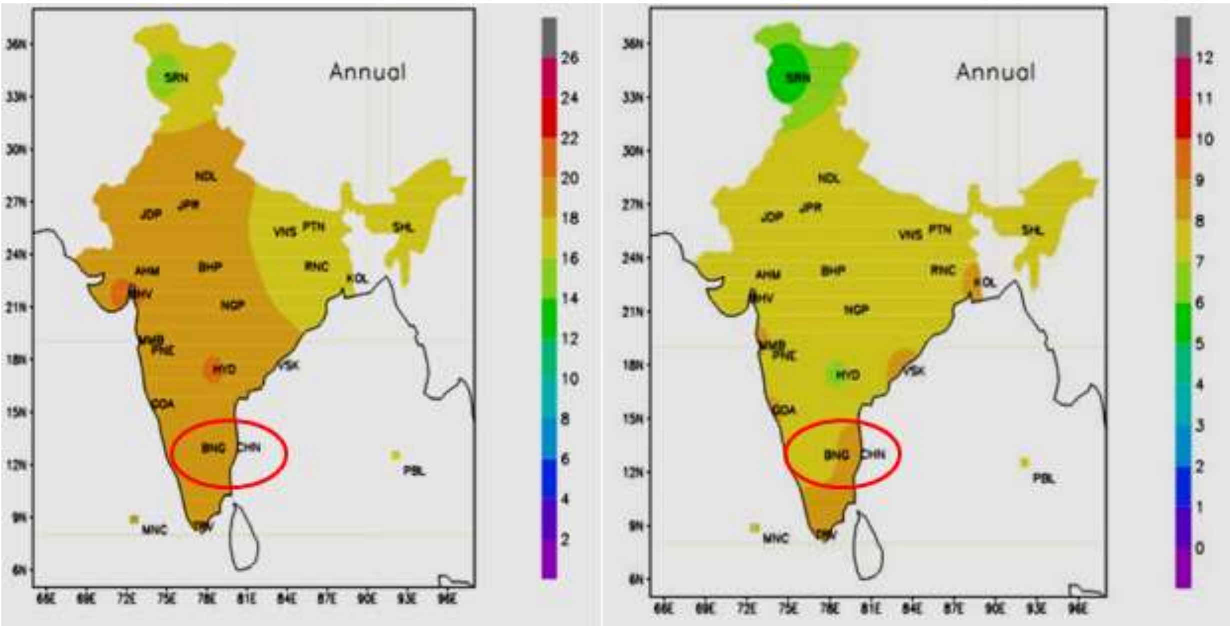


Figure 26. Solar Radiation maps (GHI and DI) of India
(Source: http://www.indiaenvironmentportal.org.in/files/srd-sec.pdf)

All the databases of IMD mainly comprises of GHI; however DNI is referred for few locations. The long term DNI is not published by IMD. It is observed that long term DNI data is not available with IMD databases; however the available data gives a platform to determine DNI through the average values of GHI and DHI using established Earth-Sun geometry. This approach is used in various solar radiation measuring sensors like radiometer etc. Figure 26 presents the GHI and DI map of India developed by IMD as per the database entitled Solar Radiation handbook published by Solar Energy Center (SEC), MNRE in year 2008.

4.4.2. C-WET data (Ground Data)

In order to promote Solar Thermal technologies under JNNSM, an initiative has been taken by MNRE towards implementation of measuring stations across the country for measurement of periodic DNI. The Solar Radiation Resource Assessment (SRRA) program is monitored by the Center for Wind Energy Technology (C-WET), a Nodal Agency of MNRE.

In order to promote large scale solar projects under several initiatives taken by GOI, India (viz. Jawaharlal Nehru National Solar Mission, State's Solar Power Policies, Renewable Energy Certificate Mechanism etc.) an initiative has been taken by MNRE along with GIZ (The Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH) towards implementation of measuring stations across the country for periodic measurement of periodic GHI, DI, DNI and other climatic parameters under Solar Radiation Resource Assessment (SRRA) program. The SRRA programme is monitored by C-WET, MNRE. Under Phase-1 of the exercise C-WET has implemented a network of 51 AWS in different states in the first phase using high quality, high resolution equipment/instruments. The Second Phase of the project envisages a further addition of 60 stations in parts of India that currently have no monitoring stations. The solar radiation data of around one year is available for the locations under Phase-1 from C-WET in hourly format. Figure 27 presents the locations of C-WET weather stations across the country under Phase-I and II. The location of AWSs implemented by C-WET under SRRA programme of MNRE under Phase-I&II in the state of Karnataka are presented in Table 15 below.

Figure 27. C-WET network for measurement of solar radiation in India
(Source: IRENA)

Table 12. AWS implemented by C-WET in the state of Karnataka, India

Location	Latitude (ºN)	Longitude (ºE)	Altitude (m)	Date of installation of AWS
Bellary	14.904	75.991	885	08/29/2011
Belgaum	16.419	74.793	803	09/04/2011
Gulbarga	17.320	76.855	478	09/01/2011
Bijapur	16.847	75.752	567	09/10/2011
Chitradurga	14.216	76.428	760	09/20/2011
Mysore	12.371	76.585	79	05/19/2014

4.4.3. RETScreen Data

RETScreen is essentially a clean energy software package developed by the Government of Canada. It is excel-based clean energy project analysis software tool which helps decision makers determine the technical and financial viability of renewable energy, energy efficiency and cogeneration (combined heat & power) projects. It is possible to carry out the techno-economic evaluation of solar power project using RETscreen as it comprises; a number of databases to assist the user, including a global database of climatic conditions obtained from 6,700 ground-based stations and NASA's satellite data; benchmark database; project database; hydrology database and product database. RETScreen provides most updated measured GHI values of all IMD locations and for those locations where ground data is not available it provides GHI through NASA satellite data for one representative day of each month.

Mapping of solar radiation resources using satellite images lowers costs because of reduced dependence on ground weather stations. The satellite based solar radiation and climatic data could be achieved from both polar and geostationary satellites. Following satellite databases are available in India context which provides monthly average daily values (i.e. representative day of each month of the year) of GHI and DNI.

4.4.4. Satellite Database – NASA Satellite Data

The United States National Aeronautics and Space Administration (NASA) based satellite measurements produce the general assessment of GHI and DNI for any grid reference across the globe. The Surface Meteorology and Solar Energy (SMSE) dataset provides the satellite data of daily global solar radiation (1º x 1º) for a 22 year period. The data is in monthly average daily form derived for 22 years (from 1983-2005). NASA data is available for any location on Earth, and can be obtained by specifying the geographical coordinates of the location. The data is available in near real time for daily averages. NASA gives the data for the period 1983-2005 with spatial resolution of 100 x 100 km. The daily average data is freely available with parameters like GHI, DI, DNI and other meteorological parameters from this database over any location. This weather database is freely available and linked with the computer software(s) RETScreen and HOMER for evaluation of renewable energy projects.

4.4.5. Satellite Database – NREL Satellite data

The National Renewable Energy Laboratory (NREL) also provides solar resource maps based on satellite data using a set of algorithms based on mathematical expressions. The Solar Energy Center (SEC) of MNRE with NREL has developed GHI and DNI map of India with a resolution of 10 km. NREL has developed solar radiation maps for monthly and annual GHI data using the hourly satellite data spanning from January 2002 to December 2008 generated through application of the Sunny satellite to irradiance model. A deep investigation on Aerosol Optical Depth (AOD) data and their inter-annual variations is carried out due to their strong impact on solar radiation.

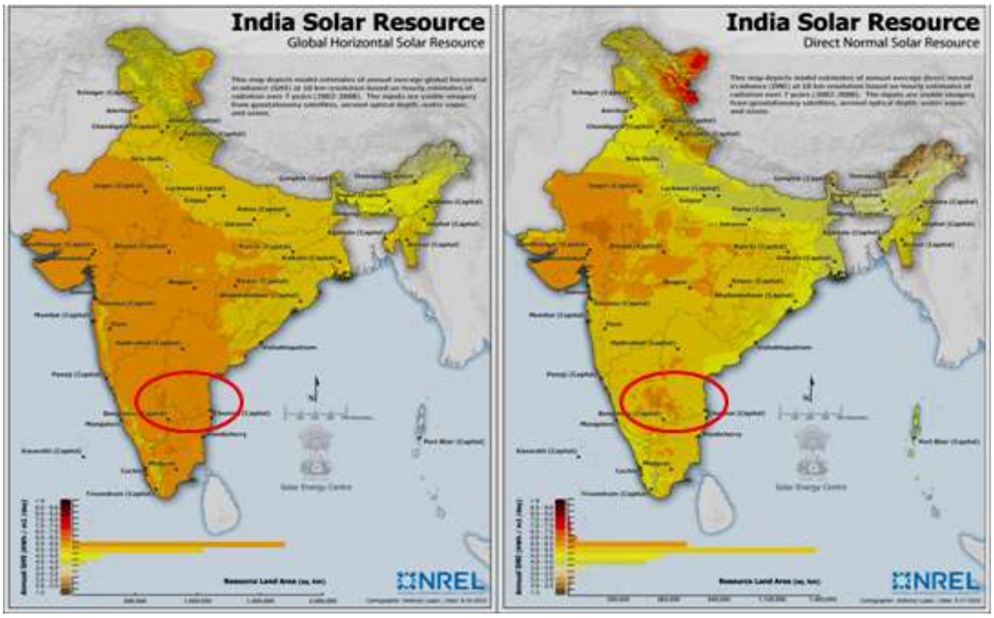


Figure 28. GHI and DNI solar radiation maps of India developed by SEC-NREL
(Source: http://mnre.gov.in/sec/solar-assmnt.htm)

The Monthly gridded AOD values were developed for each month of the Sunny model run for India. This approach is applied because of the variation in concentration of aerosols over India. Solar mapping of the entire country based on satellite imagery and duly validated by ground truth data will provide information of GHI on a continuum basis with an approximate accuracy of 15%. It is possible to identify the areas with higher solar radiation and set up ground stations for more accurate measurement of solar radiation and other meteorological parameters. NREL also provides time series data for few locations of India. Figure 28 above presents the GHI and DNI maps developed with SEC-NREL for India.

4.4.6. Satellite Database – SWERA Data

Solar and Wind Energy Resource Assessment (SWERA[14]) database is developed by United Nations Environment Program (UNEP). Under SWERA, the solar radiation data is offered at different scales and accuracies for the various countries considered. India is included in the continent-wide data set for Asia created by NREL employing the Climatological Solar Radiation (CSR) Model. This data set has a spatial resolution of 40 km and grid and is based on climatic data from 1985-1991. The modeled values are accurate to approximately 10% of a true measured value within the grid cell due to the uncertainties associated with meteorological input

[14] The Solar and Wind Energy Resource Assessment (SWERA) started in 2001 to advance the large-scale use of renewable energy technologies by increasing the availability and accessibility of high-quality solar and wind resource information. SWERA began as a pilot project with funding from the Global Environment Facility (GEF) and managed by the United Nations Environment Programme's (UNEP) Division of Technology, Industry and Economics (DTIE) in collaboration with more than 25 partners around the world. The data is generated by known environmental modeling and solar research institutions such as DLR, NREL, INPE, and TERI.

to the model. GHI and DNI maps have been developed for India for each month under this program. That data set has a spatial resolution[15] of 40 km and grid and is based on climatic data from 1985-1991. The modeled values are accurate to approximately 10% of a true measured value within the grid cell due to the uncertainties associated with meteorological input to the model. Figure 35 presents the GHI and DNI map of selected south Asian countries developed under SWERA indicating Tumkr region of Karnataka, India.

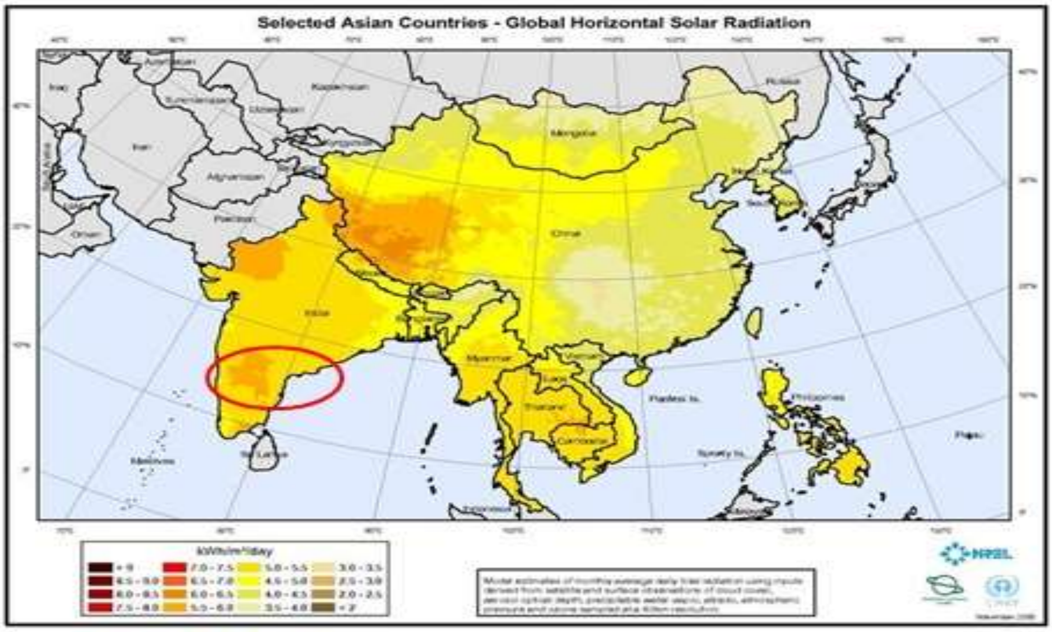


Figure 29. SWERA's GHI map for South Asian Countries
(Source: www.swera.net)

In the Indian context, the ground and satellite weather databases provides solar radiation and climatic parameters in monthly average daily formats; hence could be used for static analysis of solar energy systems. In order to carry out the realistic (transient) analysis of the solar energy system the solar radiation data is required in time series (dynamic) format. There are few weather databases which are available in time series (hourly) format for all locations of India.

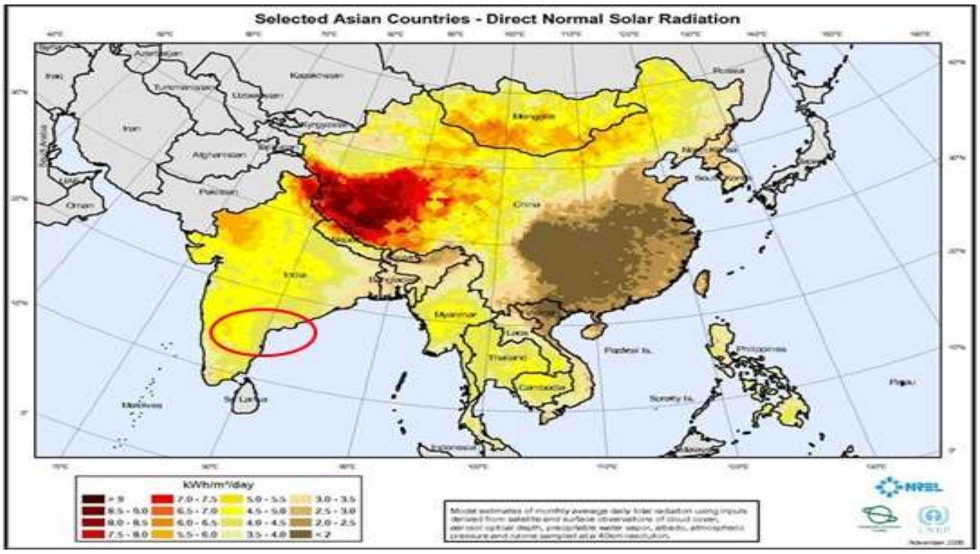


Figure 35. SWERA's DNI map of South Asian Countries

[15] Spatial resolution is the smallest area on Earth that a satellite can observe. It depends upon the type of satellite instrument. There are different types of satellite instrument which broadly belong to two different categories:

- Low (e.g 1-10 km)
- High (e.g, 1-10 m)

It can also be defined as; Spatial resolution refers to the area that one pixel represents. For example, the resolution of the visible imagery is approximately 1 km x 1 km. This means that one square pixel represents 1 km by 1 km. The smaller the resolution values the more details that are present in the image.

(Source: www.swera.net)

4.4.7. 3TIER Data

3TIER weather database provides hourly values of GHI, DHI and DNI over any location for an assessment of around 3 km resolution. The database statistically integrate the observations (measurements) with satellite models towards assessment of long-term power potential, forecast production, and reconcile performance of solar energy systems with good accuracy. The dataset is based on over 13 years of high resolution visible satellite imagery from geostationary satellites. The dataset comprise of satellite measurements from December 1998 to May 2011 and processed to create over 13 years of hourly values of GHI, DI and DNI at a horizontal resolution of 2 arcs–minutes (approx. 3.0 km).

4.4.8. ISHRAE Weather Database

In addition to above, there are solar radiation data available in TMY format (*.epw or *.wea format) for 50 locations of India. The database of Indian Society of Heating, Refrigerating and Air-conditioning Engineers (ISHRAE) could be used in different computer software(s) viz. Energy Plus, TRNSYS etc. This database is essentially used for sizing of thermal and air-conditioning appliances in buildings.

4.4.9. SolarGIS Data

SolarGIS is essentially a web based system which comprises high-resolution climate databases, maps and software for solar energy applications. In SolarGIS, the solar radiation is derived from METEOSTAT second generation (In prime region from April 2004 up to present, temporal resolution is 15 minutes) and METEOSTAT first generation (In prime region from 01/1994 to 12/2005, in Indian Oceanographic Data Centre (IODC) region from 01/1999 up to present, temporal resolution 30 minutes). The spatial resolution of the time series data products is enhanced by terrain SRTM-3 (3-arc seconds, i.e. about 90 meters at the equator). The nominal time of the data product is 15 min (30 min) instantaneous and 60 min (1 hour) average values. Figure 30 presents the GHI and DNI maps of India developed by SolarGIS.

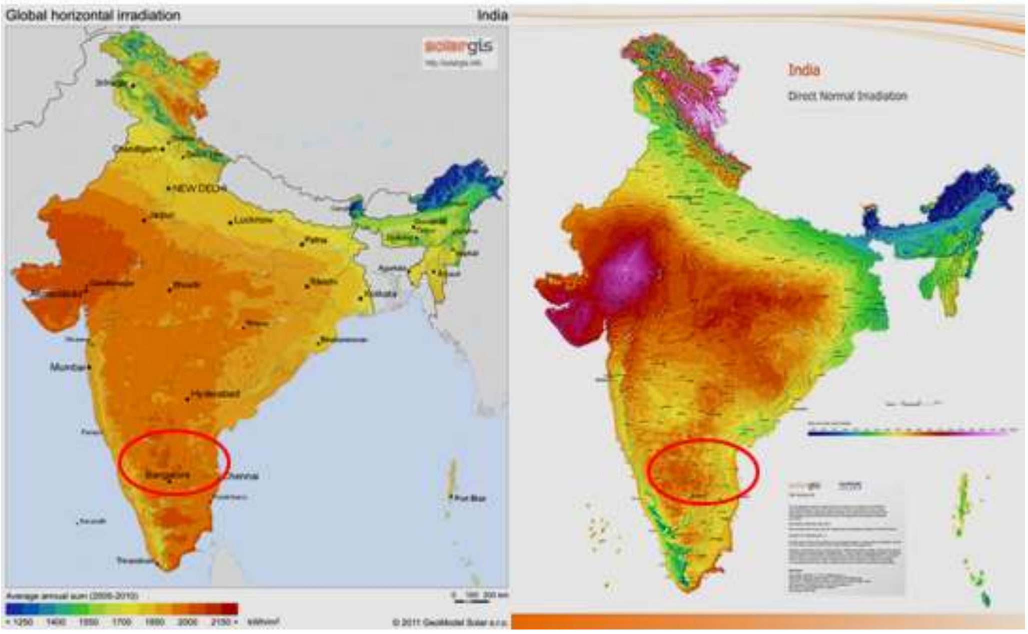


Figure 30. SolarGIS's GHI and DNI maps of South Asian Countries
(Source: www.swera.net)

4.4.10. Meteonorm Database

Meteonorm is the weather data and modelling tool that provides approximately 20 years of data for GHI and other climatic parameters (viz. ambient temperature, humidity, wind speed etc.). In Meteonorm weather database, numerous global and regional databases have been combined and checked for their reliability. Most of the data is taken from the Global Energy Balance Archive (GEBA), from the World Meteorological Organization (WMO) Climatological Normal 1961–1990 and from the Swiss database compiled by MeteoSwiss. The periods 1961–1990 and 2000–2009 are available for temperature, humidity, wind speed and precipitation whereas solar radiation is available for the period 1981–1990 and 1986–2005. The data is essentially collected from ground based weather stations and supplemented with satellite data where there is a low density of weather stations. Hourly values calculated from collected data using a stochastic model comprising interpolation.

Meteonorm 6.0 and 7.0 weather database comprise of several long-term ground measurement stations in the region, calculates through corrected interpolation of ground measurement station and pre-calculated satellite data. Meteonorm generates a synthetic Typical Meteorological Year (TMY) which is representative of long-term conditions and is generally used for energy calculations. Meteonorm data is available in hourly/daily and monthly forms for all locations and could be converted into any desired format like TMY specific for various solar energy software(s) like TRNSYS, Energy Plus, SAM, PVsyst etc.

4.5. Solar Radiation over Tumkur, Karnataka

The state of Karnataka comprises two major climatic zones[16] namely Moderate (Bangalore) and 'Warm and Humid' (Tumkur); hence there is significant variation in annual solar irradiance within the state (2.5kWh/m² to 6.5 kWh/m² daily[17]).

Long term measured data of solar irradiance sis not available for most of the parts of Karnataka; as there is only one AWS of IMD at the location of Bangalore (latitude 13°N, longitude 77.6°E. altitude 921 msl). C-WET has implemented an AWS in the region; from which short term ground data could be explored. As per the latest data book published by IMD-MNRE (2009) the long term annual GHI over Srinagar has been reported as 1942 kWh/m². Figure 31 presents the monthly average daily profile of solar radiation over Bangalore. Satellite based solar radiation data is available for Karnataka in static and dynamic formats viz. NASA, SEC-NREL, SWERA, Meteonorm, 3TIER and SolarGIS etc.

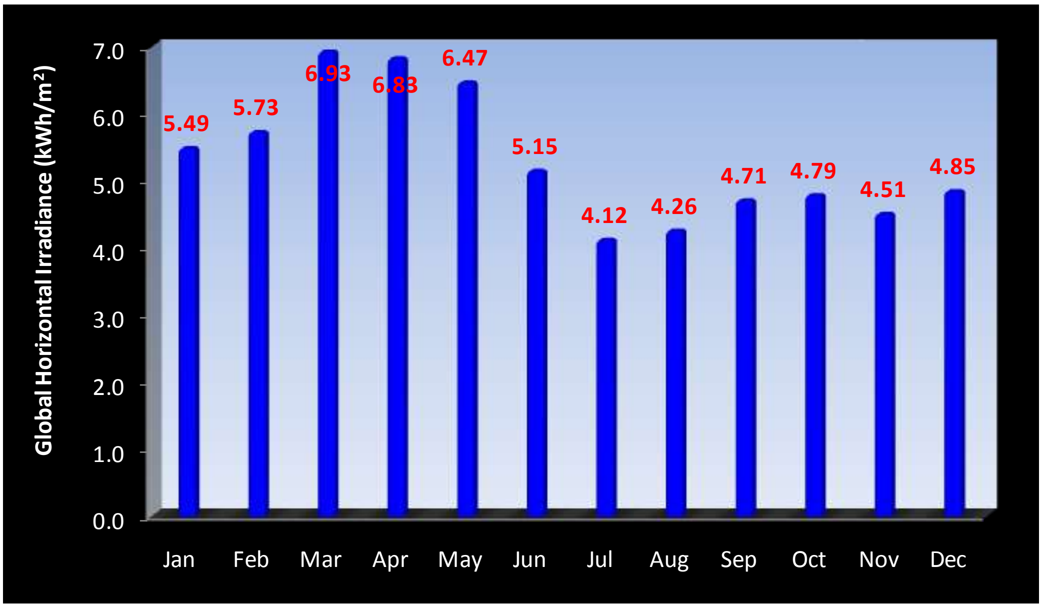


Figure 31. Monthly average daily solar radiation over Banglore, Karnataka
(Source: www.retscree.net)

4.6. Solar radiation over Tumkur

The Solar Park is proposed to be located in Taluka- Pavagada, District-Tumkur. The proposed site is spread across five villages in the same taluka of the Tumkur district. The total land availability for the proposed site is over 11000 Acres. The spread of the project site across the villages (which have been taken over on lease basis till date) along-with its coordinates for setting the project have been provided in Table 13 below.

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16 There are six major climatic zones in India namely Composite (e.g. New Delhi, Indore etc.), Hot and Dry (e.g. Jodhpur, Jaisalmer etc.), Warm and Humid (e.g. Mumbai, Hyderabad etc.), Cold and Cloudy (e.g. Shimla, Srinagar etc.), Cold and Sunny (e.g. Leh etc.) and Moderate (e.g. Pune, Banglore etc.).

17 http://www.eai.in/club/users/krupali/blogs/627

Table 13. Geographical coordinates of the land for Solar Park in Karnataka

S. No.	Name of the village	Coordinate spread	
		Latitude	**Longitude**
1	Valluru,	14°16'10.94°N to14°14'32.68°N	77°23'18.17°E to 77°24'33.07°E
2	Rayacharlu	14°16'57.05°N to14°16'45.24°N	77°26'54.79°E to 77°26'51.37°E
3	Balasamudra	14°14'32.68°N to14°14'59.27°N	77°24'33.07°E to 77°25'42.52°E
4	Kyathaganacharlu	14°18'33.18°N to14°17'33.35°N	77°22'42.38°E to 77°23'5.88°E
5	Thirumani	14°13'54.48°N to14°13'31.82°N	77°24'33.14°E to 77°25'2.71°E

The selected location within the vicinity of Tumkur, Karnataka lies in the Warm and Humid climatic zone of India and comprises extreme winter climatic conditions across the year. The selected project location for implementation of targeted 2000 MW capacity solar PV project(s) is spread in five villages of Tumkur district.

Figure 32 above presents the Stereographic Sun Path Diagram[18] of the location of Pavagada (Tumkur), Karnataka and the sun-path diagram has been plotted for 21st June. It has been observed that the monthly average day length for the proposed location varies from 10 hours (in winters) to 13 hours (in summers) over the year. A cumulative number of sunshine hours (when GHI is 1 W/m^2) have been estimated around 4500 in a year at the project location with Meteonorm7.0 weather database.

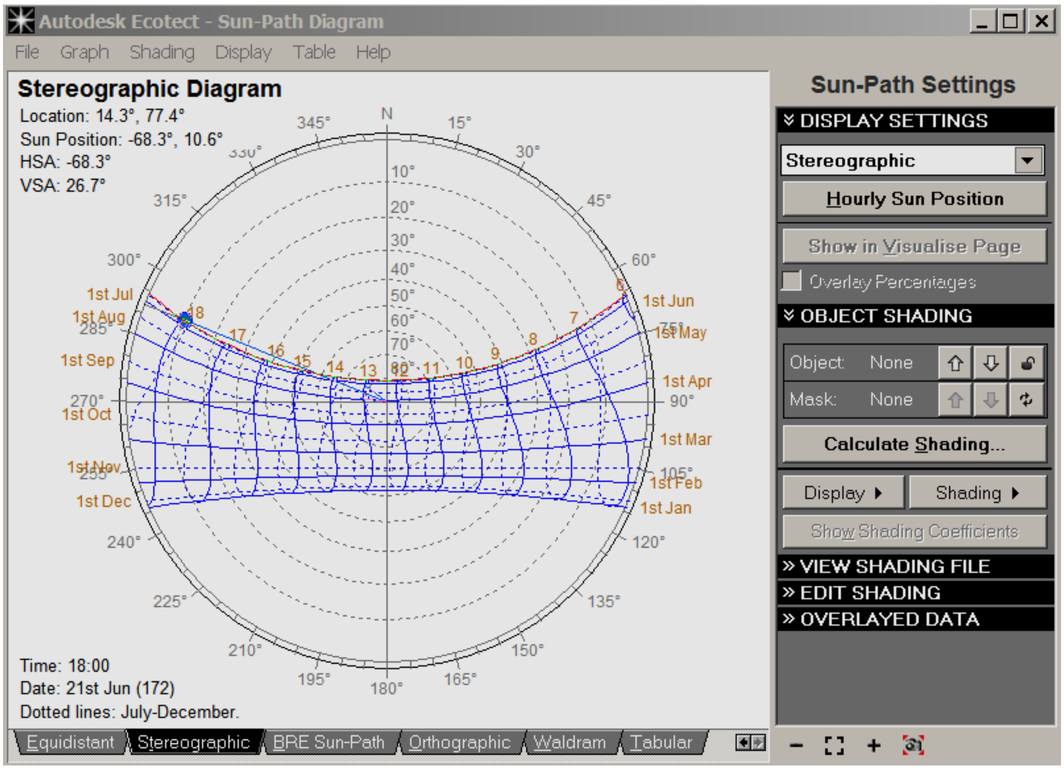


Figure 32. Stereographic Sun Path diagram of Tumkur, Karnataka
(Source: ECOTECT software)

4.6.1. IMD Data

The proposed location of Tumkur district do not comprises any AWS of IMD for long term ground solar radiation and meteorological data. The nearest IMD station in the state is at Bangalore which is located around

[18] Sun path refers to the apparent significant seasonal-and-hourly positional changes of the sun (and length of daylight) as the Earth rotates, and orbits around the sun. The relative position of the sun is a major factor in the heat gain of buildings and in the performance of solar energy systems. Accurate location-specific knowledge of sun path and climatic conditions is essential for economic decisions about solar PV/collector area, orientation, landscaping, summer shading, and the cost-effective use of solar trackers.

150 km from the proposed location of Solar Park. The data of Bangalore could not directly be used for the selected location but could be adopted as a benchmark for optimizing the representative database for the project location.

4.6.2. NASA Satellite Data

Using the link of surface meteorology and solar energy of NASA satellite link; the 22 years average solar radiation data over the selected location in Tumkur district has been explored. It has been estimated that using NASA satellite data the selected location receives daily average solar radiation of 5.35 kWh/m²; which refers its annual magnitude of 1953 kWh/m². Figure 33 present the month wise solar radiation (GHI/DNI) pattern of the year at the selected location of District-Tumkur, Karnataka using NASA satellite database.

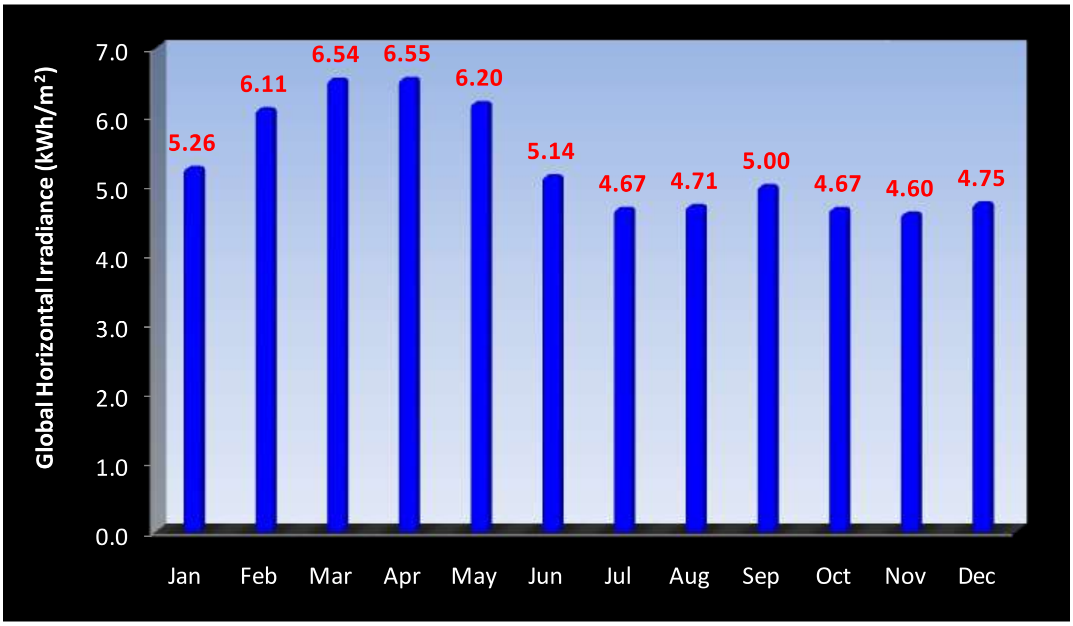


Figure 33. Solar Radiation over Tumkur, Karnataka (NASA Satellite Data-22 year average)

4.6.3. SWERA Satellite Data

As per the SWERA satellite data the selected project location of District-Tumkur, Karnataka receives daily average solar radiation of 5.88 kWh/m²; which refers its annual magnitude of 2148 kWh/m². Figure 34 present the month wise solar radiation (GHI) pattern of the year at the selected location using SWERA satellite database.

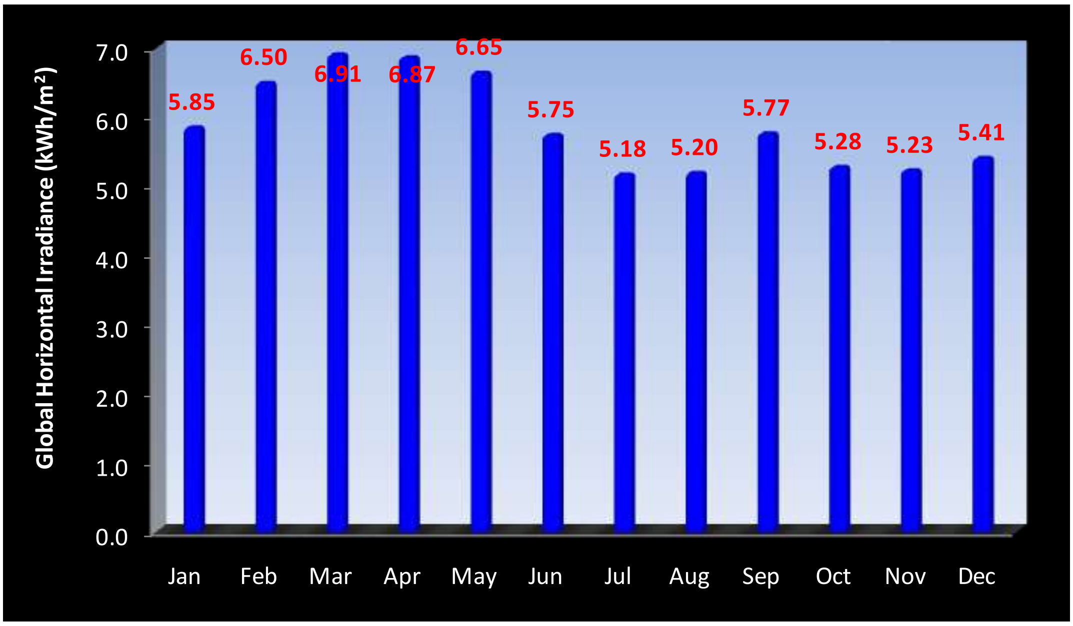


Figure 34. Solar Radiation over Tumkur, Karnataka (SWERA Satellite Data)

4.6.4. SEC-NREL Satellite Data

As per the SECNREL satellite data the selected project location of District-Tumkur, Karnataka receives daily average solar radiation of 5.99 kWh/m²; which refers its annual magnitude of 2185 kWh/m². The databases used similar specifications as SWERA. Figure 34 present the month wise solar radiation (GHI) pattern of the year at the selected location using SEC-NREL database.

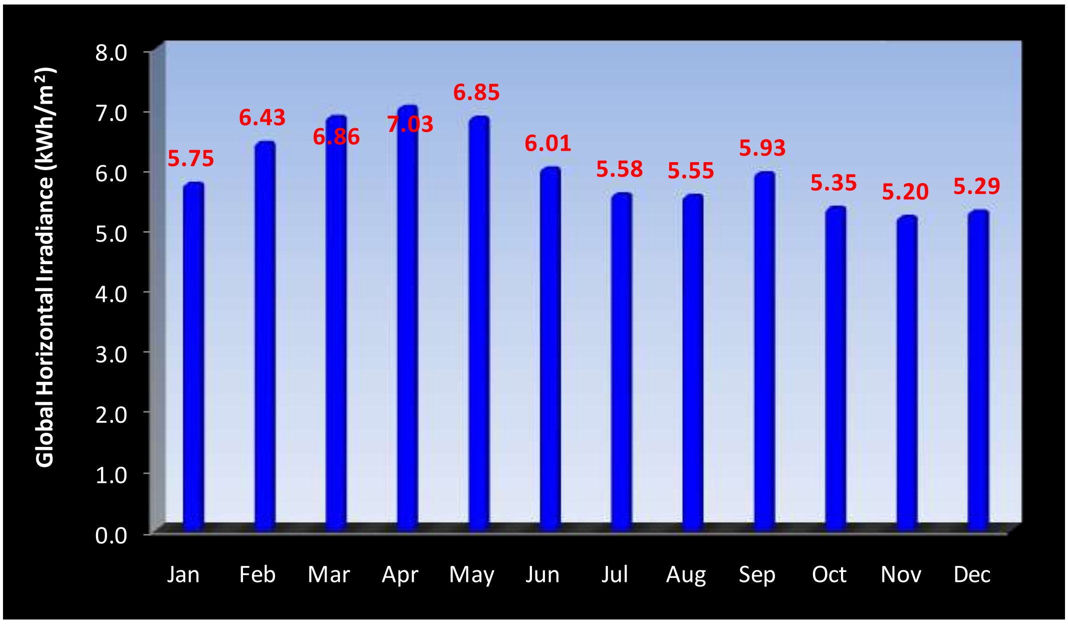


Figure 35. Solar Radiation over Tumkur, Karnataka (SEC-NREL Satellite Data)

4.6.5. Meteonorm (6.0) Time Series Data

Meteonorm 6.0 software produces time series interpolated data over the desired location. As per Meteonorm 6.0 weather database the selected project location of District-Tumkur, Karnataka receives daily average solar radiation of 5.62 kWh/m²; which refers its annual magnitude of 2053 kWh/m². Figure 34 present the month wise solar radiation (GHI) pattern of the year at the selected location using Meteonorm 6.0 database.

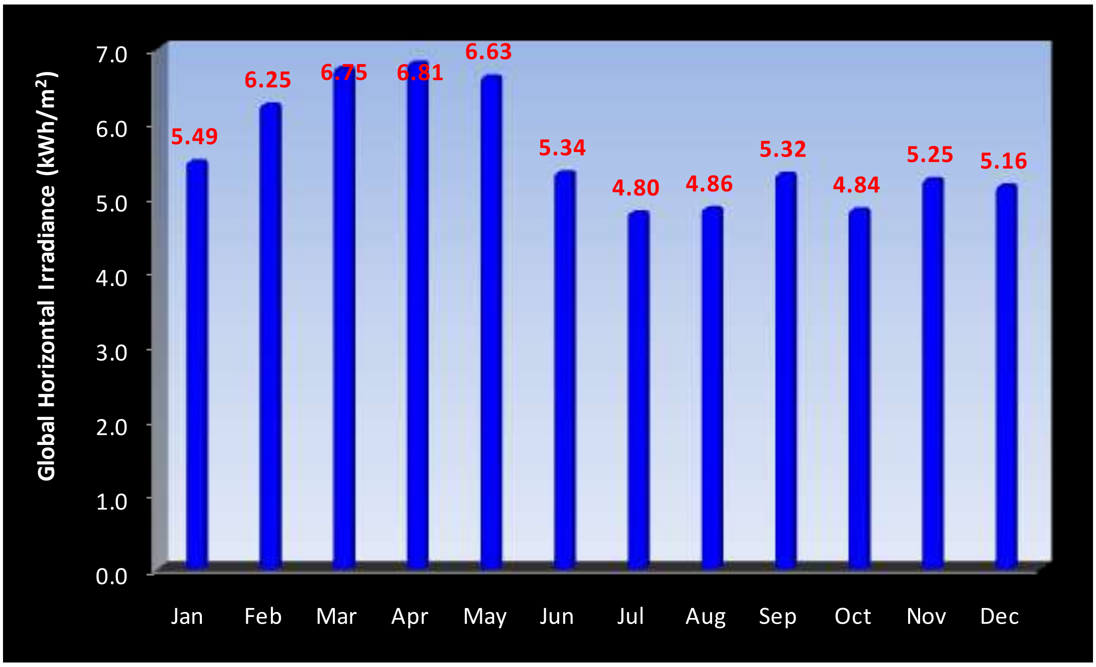


Figure 36. Solar Radiation over Tumkur, Karnataka (Meteonorm 6.0 time series Data)

4.6.6. Meteonorm (7.0)- Time Series Data

Meteonorm 7.0 software produces time series interpolated data over the desired location. As per Meteonorm 6.0 weather database the selected project location of District-Tumkur, Karnataka receives daily average solar radiation of 5.50 kWh/m²; which refers its annual magnitude of 2008 kWh/m². Figure 34 present the month wise solar radiation (GHI) pattern of the year at the selected location using Meteonorm 7.0 database.

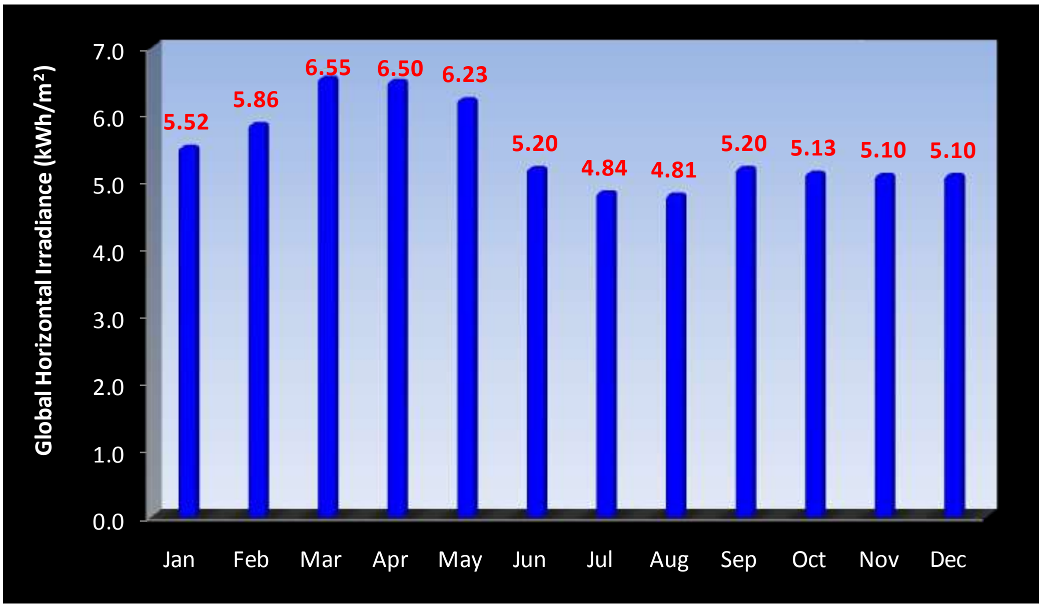


Figure 37. Solar Radiation over Tumkur, Karnataka (Meteonorm 7.0 time series Data)

4.6.7. SolarGIS Data

SolarGIS database produces high resolution time series interpolated data over the desired location. As per Meteonorm 6.0 weather database the selected project location of District-Tumkur, Karnataka receives daily average solar radiation of 5.49 kWh/m²; which refers its annual magnitude of 2004 kWh/m². Figure 34 present the month wise solar radiation (GHI) pattern of the year at the selected location using SolarGIS database.

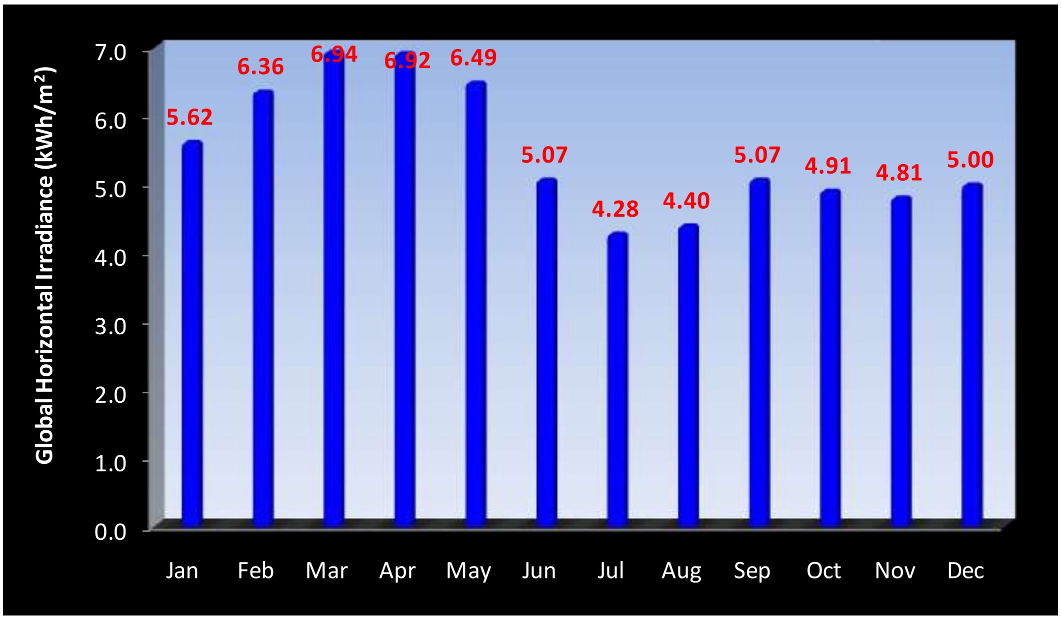


Figure 38. Solar Radiation over Tumkur, Karnataka (SolarGIS Data)

In addition to this other databases like 3TIER could also be explored. The data of Tumkur, Karnataka is not available with ISHRAE weather database. Figure 39 graphically presents the annual values of GHI through above weather databases. Based on the outcome of various weather databases (GHI is higher 1800 kWh/m³ annual) than it is well established that the location of Tumkur, Karnataka is suitable for implementing large scale solar PV power projects and development of Solar Park.

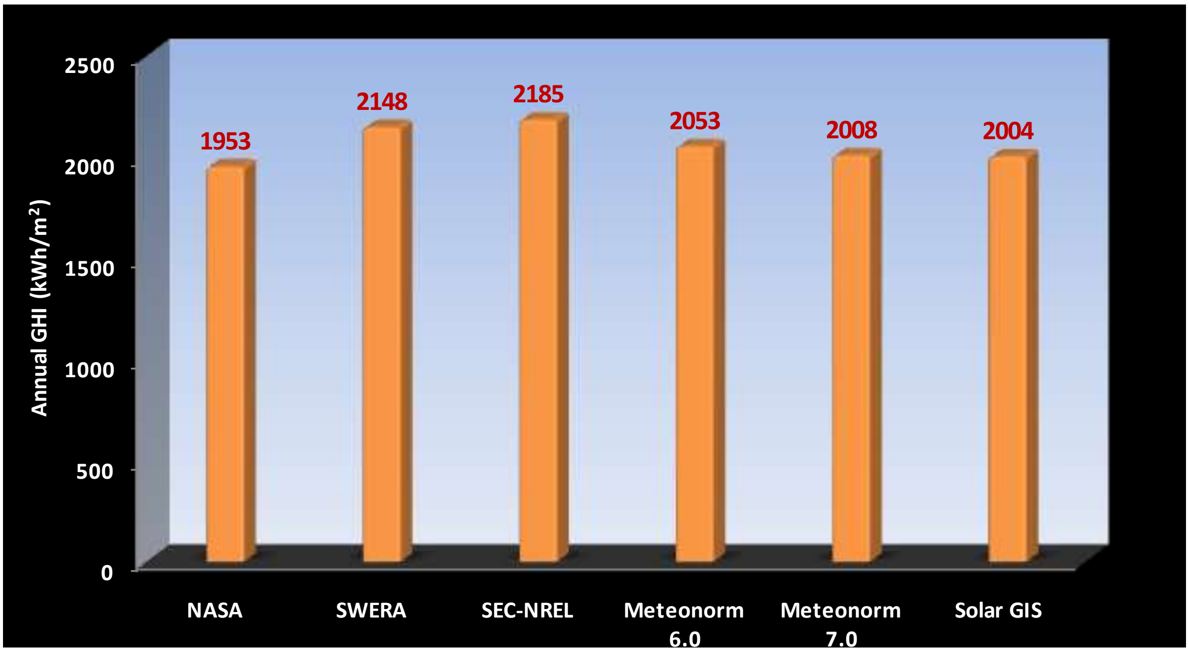


Figure 39. Annual GHI and DNI over Tumkur, Karnataka through various databases

4.7. Optimization of the Solar Radiation Database (GHI)

Out of above solar radiation and weather databases the optimum database has been selected statistically. It is well established that in order to carry out long term realistic energy yield estimation of solar power projects the dynamic weather data bases are preferred. Out of above solar radiation databases; only Meteonorm 6.0 and Meteonorm 7.0 are dynamic databases; however NASA, NREL, SWERA and SolarGIS[19] databases are static. In fact, the IMD data reported in 1982; is essentially estimated data of Bangalore is also static data. In addition to this most of the databases do not have defined uncertainty range. Figure 40 presets the statistical approach adopted for optimization of database at Pavagada (Tumkur), Karnataka.

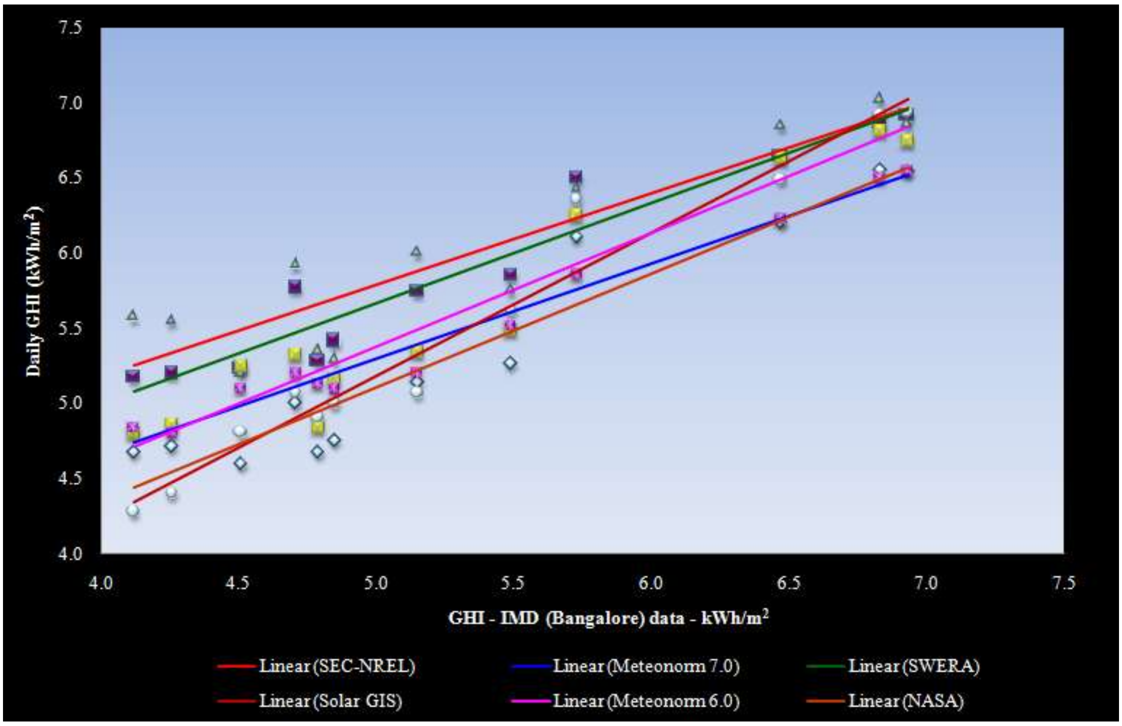


Figure 40. Statistical analysis of solar radiation databases for Tumkur, Karnataka (correlation coefficient, R^2)

The statistical analysis has been carried out based on IMD-MNRE data of Bangalore, Karnataka using correlation coefficient and Mean Parentage Error (MPE). The NASA (100 km), SEC-NREL and SWERA (10 km)

[19] SolarGIS time series data is commercially available for multiple years.

satellite databases are low and moderate resolution respectively; however SolarGIS is high resolution (3 km) but available in static formats only. The time series data of SolarGIS could be explore at the project designing stage.

For GHI Meteonorm 6.0 presents 94% value of R^2 against IMD data; which is observed as 97% in case of Meteonorm 7.0. In addition the MPE for Meteonorm 6.0 has been observed as 5.4% which is 3.2% for Meteonorm 7.0. Hence in the present analysis Meteonorm 7.0 weather database (software) has been selected as optimum solar radiation and weather database for the location of Tumkur, Karnataka.

Meteonorm 7.0 database considered the long term data of solar radiation from the years 1981-2000 for GHI and DNI estimation. It could be observed that the monthly average daily GHI over the location of Tumkur, Karnataka varies from 4.81 **kWh/m²**(August) to **6.55 kWh/m²** (March). The annual GHI is **2008 kWh/m²** (annual average daily 5.50 kWh/m²) which contains 826 **kWh/m²** (annual average daily 2.26 kWh/m²) diffuse component (around 41%). Using Meteonorm 7.0; the month wise GHI and diffuse irradiance over the location are presented in Figure 41 and Figure 42 respectively; however the intensity distribution map of annual GHI and diffuse irradiance are presented in Figure 43 and Figure 44 below using D-VIEW computer software.

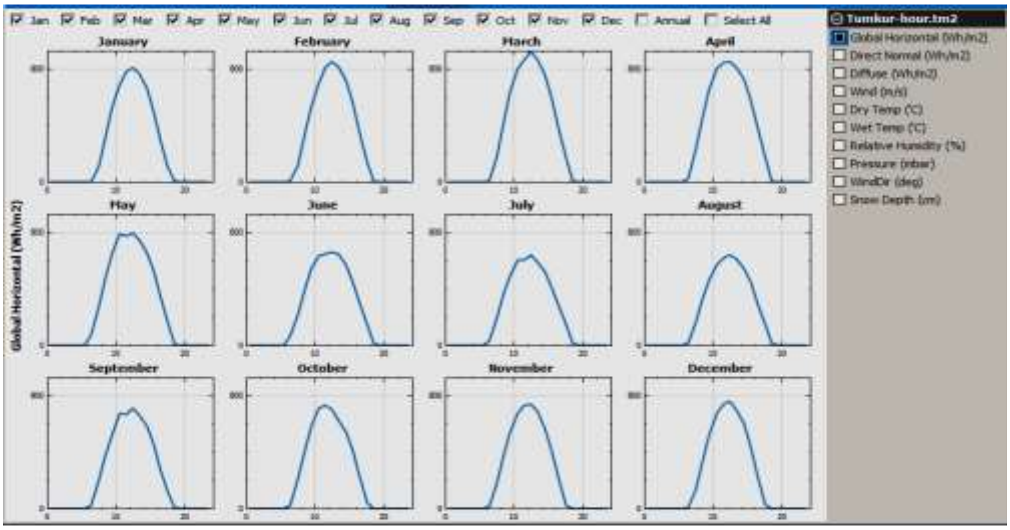


Figure 41. Month wise pattern of GHI at Tumkur, Karnataka (Meteonorm 7.0)

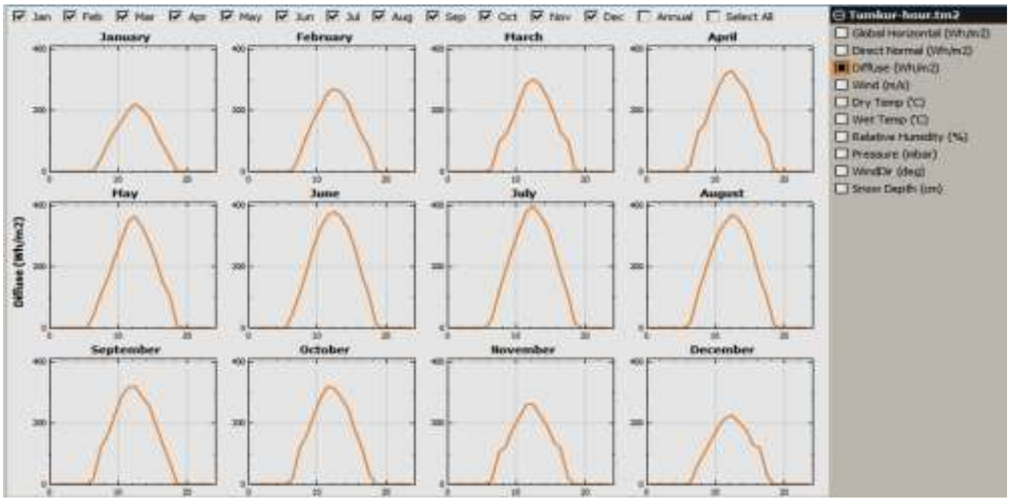


Figure 42. Month wise pattern of diffuse irradiance at Tumkur, Karnataka (Meteonorm 7.0)

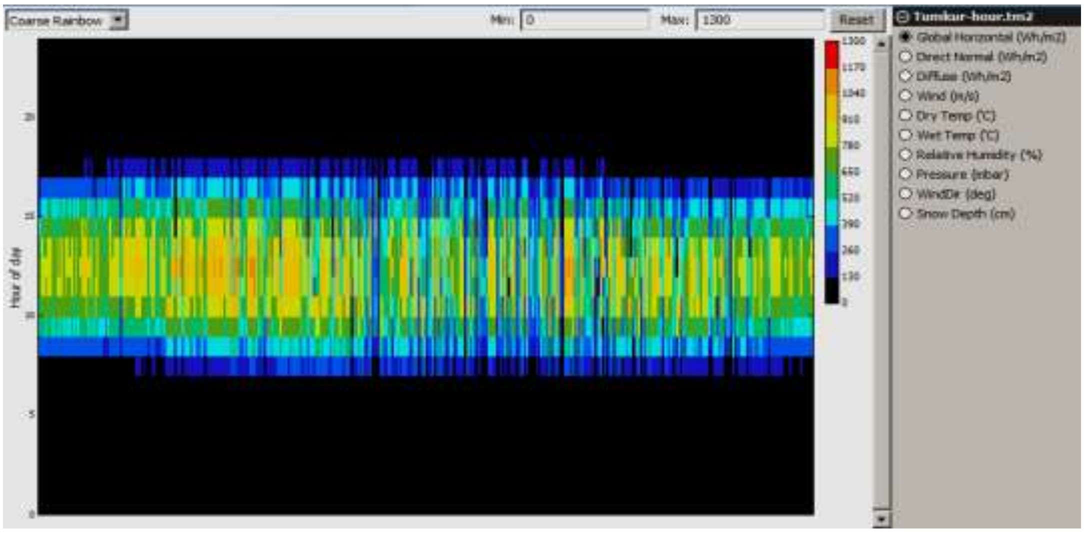


Figure 43. Intensity distribution of DHI at Tumkur, Karnataka (Meteonorm 7.0)

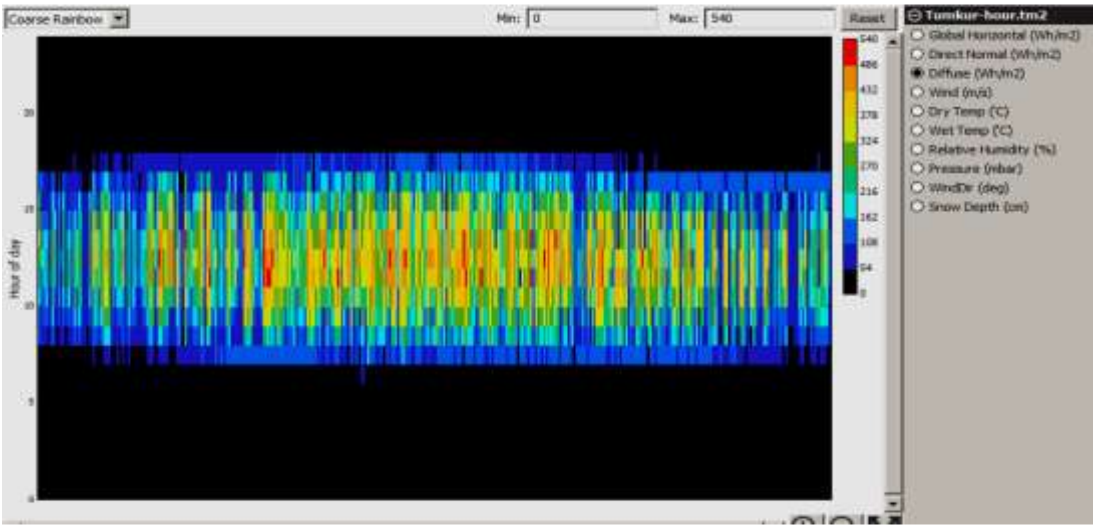


Figure 44. Intensity distribution of diffuse irradiance at Tumkur, Karnataka (Meteonorm 7.0)

The daily values of GHI and diffuse irradiance over the location of Tumkur, Karnataka are presented in Table 14 and Table 15 respectively.

Table 14. Daily GHI (kWh/m²) at Tumkur, Karnataka

Days	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.59	4.66	5.75	7.35	7.17	4.87	5.11	6.70	6.23	6.60	5.02	3.07
2	4.66	4.41	6.41	4.89	7.45	6.04	5.47	7.68	5.64	7.17	4.73	3.42
3	5.61	5.40	5.43	7.71	7.08	6.64	2.71	7.10	6.99	4.82	5.14	4.61
4	5.54	6.47	5.52	8.09	7.65	4.67	4.62	6.70	2.31	5.89	6.41	6.04
5	5.38	5.61	7.27	7.87	4.44	3.33	4.15	2.57	1.12	2.61	6.27	5.60
6	6.08	6.20	5.99	4.01	6.41	7.44	7.32	4.27	7.84	5.72	5.52	5.21
7	5.83	5.93	4.22	5.84	6.57	2.63	3.53	6.18	7.57	4.02	6.43	6.14
8	5.00	6.05	7.36	6.35	2.95	2.65	7.73	4.31	7.76	4.00	4.85	5.35
9	5.37	2.84	7.59	4.92	6.95	5.14	4.59	6.89	7.18	4.23	5.19	5.22
10	6.23	6.55	4.84	7.55	7.00	1.98	4.87	1.75	7.96	5.89	6.37	4.67
11	5.20	6.73	6.87	7.80	5.74	4.35	7.20	4.00	3.57	5.49	6.63	3.11
12	6.03	6.03	7.09	7.85	5.59	5.76	3.37	6.45	5.05	3.30	6.27	5.86
13	5.17	6.58	7.22	8.06	5.40	4.26	4.59	6.99	4.31	6.22	3.40	5.87
14	6.26	6.29	6.75	7.63	6.61	4.33	4.64	2.63	7.36	2.95	3.07	5.97
15	5.58	6.38	6.40	4.53	7.69	5.78	6.26	2.47	3.09	6.65	6.42	5.81
16	5.46	6.87	6.71	6.25	7.10	7.71	4.64	4.51	4.46	4.87	5.61	5.88
17	5.96	6.90	5.53	5.66	7.01	5.65	4.94	7.80	4.30	6.81	4.07	4.90
18	5.21	6.59	5.84	3.94	6.43	5.58	5.86	4.24	4.49	6.78	5.47	4.72
19	5.75	6.51	7.66	5.87	4.15	5.36	6.89	7.40	6.24	6.54	6.32	5.35
20	5.23	6.59	5.38	6.71	3.66	5.56	6.65	2.90	2.70	5.90	2.87	4.69
21	5.58	6.09	4.68	4.12	7.94	6.08	1.75	3.21	3.05	4.70	3.83	5.87
22	6.42	4.59	7.17	6.59	7.20	7.22	5.12	3.95	4.31	2.82	4.99	5.45
23	6.33	5.82	7.45	6.55	4.88	7.39	6.91	2.72	7.77	6.00	1.30	5.16
24	6.66	6.82	7.02	6.91	5.69	6.11	4.76	4.73	4.88	6.95	5.97	5.00
25	5.54	6.51	7.66	5.05	6.21	4.05	6.05	3.07	3.58	5.74	3.26	4.63
26	6.23	4.57	7.36	7.49	8.01	4.02	2.24	6.64	2.68	6.03	4.66	6.10
27	4.77	4.55	7.49	7.21	7.65	7.09	2.97	5.21	5.33	3.69	5.47	4.88
28	4.57	5.85	7.71	7.56	5.62	7.56	5.80	5.96	7.11	3.94	5.63	4.90
29	5.99		7.03	6.95	3.26	3.28	2.93	1.41	3.47	4.02	5.74	4.09
30	5.17		6.06	7.79	6.76	3.72	2.74	5.30	7.57	6.18	5.91	5.21
31	5.46		7.38		6.44		2.99	3.08		2.93		5.70
Total	**171**	**164**	**203**	**195**	**193**	**156**	**149**	**149**	**156**	**159**	**153**	**158**
Avg.	**5.51**	**5.87**	**6.54**	**6.50**	**6.22**	**5.21**	**4.82**	**4.89**	**5.20**	**5.14**	**5.09**	**5.11**

(Source: Meteonorm 7.0 Database)

Table 15. Daily Diffuse Irradiance (kWh/m²) at Tumkur, Karnataka

Days	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.45	2.92	2.62	1.81	2.49	2.64	2.77	2.70	2.92	2.11	2.44	2.70
2	2.07	3.14	2.16	2.67	2.03	3.32	2.87	1.54	2.95	1.30	2.88	2.27
3	1.11	2.21	2.87	1.33	2.45	2.77	2.60	2.34	2.37	2.86	2.60	2.33
4	1.24	0.93	2.87	1.06	1.74	3.70	3.68	2.69	2.27	2.68	1.12	0.83
5	1.48	2.10	1.06	1.21	3.71	3.18	3.63	2.47	1.11	2.18	1.25	1.22
6	0.71	1.35	2.62	3.58	3.02	2.00	2.10	3.63	1.16	2.90	2.11	1.70
7	0.91	1.83	2.13	3.34	2.97	2.56	3.23	3.20	1.42	1.80	1.02	0.82
8	1.98	1.68	1.11	2.93	2.74	2.55	1.46	3.46	1.18	2.70	2.62	1.54
9	1.59	2.51	0.97	3.72	2.55	2.73	3.44	2.53	2.03	2.64	2.38	1.68
10	0.70	1.02	3.47	1.70	2.52	1.96	3.21	1.73	1.06	2.55	0.98	2.23
11	1.83	0.90	1.93	1.36	3.02	2.73	2.23	3.06	3.10	2.71	0.88	2.34
12	0.80	1.92	1.58	1.32	2.88	3.05	3.15	2.94	2.69	2.70	1.04	0.81
13	1.84	1.10	1.45	1.13	2.86	3.67	3.44	2.44	3.54	2.19	2.81	0.80
14	0.71	1.59	2.20	1.64	2.79	3.64	3.07	2.55	1.56	2.78	2.77	0.78
15	1.45	1.52	2.41	3.77	1.64	3.26	3.15	2.40	2.82	1.61	0.87	0.84
16	1.60	0.94	2.18	3.09	2.43	1.48	3.45	3.69	3.57	2.87	1.76	0.80
17	0.94	0.95	3.24	3.63	2.51	3.12	3.80	1.35	3.49	1.28	2.51	1.86
18	1.98	1.34	3.01	3.55	3.01	3.60	3.38	3.19	3.63	1.27	1.87	2.13
19	1.32	1.54	1.08	3.33	3.65	3.74	2.57	1.96	2.63	1.59	0.86	1.44
20	1.90	1.46	3.39	2.69	2.86	3.05	2.75	2.77	2.61	2.27	2.57	2.14
21	1.56	2.15	3.60	2.89	1.26	3.19	1.74	3.03	2.56	3.00	2.90	0.79
22	0.73	3.36	1.84	2.81	2.43	2.22	2.82	3.50	2.52	2.69	2.16	1.25
23	0.77	2.37	1.46	2.88	2.68	1.97	2.51	2.61	1.48	2.07	1.29	1.67
24	0.74	1.28	2.19	2.57	2.88	3.09	3.75	3.79	2.55	0.98	1.01	1.74
25	1.78	1.81	1.20	2.73	3.21	3.58	3.15	2.94	2.19	2.32	2.44	2.22
26	0.91	3.42	1.63	1.96	1.19	3.25	2.22	2.69	2.59	2.03	2.44	1.29
27	2.69	3.42	1.48	2.44	1.67	2.43	2.87	3.59	3.08	3.09	1.68	1.94
28	2.20	2.48	1.21	1.84	3.17	1.69	3.50	3.28	1.52	2.80	1.34	1.93
29	1.32		2.31	2.55	2.70	3.11	2.81	1.40	3.21	2.15	1.16	2.44
30	2.31		3.04	1.50	2.71	3.43	2.65	2.87	0.98	1.63	0.97	1.62
31	2.00		1.75		2.94		2.63	2.95		2.77		0.96
Total	**46**	**53**	**66**	**73**	**81**	**87**	**91**	**85**	**71**	**70**	**55**	**49**
Avg.	**1.47**	**1.90**	**2.13**	**2.44**	**2.60**	**2.89**	**2.92**	**2.75**	**2.36**	**2.27**	**1.82**	**1.58**

(Source: Meteonorm 7.0 Database)

4.8. Climatic Study of Tumkur, Karnataka

Following climatic parameters (relevant for solar power project) have been analyzed based on their hourly values obtained from Meteonorm 7.0 database;

- Ambient Temperature
- Relative humidity and Precipitation
- Rainfall and
- Wind speed

The project location has a typical 'Warm and Humid' climate, hence annual variation in ambient temperature is moderate. The minimum and maximum ambient temperature varies from 14.5°C to 40.4°C over the location; however the annual average ambient temperature is 26.59°C. Figure 45 presents the monthly average values of ambient temperature over the project location along with its D-VIEW intensity distribution pattern.

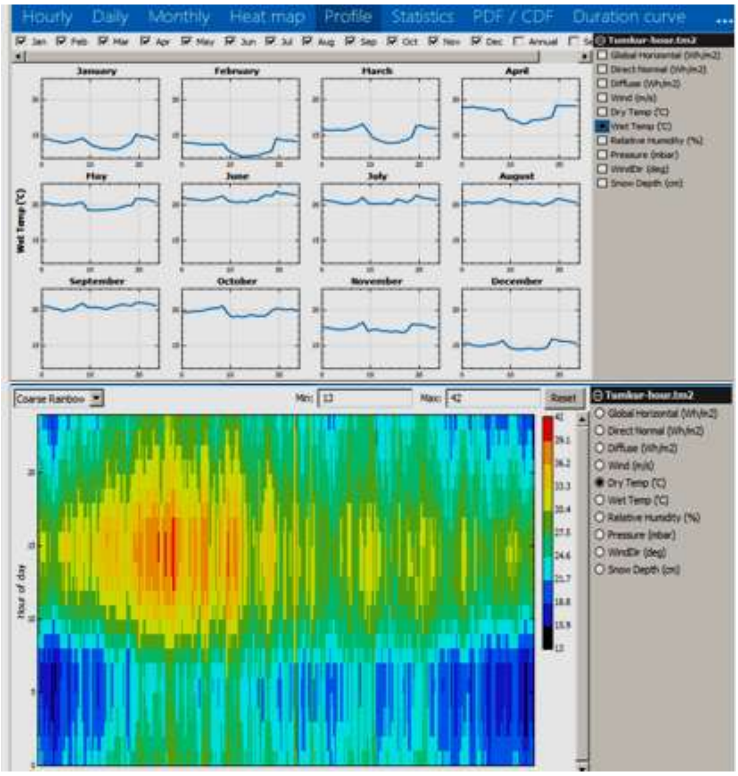


Figure 45. Monthly average ambient temperatures (°C) at Tumkur, Karnataka

The minimum and maximum relative humidity varies from 19% to 100% over the location; however the annual average relative humidity is 62.2%. Figure 46 presents the monthly average values of relative humidity over the project location along with its D-VIEW intensity distribution pattern.

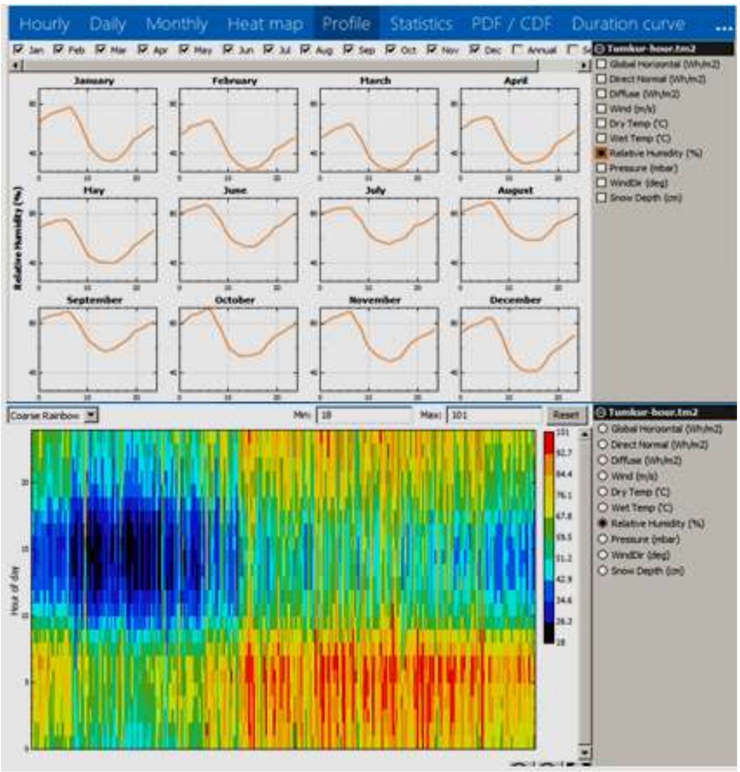


Figure 46. Monthly average relative humidity (%) at Tumkur, Karnataka

The precipitation pattern at Tumkur, Karnataka is presented in Figure 47 using Meteonorm 7.0 weather database[20].

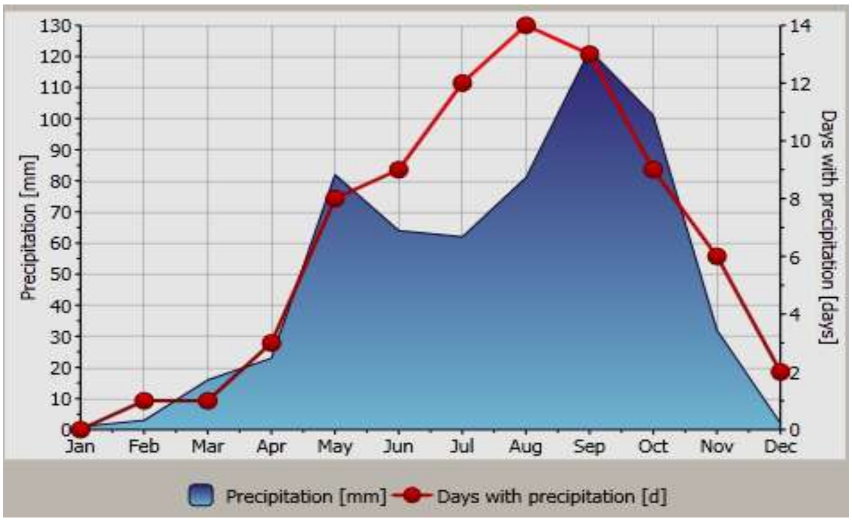


Figure 47. Monthly pattern of precipitation at Tumkur, Karnataka

Few locations of Tumkur district receive high wind speed. The minimum and maximum wind speed varies from 0.0 m/s to 15.5 m/s over the location; however the annual average wind speed is 2.5m/s. As the location is within the vicinity of hilly area; hence wind is highly intermittent in the region. The annual average wind speed is 1.23 m/s. Figure 48 presents the monthly average values of prevailing wind speed over the project location along with its D-VIEW intensity distribution pattern.

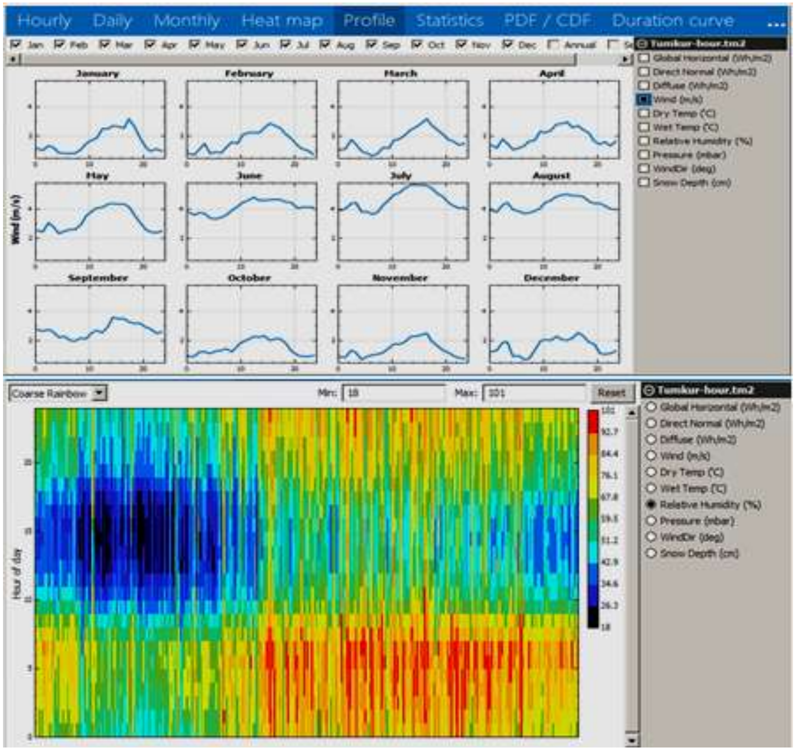


Figure 48. Monthly average wind speed (m/s) at Tumkur, Karnataka

The daily average values of climatic parameters namely ambient temperature, relative humidity and prevailing wind speed have been presented from Table 16, .0 Database)

[20] Precipitation refers to the falling of water from the clouds, where Humidity refers to the amount of water vapor in the air. **Relative humidity** is the ratio of the partial pressure of water vapor to the equilibrium vapor pressure of water at the same temperature. The definition of **Precipitation** is any form of water - liquid or solid - falling from the sky. It includes rain, sleet, snow, hail and drizzle plus a few less common occurrences such as ice pellets, diamond dust and freezing rain.

Table 17 and

Table 18 respectively.

Table 16. Daily average Ambient Temperatures (ºC) at Tumkur, Karnataka

Days	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	26.1	27.0	29.3	28.7	30.6	26.2	27.3	25.2	27.6	25.4	22.5	23.6
2	24.6	26.9	29.1	29.1	32.0	28.3	27.5	24.9	27.7	25.1	23.3	22.5
3	24.8	26.1	27.7	30.1	31.8	27.4	27.6	24.2	27.9	25.5	23.5	24.2
4	24.2	23.7	27.4	30.0	31.2	26.8	26.6	23.4	28.6	25.8	23.4	24.1
5	24.1	25.5	28.2	32.5	32.5	27.0	26.2	24.7	28.0	26.1	22.7	23.4
6	23.4	25.4	28.7	32.2	32.4	27.0	25.8	24.4	27.4	26.5	24.3	23.1
7	24.0	26.3	28.2	32.8	30.3	26.5	26.5	23.8	24.0	26.7	23.9	23.2
8	23.3	25.2	25.9	32.7	28.2	25.7	27.1	25.0	25.7	26.1	25.6	23.4
9	22.9	24.6	26.6	31.8	28.3	26.2	32.5	24.6	25.3	26.9	25.9	22.9
10	23.2	25.7	27.9	33.1	27.0	26.2	27.3	25.1	25.0	28.0	26.3	23.3
11	23.6	26.0	28.8	33.4	28.9	27.3	26.8	25.7	23.7	28.5	26.6	22.4
12	20.9	25.8	28.5	31.4	25.9	25.3	26.7	26.0	24.5	27.5	25.4	23.5
13	21.6	26.7	29.0	30.9	27.8	29.4	26.4	25.6	24.7	27.4	24.6	22.8
14	22.6	24.2	29.4	30.5	26.5	27.5	24.9	26.1	26.5	27.0	24.2	23.9
15	22.4	24.9	29.7	31.3	29.9	25.7	24.4	25.7	25.2	26.7	23.8	24.0
16	22.8	26.6	30.0	30.9	29.1	27.2	24.6	25.9	24.8	25.7	22.3	25.1
17	23.7	27.4	32.4	29.6	28.7	27.4	25.6	26.6	23.2	26.1	23.4	23.8
18	24.3	26.4	30.7	30.1	27.5	28.7	26.9	27.5	26.1	25.9	23.9	24.8
19	25.0	27.2	30.4	29.0	29.6	30.5	26.8	28.1	25.5	25.3	25.8	24.6
20	24.7	27.7	29.6	29.8	33.0	30.0	25.3	26.9	25.2	26.6	24.9	24.4
21	25.3	29.0	29.8	29.2	32.8	29.2	30.5	26.2	26.0	26.3	24.1	22.3
22	26.7	29.3	30.8	30.4	31.7	29.0	27.8	25.4	25.1	24.8	24.2	23.7
23	24.9	27.8	30.2	30.7	31.4	27.9	27.2	25.4	24.5	24.7	22.9	22.6
24	23.1	28.1	30.6	29.5	30.1	26.5	26.1	26.3	26.9	24.9	22.9	21.9
25	23.8	28.0	30.3	31.0	30.8	27.0	25.4	27.1	26.1	24.2	23.9	21.4
26	25.9	27.5	30.1	30.6	31.0	26.9	23.9	26.5	25.6	23.4	23.7	21.6
27	25.6	28.6	31.5	31.2	31.3	26.6	25.5	27.3	25.6	23.7	23.2	22.0
28	24.4	29.6	31.3	29.9	32.1	25.1	25.9	26.7	24.4	22.9	22.2	22.2
29	25.2		30.9	28.1	30.3	24.3	27.0	26.3	25.9	24.4	21.4	23.0
30	25.4		31.1	27.4	29.3	26.0	25.0	26.8	25.8	24.6	21.8	23.7
31	27.2		32.0		29.5		25.9	27.7		23.9		22.7
Avg.	**24.2**	**26.7**	**29.6**	**30.6**	**30.1**	**27.2**	**26.5**	**25.8**	**25.8**	**25.7**	**23.9**	**23.2**

(Source: Meteonorm 7.0 Database)

Table 17. Daily average relative humidity (%) at Tumkur, Karnataka

Days	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	60.1	52.6	40.4	53.6	46.3	71.7	72.5	74.0	68.6	62.0	79.8	65.9
2	61.5	36.7	42.3	53.3	48.2	64.6	61.6	66.2	69.3	66.2	72.8	65.0
3	54.9	37.3	48.5	47.3	46.8	61.9	77.7	72.0	65.4	65.3	72.5	59.2
4	54.0	47.8	51.0	45.2	48.7	71.0	68.8	78.6	80.3	71.0	64.2	58.3
5	55.7	52.5	43.9	39.0	59.4	75.0	72.8	85.1	86.6	80.7	63.1	60.4
6	56.8	47.3	48.9	61.5	53.3	73.0	78.0	74.5	70.5	69.3	62.9	59.1
7	64.5	42.6	66.0	52.3	54.4	82.4	74.0	69.1	68.9	75.7	60.5	56.5

8	60.0	57.6	54.5	50.5	80.9	85.1	67.7	75.5	65.1	77.1	69.7	56.4
9	61.0	70.4	48.9	38.0	56.9	69.5	62.5	75.6	64.8	67.1	73.2	68.2
10	55.3	48.1	44.2	41.5	56.8	81.5	72.2	87.5	67.1	73.8	67.7	66.6
11	54.5	45.7	40.0	48.8	56.7	72.1	65.8	71.4	81.3	77.3	64.0	70.5
12	59.9	45.4	40.6	46.3	65.9	76.1	68.0	59.2	81.5	77.3	63.9	66.2
13	55.7	41.8	38.9	46.1	64.7	63.9	73.8	68.4	79.7	71.8	67.3	62.0
14	46.3	45.0	42.2	48.7	62.8	73.3	74.7	81.2	72.3	79.6	71.2	59.0
15	52.0	47.5	44.0	52.4	48.1	67.3	72.8	84.1	82.6	70.3	65.1	63.4
16	52.0	40.7	42.8	52.3	49.3	55.1	76.5	78.8	69.2	73.2	77.8	63.5
17	51.3	40.9	38.8	52.0	53.0	58.1	60.5	70.3	78.1	70.0	73.6	61.6
18	58.7	42.3	41.3	72.9	60.6	71.3	56.0	70.2	70.6	62.2	69.7	62.7
19	55.7	44.8	40.9	54.2	73.1	74.6	58.9	63.9	74.0	71.3	66.6	68.3
20	53.7	49.4	42.0	45.5	65.5	72.5	74.2	74.9	88.9	68.9	79.8	65.8
21	54.9	41.0	42.5	56.9	60.5	58.8	71.0	74.7	80.1	59.6	71.7	63.8
22	52.8	41.9	42.6	47.0	61.7	60.0	71.1	81.0	81.2	78.1	62.7	57.5
23	49.6	47.6	46.3	51.5	68.0	65.1	62.6	76.2	73.5	69.2	90.0	64.8
24	58.3	48.7	45.5	53.5	54.6	69.0	61.1	68.1	67.1	69.5	76.4	64.8
25	58.7	45.3	40.1	55.0	49.9	73.1	65.0	61.1	78.0	74.2	75.5	62.6
26	55.5	47.0	45.0	52.8	60.1	72.0	86.3	58.0	80.9	64.8	61.8	53.7
27	63.5	47.9	43.1	50.1	54.2	68.3	77.1	62.5	61.1	71.5	59.3	60.7
28	58.1	47.0	43.1	44.8	53.3	72.4	65.8	68.0	67.5	77.0	61.8	67.0
29	52.8		50.3	45.5	65.6	80.0	76.9	83.2	81.3	66.1	66.1	63.9
30	54.5		46.8	44.0	44.8	74.4	88.8	81.0	67.0	69.1	62.8	57.3
31	42.0		39.8		49.8		82.9	77.4		81.3		60.1
Avg.	**55.6**	**46.5**	**44.7**	**50.1**	**57.2**	**70.4**	**70.9**	**73.3**	**74.1**	**71.3**	**69.1**	**62.4**

(Source: Meteonorm 7.0 Database)

Table 18. Daily average wind speed (m/s) at Tumkur, Karnataka

Days	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1.09	1.80	1.20	2.23	3.11	4.81	9.34	5.55	2.61	0.85	1.71	0.95
2	1.16	1.84	2.31	2.63	2.11	3.62	8.45	7.39	2.10	2.60	1.10	1.96
3	1.75	0.70	1.45	0.66	0.85	5.87	5.53	5.20	0.15	1.24	2.36	0.72
4	0.98	1.40	1.11	0.92	2.30	6.66	1.34	3.23	2.23	2.88	1.35	0.63
5	1.53	1.73	1.21	1.58	0.63	6.33	3.07	1.68	1.78	1.27	1.72	1.73
6	1.53	1.33	2.15	1.05	2.22	3.83	7.49	1.04	1.36	1.89	1.21	2.07
7	0.85	0.83	2.13	2.68	2.96	3.32	5.70	2.68	3.06	1.66	0.65	1.92
8	1.97	1.28	2.00	1.72	3.18	2.16	3.30	6.36	5.82	1.62	0.96	0.60
9	1.48	1.30	1.65	2.62	3.35	2.94	6.01	8.64	2.30	1.23	1.73	0.77
10	3.03	1.13	1.73	2.62	2.47	6.28	4.98	4.16	2.01	2.74	0.87	0.97
11	2.26	2.22	0.27	0.55	3.33	3.63	3.84	7.74	3.73	1.45	2.17	1.44
12	1.06	1.52	1.17	2.83	2.09	2.21	3.37	7.21	2.39	0.78	2.12	2.68
13	1.50	1.87	1.97	1.85	4.31	1.28	3.83	3.65	1.94	0.62	1.25	2.21
14	0.76	2.15	1.68	3.51	4.77	3.25	4.55	5.18	4.43	0.92	0.62	3.70
15	2.65	4.30	1.93	3.40	6.73	6.96	1.24	4.94	3.56	1.47	1.48	0.68
16	0.95	1.63	1.88	1.04	7.03	4.17	3.66	4.33	4.34	1.12	0.98	2.13
17	1.78	2.70	1.05	0.62	4.45	2.09	1.67	3.84	2.10	1.78	2.35	2.21
18	2.32	1.07	1.14	0.88	3.18	5.82	3.99	1.62	1.12	0.88	1.53	1.91

19	2.29	0.98	1.71	1.93	2.42	5.50	2.86	3.62	2.19	1.64	2.46	2.97
20	1.64	1.50	1.22	2.17	1.17	4.08	4.36	3.29	1.46	1.25	1.03	1.01
21	3.18	1.56	3.01	1.97	2.52	3.78	1.91	3.70	2.11	1.58	1.04	0.83
22	1.47	1.68	1.13	1.17	4.60	3.70	4.64	2.79	2.79	3.88	1.35	1.30
23	0.49	1.50	2.04	3.70	5.61	0.91	8.13	4.16	3.78	0.87	1.68	1.68
24	0.83	1.60	2.28	1.74	5.57	2.03	5.67	2.93	5.16	3.00	1.12	0.80
25	0.73	1.07	1.49	1.11	2.13	1.95	6.27	1.42	1.61	1.14	1.42	1.66
26	1.77	1.20	2.55	2.97	3.13	2.04	3.80	2.60	5.13	1.02	0.29	1.22
27	3.33	1.48	1.36	1.93	3.20	1.98	7.00	6.61	3.76	0.64	0.97	1.75
28	1.53	1.06	2.70	2.11	1.60	5.51	5.06	5.64	1.75	0.67	2.53	1.36
29	1.33		1.37	0.97	1.74	6.00	2.79	3.49	2.17	0.68	1.16	2.90
30	1.32		2.43	1.72	1.80	10.10	4.42	2.82	1.91	1.94	0.85	1.40
31	1.14		1.26		4.57		4.23	5.72		0.90		1.30
Avg.	**1.6**	**1.6**	**1.7**	**1.9**	**3.2**	**4.1**	**4.6**	**4.3**	**2.7**	**1.5**	**1.4**	**1.59**

(Source: Meteonorm 7.0 Database)

5. Assessment of Solar Photovoltaic (SPV) Module Technologies

Solar Photovoltaic (SPV) technology is primarily a solid-state semiconductor-based technology, which converts a fraction of the incident solar radiation (photons) in to direct electricity. Solar PV system can deliver electric energy to a specific appliance and/or to the electric grid. Photovoltaic systems are flexible and modular; hence the technology can be implemented on virtually any scale size, connected to the electricity network or used as stand-alone or off grid systems, easily complementing other energy sources. Solar PV offers several advantages viz.

- Complementarities with other energy resources; both conventional and renewable
- Flexibility towards implementation, highly modular and
- Environmental advantages

Depending on the location, resource availability, meteorological parameters, manufacturing, proven history, technology track record, availability and other factors; the appropriate solar PV technology is selected for any location.

5.1. Global Scenario of Solar PV

The grid connected solar PV power projects of cumulative capacity of 30 GW were implemented in year 2013; while it has been increased up to 39 GW by year 2013. Germany has the maximum implemented capacity of solar PV power projects of 37.052 GW by July 2014. The global solar PV market had a record year, after a brief slowdown, installing more capacity than any other renewable technology except perhaps hydropower. More than 39 GW was added, bringing total capacity to approximately 139 GW. Almost half of all PV capacity in operation was added in the past two years, and 98% has been installed since the beginning of year 2004. Global solar analysts NPD Solarbuzz have forecast in their latest Quarterly Report that global PV demand is likely to reach 49 GW in 2014. Figure 49 presents the growth of solar PV installation from year 2004 to 2015.

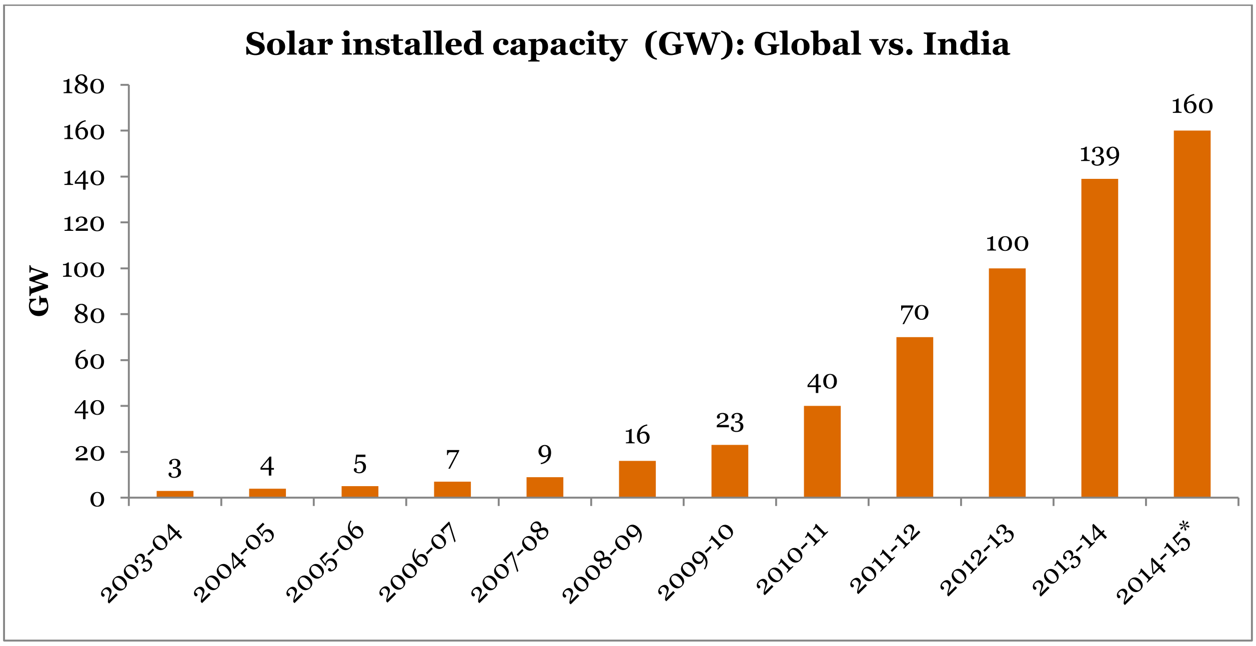


Figure 49. Solar PV Global Capacity from year 2004 to year 2015
(Source: http://www.ren21.net/)

The production of multi-crystalline silicon (c-Si) solar photovoltaic (PV) modules is set to dominate PV manufacturing during 2014, with p-type multi c-Si technology accounting for 62% of all modules produce. Solar PV manufacturers are currently planning to increase module production by 25% in 2014, to 49.7 GW of modules, compared to the 39.7 GW of modules being produced in 2013. Figure 50 presents the global manufacturing percentage of different commercialized and emerging solar PV technologies.

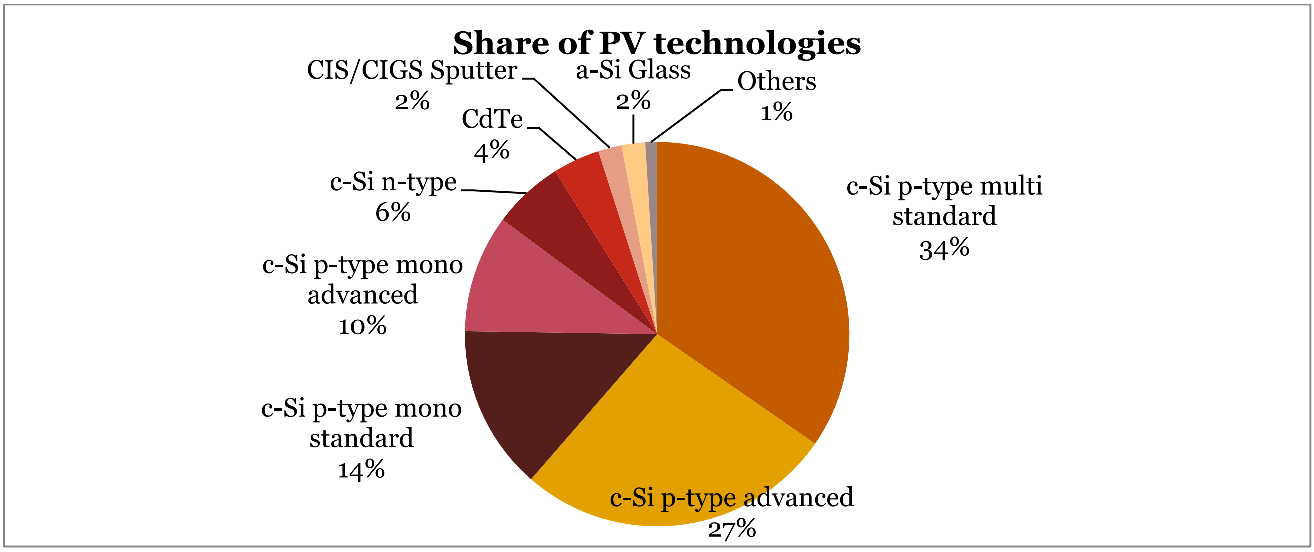


Figure 50. Global manufacturing breakup of solar PV technologies
(Source: NPD Solarbuzz PV Equipment Quarterly)

The manufacturing capacity of global manufacturers has increases in recent years due to exponentially growing market. The global solar PV manufacturing growth and country wise manufacturing of solar PV modules is presented in Figure 51 and Figure 52 respectively.

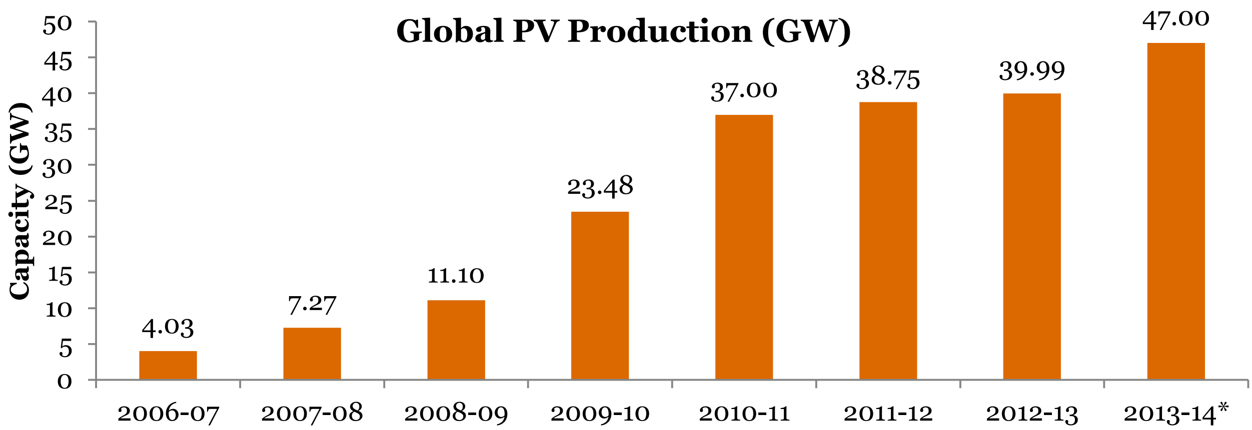


Figure 51. Global Solar PV Production from Year 2007 to 2013
(Source: http://www.greentechmedia.com/)

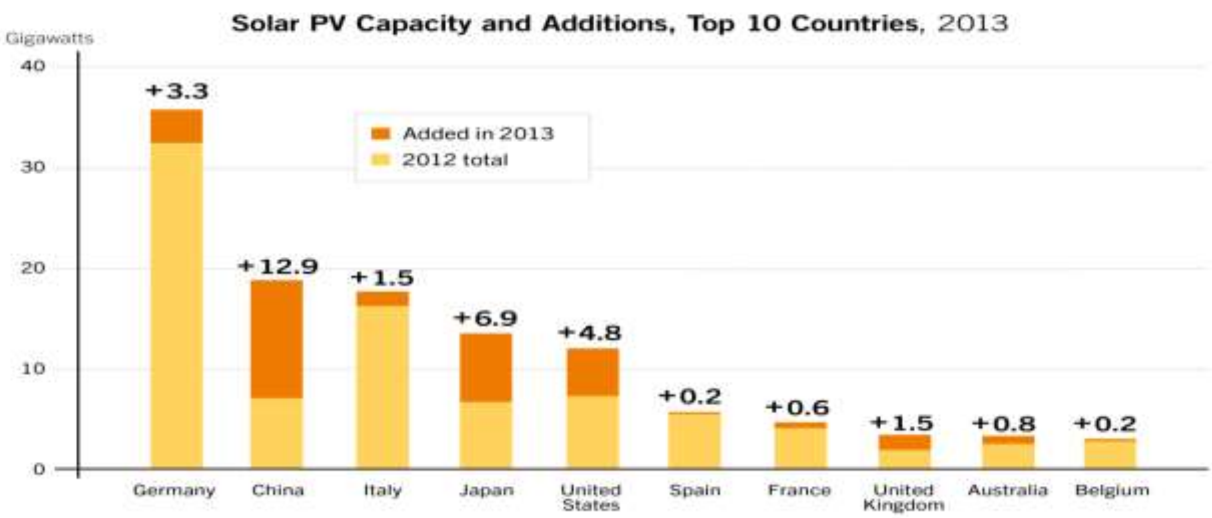


Figure 52. Country wise solar PV manufacturing and growth
(Source: http://www.ren21.net/)

5.2. Indian Scenario

India is slowly building upon its installed solar power capacity, through comprehensive and ambitious National Solar Mission, state solar policies, and relatively increased enforcement of the Renewable Purchase Obligation. The country added almost 950 MW of solar power capacity between April 2013 and March 2014 (that is, FY2013-14). The 56 percent increase in installed solar capacity witnessed in FY2013-14 was mainly due to projects commissioned under the state solar policies and the Renewable Energy Certificate (REC) scheme. Of the 3700 MW installed capacity till 31st March 2014, 50 percent operates under the state solar policies. Presently more than the capacities of 1000 MW solar PV power projects are under implementation in India under various policies. Figure 53 presents the growth of solar power projects implementation in India from FY 2009 to FY 2013.

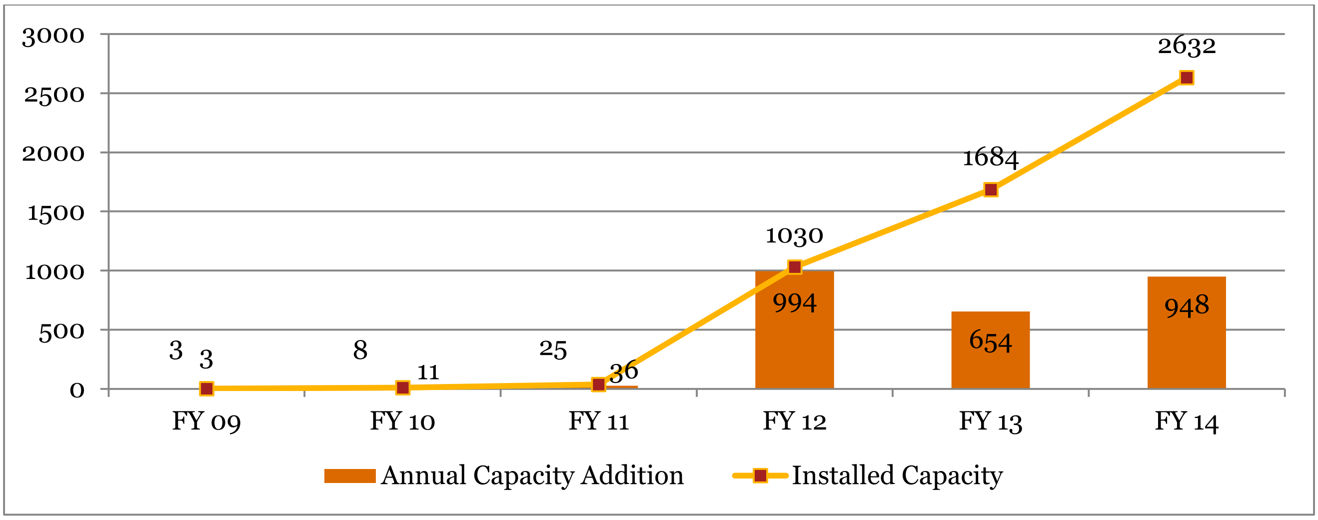


Figure 53. Solar PV based installed capacity in India (MW)
(Source: www.mnre.gov.in)

In 2013, MNRE announced that the total solar PV module manufacturing capacity in India touched 2000 MW. According to the MNRE, India had a solar cell manufacturing capacity of 848 MW and Ingot & Wafer manufacturing capacity of 15 MW at the end of 2012. There is no poly-silicon production capacity. The launch of the National Solar Mission brought with it the prospect of significant domestic demand, and the allied goal of establishing India as a major player in the international solar manufacturing market. National Solar Mission aims at deploying solar power across the country but it also mandates to ensure that development across the entire value chain. Hence, developing domestic manufacturing capacity across value chain is also one of the key areas of the Mission. To ensure the development of domestic manufacturing, provision of Domestic Content Requirement (DCR) is introduced under the Mission.

In an effort to support the domestic manufacturing sector, which began planning ambitious capacity expansions, the first phase of the Mission mandated locally manufactured crystalline PV modules for Batch I projects, and both cells and modules for Batch II projects. During the second phase auctions, bids were invited in two separate categories – half the capacity was restricted to domestically manufactured content whereas the rest was unrestricted.

Table 19. Domestic Content requirements under central schemes

	Phase I Batch I	Phase I Batch II	Phase II Batch I
Capacity Allocation	PV: 140 MW CSP: 450MW	PV 350 MW	PV 750 MW
Domestic Content Requirement	PV: c-Si modules 100% DCR CSP: 30% DCR	PV: c-Si modules 100% DCR	375 MW 100% DCR 375 MW unrestricted

As on May 2014, the current module production capacity stands at 2756 MW, while the solar cell manufacturing capacity is 1386 MW. The growth over the years is plotted below.

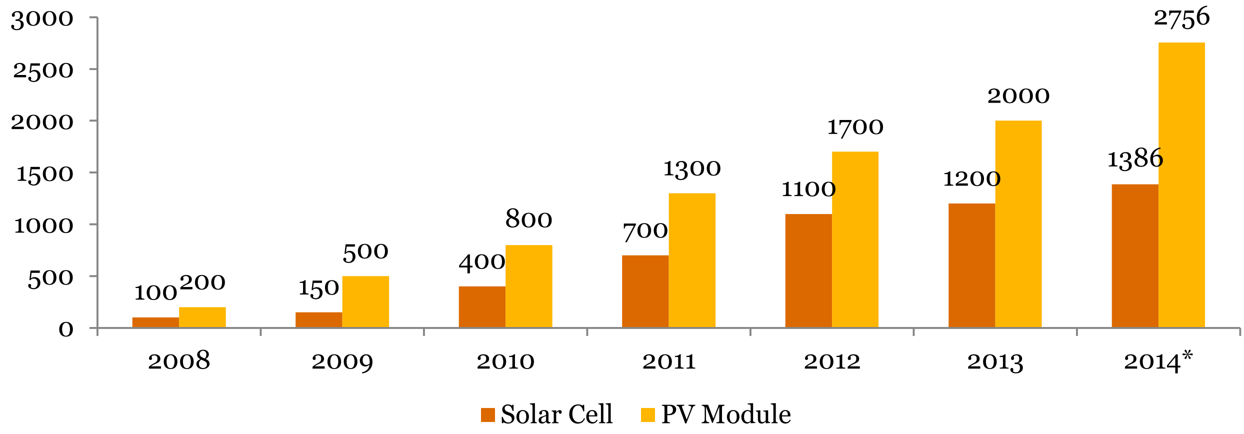


Figure 54. Solar PV manufacturing in India

The market currently consists of 44 companies engaged in the business of production of solar PV modules while 14 are in the business of production of cells. Module capacity has seen good growth in the last few years whereas cell production has stagnated in the last year. Profile of the key players is tabulated below.

Table 20. Capacity of key manufacturers in India

Manufacturing capacity of Solar Cells and Modules in India				
Companies	**Cells (MW)**		**Module (MW)**	
	Installed capacity	**Capacity under Operation**	**Installed capacity**	**Capacity under Operation**
Access Solar	-	-	18	
Ajit Solar	-	-	20	
Alpex	-	-	75	50
Bharat Heavy Electricals Limited (BHEL)	8	-	8	
CEL	3	-	10	2
EMMVEE Solar	-	-	135	135
Euro Multivision Ltd.	40	-	-	
Evergreen	-	-	20	-
Enfield Solar	-	-	20	-
Green Brilliance	-	-	45	-
HHV	-	-	50	-
Indosolar Ltd	450	-	-	-
Jupiter Solar	50	50	-	-
KL Solar	-	-	-	-
Kotak Urja Pvt. Ltd.	-	-	25	25
Lanco	-	-	75	75
Maharishi Solar Technology	10	-	20	-
Microsol	-	-	14	-
Moser Baer	200+50	-	230	-
Photon Energy Systems	-	-	45	40
photonix	-	-	15	-
PLG Power	-	-	-	-
Premier Solar Systems (P) Ltd.	3	-	75	40
Rajasthan Electronics & Instruments Ltd.	-	-	20	-
Reliance Industries Ltd	-	-	-	-
Shurjo	-	-	5	-
Solar Semiconductor	30	-	195	-

Surana Ventures	-	-	40	-
TATA Solar	180	70	200	-
Titan Energy	-	-	100	-
TopSun Energy	-	-	30	-
UPV Solar – Udhaya Energy Photovoltaics Pvt Ltd	12	-	7	-
USL Photovoltaics PVT Ltd.	-	-	7	-
Vikram Solar	-	-	150	75
Waaree Energy	-	-	125	-
Websol Energy System Limited	120	120	100	-
XL Energy Ltd.	60	-	210	-
Gautam Solar	-	-	25	25
Modern Solar	-	-	25	25
Shan Solar	-	-	60	30
Sova Power	-	-	50	50
Jain Irrigation	-	-	55	55
Andromeda	-	-	30	20
PV Power	-	-	14	14
Total	1216	240	2348	661

(Source: www.mnre.gov.in)

As the targeted project capacity is 2000 MW in Tumkur, Karnataka; hence the technology assessment needs not to be limited only of the techno-commercial aspects but on the manufacturing, capability to deliver within the targeted implementation time and track record of the respective manufacturer(s)/ supplier(s). Figure 55 presents global top manufacturers of solar PV cells/ modules in the year 2013.

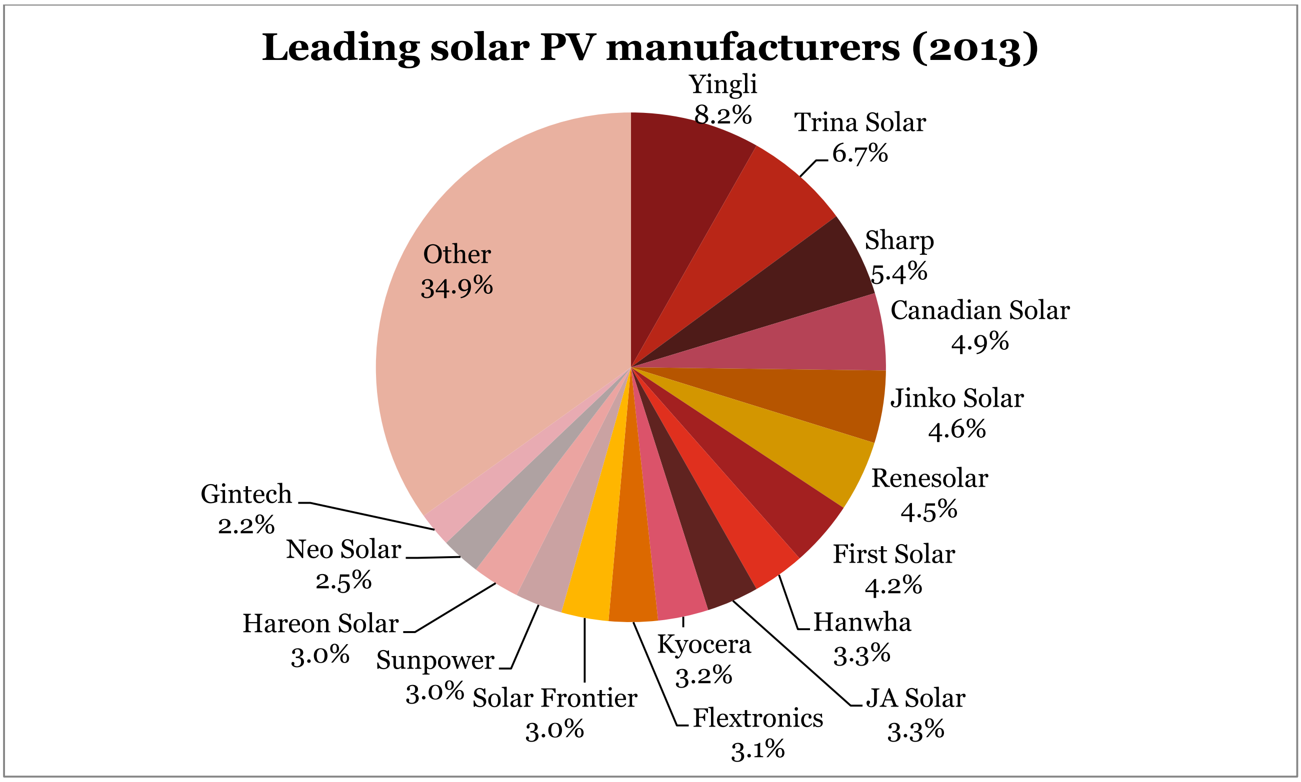


Figure 55. Top 15 global crystalline solar PV module producers
(Source: iSuppli, USA)

5.3. Solar PV system

A solar PV system consists of PV cells that are grouped together to form a PV module and auxiliary components (i.e. balance of system - BOS) including the inverters, controls etc. A typical schematic of grid-connected PV system is given in Figure 56 below.

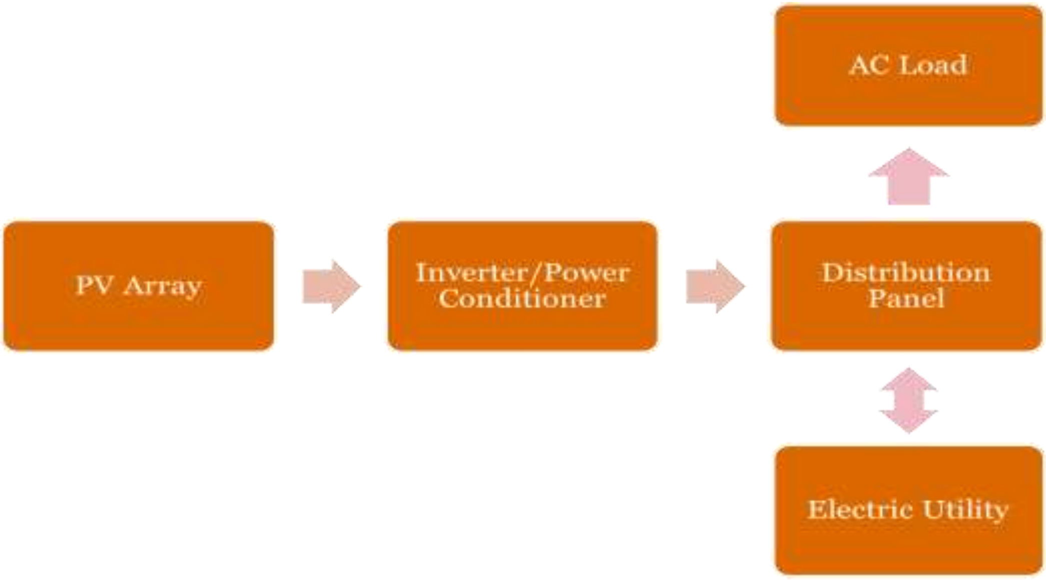


Figure 56. Schematic of grid-connected photovoltaic system

Solar cells represent the fundamental power conversion unit of a photovoltaic system. For practical operation, solar cells are usually assembled into modules. Solar PV technologies are usually classified into three generations; depending on the basis material used and the level of commercial maturity.

- **First generation PV System (Fully commercial):** Use of wafer based crystalline silicon (c-Si) either single crystalline or multi-crystalline
- **Second Generation PV Systems:** Based on the thin-film technology and generally includes:
  - Amorphous and micromorph silicon
  - Cadmium Telluride (CdTe) and
  - Copper Indium – Selenide (CIS) & Copper Indium Gallium Di-Selenide (CIGS)
- **Third Generation PV Systems**: Concentrating Solar PV (CPV), Desensitize PV, Polymer cells etc. are still in demonstration or have not yet been commercialized widely.

5.3.1. Wafer-based crystalline silicon solar cell technology

The technology used to make most of the solar cells, fabricated so far, borrows heavily from the microelectronics industry; which is further classified into two categories as:

- Single / Mono-Crystalline silicon solar cell and
- Multi-Crystalline silicon solar cell

5.3.1.1. Single/mono-crystalline silicon solar cell

This is the most established and efficient solar cell technology till date, having a module efficiency of 15-19%. The cell and module fabrication technology is well developed and reliable. These cells are manufactured from single silicon crystal. During manufacturing, C-Si crystals are cut from cylindrical ingots and therefore the cells do not completely cover a square solar cell module.

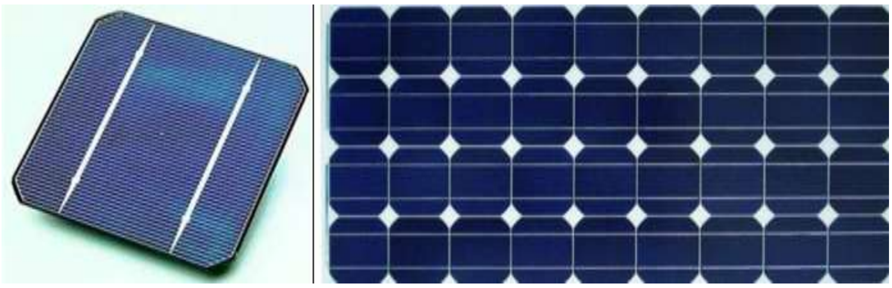


Figure 57. Mono-crystalline silicon solar cell and modules

5.3.1.2. Multi-Crystalline silicon solar cell (poly-Si or mc-Si)

The production of Multi-crystalline cells is more cost-efficient. These are manufactured by cooling a graphite mould filled with molten silicon. In this process, liquid silicon is poured into blocks that are subsequently sawed into plates. During solidification of the material, crystal structures of varying sizes are formed. These cells have module efficiency of around 12-15%.

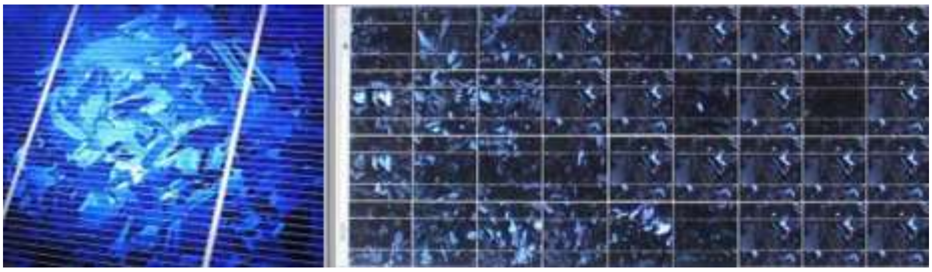


Figure 58. Multi-Crystalline silicon solar cell and module

5.3.2. Thin film solar cell technology

In this approach, thin layers of semiconductor materials are deposited on a supporting substrate, such as a large sheet of glass.

Figure 59. Thin film solar cell and module

These are fundamentally different in their composition and their production from crystalline photovoltaic modules. In general, thin-film modules are made by coating and patterning entire sheets of substrate, generally glass or stainless steel, with micron-thin layers of conducting and semiconductor materials, followed by encapsulation. Typically, less than a micron thickness of semiconductor material is required, 100-1000 times less than the thickness of Silicon wafer. A brief comparison of different solar PV technologies with respect to efficiency, stability, current status etc. is presented in Table 21 below.

Table 21. Comparison of different conventional SPV technologies

Material	Thickness	Efficiency (%)	Colour	Features
Mono-crystalline Si solar cells	0.3 mm	15 – 18	Dark blue, black with AR coating, grey without AR coating	Lengthy production procedure, wafer sawing necessary. Best researched solar cell material – highest power/area ratio.
Multi-crystalline Si solar cells	0.3 mm	12 – 15	Blue with AR coating, silver-grey without AR coating	Wafer sawing necessary. Most important production procedure at least for the next ten years.
Multi-crystalline transparent Si Solar Cells	0.3 mm	10 %	Blue with AR coating, silver-grey without AR coating	Lower efficiency than mono-crystalline solar cells. Attractive solar cells for different BIPV applications.
EFG (Edge Defined Film fed Growth)	0.28 mm	14	Blue, with AR coating	Limited use of this production procedure Very fast crystal growth, no wafer sawing necessary
Poly-crystalline ribbon Si solar cells	0.3 mm	12	Blue, with AR coating, silver-grey without AR coating	Limited use of this production procedure, no wafer sawing necessary. Decrease in production costs expected in the future.
Apex (polycrystaline Si) solar cells	0.03 to 0.1 mm + ceramic substrate	9.5	Blue, with AR coating, silver-grey without AR coating	Production procedure used only by one producer, no wafer sawing, production in form of band possible. Significant decrease in production costs expected in the future.

Mono-crystaline dendritic web Si solar cells	0.13 mm contacts	13	Blue, with AR coating	Limited use of this production procedure, no wafer sawing, and production in form of band possible.
Amorphous silicon	0.0001 mm + 1 to 3 mm substrate	5 – 8	Red-blue, Black	Lower efficiency, shorter life span. No sawing necessary, possible production in the form of band.
Cadmium Telluride (CdTe)	0.008 mm + 3 mm glass substrate	6 – 9 (module)	Dark green, Black	Poisonous raw materials, significant decrease in production costs expected in the future.
Copper-Indium-Selenide (CIS)	0.003 mm + 3 mm glass substrate	7.5 – 9.5 (module)	Black	Limited Indium supply in nature. Significant decrease in production costs possible in the future.
Hybrid silicon (HIT) solar cell	0.02 mm	18	Dark blue, black	Limited use of this production procedure, higher efficiency, better temperature coefficient and lower thickness.

(**Source:** www.pvresources.com)

Table 22 below presents the maximum attainable efficiencies of solar PV modules manufactured using different technologies.

Table 22. Maximum Efficiencies of different type of solar cells

S. No.	Solar Cell Material	Cell Efficiency (Laboratory)	Cell Efficiency (Production)
1	Mono Crystalline Silicon	24.7 %	18.0 %
2	Multi Crystalline Silicon	19.8 %	16.0 %
3	Ribbon Silicon	19.7 %	14.0 %
4	Crystalline Thin Film Silicon	19.2 %	9.5 %
5	Amorphous Silicon	13.0 %	10.5 %
6	Micro-amorphous Silicon	12.0 %	10.7 %
7	Hydrid HIT Solar Cell	20.1 %	17.3 %
8	CIS, CIG	18.8 %	14.0 %
9	Cadmium Telluride	16.4 %	10.0 %
10	III-V Semiconductor	35.8 %	27.4 %
11	Dye-Sensitised Cells	12.0 %	7.0 %

(Source: GSES Solar PV project Design manual)

5.3.3. Concentrating solar photovoltaic (CPV)

Concentrating the sunlight by optical devices like lenses or mirrors reduces the area of expensive solar cells or modules, and, moreover, increases their efficiency. CPV systems use optical concentrators to focus direct solar radiation onto solar cells for conversion into electricity. One disadvantage of CPV is the necessity to track the sun's orbit by moving the system accordingly, is partly compensated by a longer exposition time of the cells during the day. The main reasons for this development are the following:

- PV production and application has grown into a size where larger systems are desirable.
- Solar cells made of III-V semiconductor compounds offer the option of very efficient systems with efficiencies of 30 % possibly 40 % or larger in future.

Figure 60. Concentrating Solar PV cell and module

CPV systems employ solar radiation concentrated onto photovoltaic surfaces for electricity production. Solar concentrators of all varieties may be used, and these are often mounted on a solar tracker in order to keep the focal point upon the cell as the Sun moves across the sky. Additionally, increasing the concentration ratio improves the performance of general PV materials. CPV systems are categorized according to the amount of their solar concentration and categorized types:

- Dish CPV
- Lens CPV
- Non-Tracking CPV
- Low Concentration PV

The technical comparability between CPV and stationary solar PV modules has been presented in Table 23.

Table 23. Comparison of different conventional SPV and CPV Technologies

Technology	System	Power Conversion	Concentration Ratio	Tracking Required	Insolation required	Footprint (Acres/ MW)
Concentrating Photovoltaic (CPV)	Dish CPV	Multi-Junction or Silicon PV	500-1500	Double- axis	DNI	**8.0**
	Lens CPV	Multi-Junction PV	500-1000	Single /Double-axis	DNI	**8.0**
	LCPV	Silicon PV	1.5 – 3.0	Single /Double-axis	GHI	**11.0**
	Non-Tracking CPV	Multi-Junction or Silicon PV	> 2	Non-tracking	GHI	**NA**
Conventional Photovoltaic	Mono-crystalline	Silicon	1	Non-tracking	GHI	**4-5**
	Poly-crystalline	Silicon			GHI	**5-6**
	Thin Film	a-Si, CIS, CdTe, CIGS			GHI	**7-9**
Photovoltaic	Mono-crystalline	Silicon	1	Tracking	GHI	**6-8**
	Poly-crystalline	Silicon			GHI	**7-9**
	Thin Film	a-Si, CIS, CdTe, CIGS			GHI	**9-12**

The efficiency levels (theoretical and achieved) of all type of solar PV technologies are presented in Figure 61.

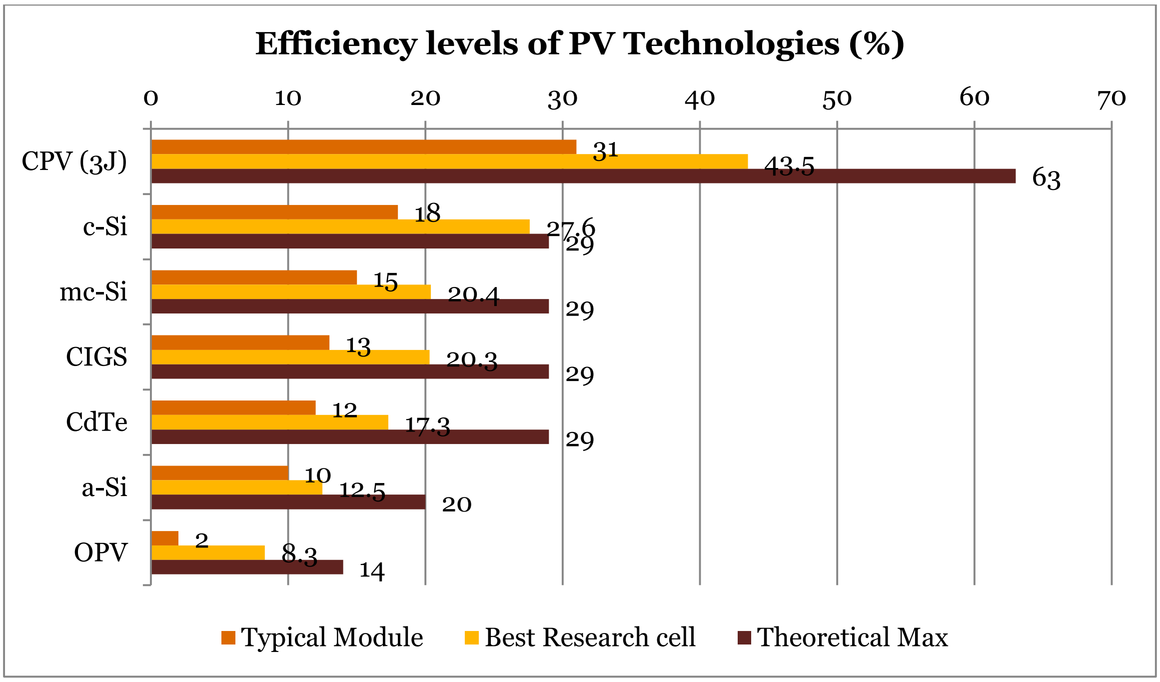


Figure 61. Efficiency levels of PV technologies

(Source: National Renewable Energy Laboratory, USA)

CPV technology is emerging technology but as compared with crystalline and thin film technology its market share and commercial availability is negligible. In addition, CPV requires tracking mechanism which increases the operation and maintenance cost of the project along with the auxiliary consumption. Taking in to account the O&M aspects of large capacity (2000 MW) solar power project at the location of Tumkur, Karnataka the CPV technology not seems and viable option. In addition, the commercial manufacturing of CPV technology across the globe not suits the targeted capacity of the project.

5.4. Market Share

The photovoltaic market is still dominated by silicon wafer-based solar cells, which accounted for about 88% of the market in 2008 and will continue to dominate for many years. It has been noticed that the global market share of crystalline solar PV technology is presently around 87 percent with the thin film capturing around 14 percent of the market share. In the last 10 years, the efficiency of average commercial wafer-based silicon modules increased from about 12 % to 15 %. At the same time, CdTe module efficiency increased from 7 % to 11 %. While the market share of multi-crystalline solar PV was around 48% in 2011, the share of mono-crystalline was around 38.7%. Within thin film technology in 2011, CdTe was the leader with an annual production of about 2 GWp and a market share in total PV production of about 8 %. In 2011, the market share of all thin film technologies was 14%. A break-up of the market share of solar PV technologies is given in Figure 62.

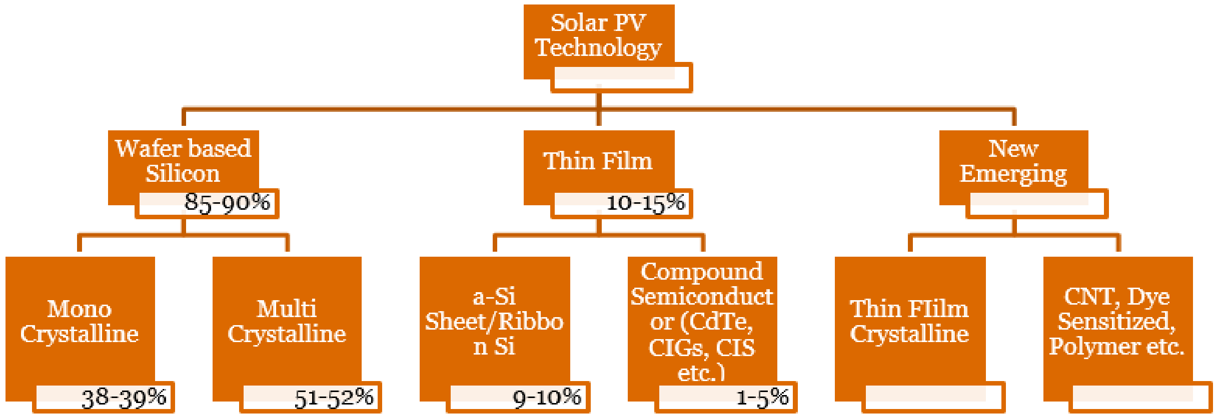


Figure 62. Market Share of Solar PV Technologies

The commonly used standards applicable for solar PV Modules which are applicable in India under all policies are:

- **IEC61215** – Crystalline silicon terrestrial PV modules (*design qualification and type approval*)
- **IEC61646** – Crystalline Thin Film terrestrial PV modules (*design qualification and type approval*)
- **IEC61730** – PV Module safety qualification (*requirements for construction & requirements for testing*)

5.5. SPV Technology Selection for the Project site at Tumkur, Karnataka

The nameplate capacity of solar PV Modules is defined at Standard Test Conditions (*Solar Irradiance=1000 W/m², Temperature=25ºC and air mass=1.5*); however depending on their installed location, higher ambient temperature and consequently module temperature can reduce output efficiency by 10-25%. As the temperature of the solar panel increases, its output current increases exponentially, while the voltage output is reduced linearly. In fact, the voltage reduction is so predictable, that it can be used to accurately measure temperature. As a result, higher temperature severely reduces the production of power of solar PV Module. In the technical data sheet of the solar PV Module, the 'temperature coefficient' is defined; which provides the rate of change (derivative) with respect to temperature of different PV module performance parameters. The temperature coefficient explains how much power the panel will lose[21] when the temperature rises say by 1°C above 25°C.

21 For example, the temperature coefficient of power for a solar PV panel is -0.485% per degree C indicates that for every degree rise of temperature above 25°C, the maximum power of PV panel will reduce by 0.485%.

From the technical performance (energy yield) point of view, Thin Film solar PV modules may perform better; but their maturity, lone term proven record and availability is not comparable with crystalline technology. CPV technology is at very initial stage across the globe. Table 24 presents the qualitative comparison between crystalline and thin film technologies.

Table 24. Technical aspects of Solar PV technologies

Parameter	Crystalline Silicon (Mono and Multi)	Thin film
Types of Materials	• Mono-crystalline • Multi-crystalline	• Amorphous silicon (a-Si) • Cadmium telluride (CdTe) • Copper indium (gallium) Di-selenide (CIS or CIGS)
Material Requirement	Requires more material. Crystalline silicon (c-Si) has been used as the light-absorbing semiconductor in most solar cells. To absorb sufficient amount of light it requires a considerable thickness (several hundred microns) of material	Requires less material The selected materials are all strong light absorbers and only need to be about 1 micron thick, so materials costs are significantly reduced.
Manufacturing Process	Mono-crystalline is produced by slicing wafers (up to 150mm diameter and 350 microns thick) from a high-purity single crystal boule. Mono-crystalline silicon, made by sawing a cast block of silicon first into bars and then wafers.	Each of the three materials is amenable to large area deposition (on to substrates of about 1 meter dimensions) and hence high volume manufacturing. The thin film semiconductor layers are deposited on either coated glass or stainless steel sheet.
Power	High power per given area	Low power per given area
Efficiency	11–17%	5 – 14 %
Effect of Temperature	Effect is more on output power to (low temperature coefficient compared to thin films)	Effect is less compared to crystalline silicon cells (High temperature coefficient)
Shade Tolerance	Less shade tolerant	More shade tolerant
Logistics	Fewer modules - lower shipping cost	More Modules - more shipping cost
Mounting structures required	Fewer modules- less mounting structures per kW	More modules- more mounting structures per kW
Accessories & additional materials	Requires less cables, Junction Boxes etc.	Requires more cables, Junction Boxes etc.
Inverters	High inverter flexibility	Limited inverter flexibility
Cost	Higher cost per watt	Lower cost per watt
Output	Output depends on number of solar cells in the module	Directly proportion on the dimension of the module
Stabilization	Guaranteed power	It takes 5-6 months to reach a stabilized output

The 2,000 MW will be the largest project capacity in the country as till date; the market experience is limited to a maximum of 150 MW capacity. Hence the entire project capacity will have to be split in multiple blocks to accelerate the implementation process through Multiple Contractors within the targeted timelines. The soul of solar PV power project (Solar PV Modules) will have to be selected from the point of view of market assessment, manufacturing base (global and Indian), availability for the targeted capacity, aspects of supply schedule and possibilities of delay, technology selection based on performance assessment (simulation using meteorological data of the site) and techno-economic inter-comparability of solar PV module technologies.

The temperature coefficient of power is always negative. With increase in temperature, the solar PV module power will decrease accordingly. Temperature coefficient for thin film silicon solar cell is -0.2%/oC while that of crystalline solar cell is -0.5%/oC which indicates that when the module operates at 50oC cell temperature, compared to the efficiency reached on 25oC test standard , thin film silicon solar module will lose around 5% while and the loss for crystalline will be around 12.5%.

From the meteorological data (generated through Meteonorm software) for the indicated location, it has been observed that the location comprises 'Hot and Dry' climatic conditions across the year. Therefore the ambient temperature is most of the time higher than the Standard Test Condition (STC) temperature of 25°C. The hour-to-hour temperature pattern of the location is presented in Figure below. The higher ambient temperature creates adverse impact on the performance of solar PV Modules; the impact being higher in Crystalline technologies in comparison to the Thin Film modules.

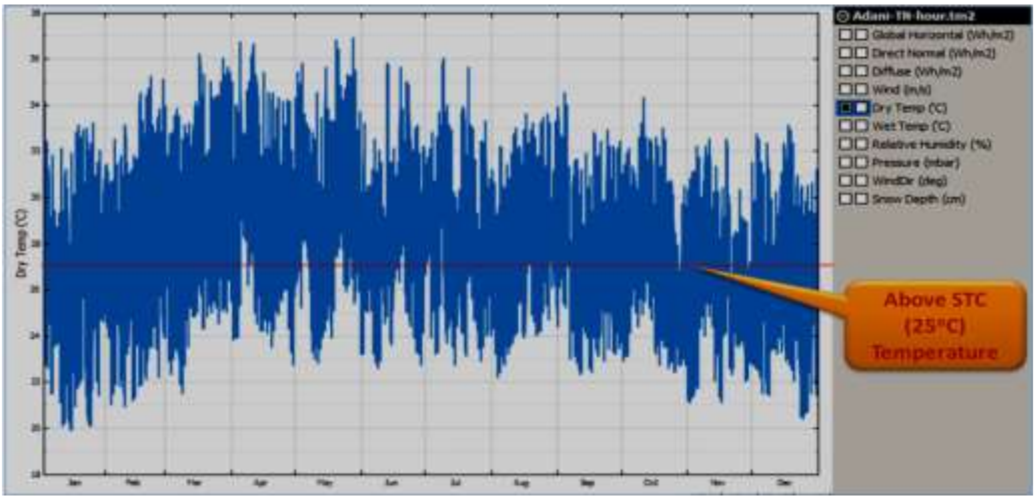


Figure 63. Temperature profile at the indicated project location

The indicative performance of several technologies has been estimated through PVSYST software using Meteonorm weather data. The indicative specific energy generation (kWh/kWp/Year) at the project location at Inverter end has been presented in Figure 64 below.

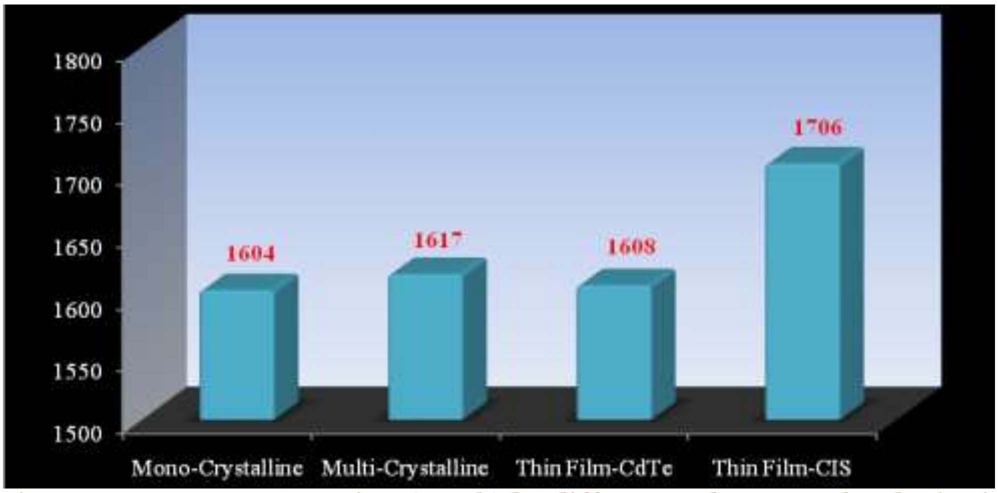


Figure 64. Energy generation (MWh) by different solar PV technologies in the region

The key Solar PV Module Suppliers shall have to be selected through TIER-1[22] listing of BNPV. In addition, the applicable codes and standards in India will be used for technical benchmarking in the technical specifications. The Multi-crystalline solar technology is the most mature technology worldwide and comprises around 50 percent international market. Mono-crystalline solar cells offer maximum efficiency although with higher cost. Thin Film solar PV technology is an emerging technology and being commercialized rapidly in all parts of the world. A comparative chart of available SPV technologies along with relative rankings as applicable for the project location is presented in Table 25.

Table 25. Solar PV Technology for Proposed Project Location at Tumkur, Karnataka

Parameter	Mono-Crystalline	Multi-Crystalline	Thin film	Remarks
Efficiency	High	Moderate	Lowest	

[22] http://about.bnef.com/content/uploads/sites/4/2012/12/bnef_2012-12-03_PVModuleTiering.pdf

Temperature Tolerance	Moderate	Moderate	High	The proposed location is in 'Cold & Sunny' climatic zone.
Shade Tolerance	Low	Moderate	High	Thin films can generate more amount of electricity under diffuse sky conditions.
Power Output	High power per given area	High power per given area	Low power per given area	
Land requirement	Low	Low	Highest	
Market share	High	High	Low	
Maturity at large scale and operating experience	Proven	Proven (Highest)	Low	Thin films is upcoming technology
Environmental Issues	No	No	Moderate	CdTe are now available with recycling process
Balance of System (mounting structure, cabling, etc.)	Low	Moderate	High	Low efficiency system will increase land and civil & foundation work too
Accessories & additional materials	Low	Moderate	High	
Inverter flexibility	High	High	Low	
Cost	High	Moderate	Low	Thin films are the cheapest PV technology presently.
Stabilization	High	High	Low	Thin film takes 5-6 months to reach a stabilized output
Status of commercialization	High	High	High	
Proven at MW scale in Hot and cold climates	Moderate	High	Low	Multi-crystalline is the most commercialized technology
Overall Ranking	**03**	**01**	**02**	**Multi-crystalline and CdTe /CIS based thin film solar PV technologies seems best option for Tumkur, Karnataka**

Making the solar resource assessment and climatic analysis over the proposed location of the Solar Park; it has been observed that multi-crystalline and CdTe/CIS based thin film solar PV modules; both are suitable at the location. Both of the technologies comprise inbuilt advances and limitations; but well commercialized in the country at MW scale. The project developers need to make their own techno-commercial assessment towards selecting the optimum technology.

Practically it will be difficult for a specific manufacturer/ supplier to supply the entire capacity solar PV modules in a single lot (if project is planned in this way). Hence an approach could be adopted towards project designing that the Multi-crystalline or Thin Film solar PV Modules of world's leading manufacturers will be taken for the purpose of present analysis. The top solar PV module manufacturers of BNEF's (Bloomberg New Energy Finance) TIER-1[23] ranking complying the required IEC codes and standards are identified.

Taking in to account the present market scenario in the country; one TIER-1 manufacturer for each solar PV technology has been selected for the further analysis in the detailed project report as following;

- Canadian solar (multi-crystalline)
- First Solar (CdTe based thin film)

[23] Ones who have provided own-brand, own-manufactured products to five different projects, which have been financed non-recourse by five different (non- development) banks, in the past two years http://about.bnef.com/content/uploads/sites/4/2012/12/bnef_2012-12-03_PVModuleTiering.pdf

In the energy yield analysis the capacity of 2000 MW of both manufacturers will be taken into account.

5.6. Technology Selection (Inverters)

The Inverters will be selected from the point of view of their capacity, availability, meeting the codes and standards applicable in India (if any), supply arrangements in line with the Project Implementation Schedule, ease of transportation and implementation, established warrantees and guarantees and appropriate operation and maintenance services. The TIER-1 Inverters will be given maximum priority. From the point of view of implementation in lesser areas and reduction of the cost from the aspect of civil infrastructure; it could be prefer to explore Outdoor Inverters for the entire plant capacity.

Use of higher rating of Inverters is likely to bring in several advantages over smaller ratings like reduction in number of Inverters/ Inverter Stations, reduction in AC side Cabling and associated AC Ohmic losses and optimization of Plant layout. The Ingress Protection Class of the proposed Inverter is IP54 i.e. it is suitable for outdoor installation. For additional protection, the Inverter locations shall be provided with sheds/ canopies. Outdoor installation reduces the time and cost for construction of Inverter Station Buildings - only the Inverter foundations need to be constructed. Two nos. Inverters will be installed in one Inverter Station. Figure 65 presents the picture of an Outdoor Type Installation of Inverters.

Figure 65. Outdoor Type Inverter Installation

At present only SMA is offering outdoor type inverters in Indian marker of 1 MW capacity. The efficiency of the proposed Inverter is around 98.6%. SMA is worldwide leader in Inverter manufacturing and having the maximum number of Inverter installations in India. The temperature range of Inverter for operation is 0 Deg C to +55 Deg C and it is therefore suitable for operation in higher ambient temperatures which are likely to be experienced at the indicated location. The Inverter complies with all relevant IEC standards and applicable codes and standards in India. As Bridge to India Report, SMA is enjoying 30.6% share in Inverter market in India.

Taking in to account the market scenario of solar inverters in Indian context; SMA made outdoor inverters have been selected in this study for energy yield estimation and project design. The project developers can select the inverters techno-commercially.

6. Energy Yield Assessment

6.1. Introduction

Solar Park essentially comprises solar PV/Thermal power projects of small capacities implemented by various project developers which use common infrastructure i.e. land, roads, water, power evacuation facilities etc. The approach of Solar Park makes the techno-commercial optimization of the projects with squeezed project implementation time.

In the present approach the minimum project size has been decided as 50 MW which could be implemented by a project developer. Similar capacity has been considered by Solar Energy Corporation of India for its further allocations under Phase-II of Jawaharlal Nehru National Solar Mission (JNNSM). However any project developer may bid for higher capacity but in multiple of 50 MW.

It is well established from previous sections that both of the commercially available solar PV technologies i.e. Multi-crystalline and Thin Film (CdTe/CIS) are suitable for the selected location of Solar Park; hence the energy yield estimation has been carried out for solar PV power projects of 50 MW capacity. The energy yield has been estimated using Meteonorm 7.0 weather data for the location with one representative case of multi-crystalline solar PV and Thin Film with Outdoor Inverter as discussed in previous sections.

6.2. Simulation using PVSYST

Annual Energy Yield for the proposed PV power plant is defined as the amount of energy fed into the grid after due consideration of all kinds of generation and distribution losses. The solar PV based power plant comprises optical energy input (which is essentially dependent on the geographical/ seasonal/ climatic and operating parameters with time) and electrical output (which depends on the technical specifications of electrical appliances in use). The present solar PV power project of 2000 MW capacity comprises favorable climatic conditions due to low temperature and high solar irradiance; which will minimize the most dominating temperature driven losses in case of crystalline solar PV Modules.
In order to keep all climatic/operating parameters on one platform, two computer software(s) namely RETScreen and PVSYST6.2.6 have been used for detailed simulation and estimation of annual yield at the project location. RETScreen is essentially used for static simulation of solar PV power project; however PVSYST is used for dynamic simulation.

- **RETscreen software**: This software is developed by National Resource Centre Canada for study of feasibility of renewable energy projects like Solar PV Systems (off grid and grid connected), Solar PV Pumps, Large Capacity Solar Water Heating, Industrial Process Heating, Wind Power Projects, Small Hydro, Co-generation, Biomass Gasification etc. This software estimates the annual energy yield based on the daily average values of global solar radiation on horizontal surface. It estimates the solar radiation on stationary (inclined) and tracking surfaces very precisely and accordingly, the monthly generation. In this study RETScreen software has been used to estimate the intensity of monthly/annual global solar radiation over stationary surfaces and further simulation were carried out using PVSYST.
- **PVSYST software:** PVSYST is a software package for study, sizing, simulation and data analysis of complete PV systems developed by Institute of Environmental Sciences (ISE), University of Geneva, Switzerland. The software comprises a wide solar PV products database including Module & Inverter database, shading Analysis & Meteo data.

The energy yield estimation will be carried out using static (RETScreen) and Dynamic (PVSYST) computer software(s). Based on the selected weather database (solar radiation and climate), and suitable technology along with the estimated project capacity (in MW) the simulation exercise will be carried out for estimation of energy generation, capacity utilization factor etc.
The simulation will freeze the basic design approach viz. optimization of tilt angle, optimization of orientation, tilt & tracking, shading, inter row spacing etc. The technical losses (optical, electrical and system) will be

analyzed in detail in line with best market practices. The process flow diagram of energy yield estimation of solar PV project has been presented below:

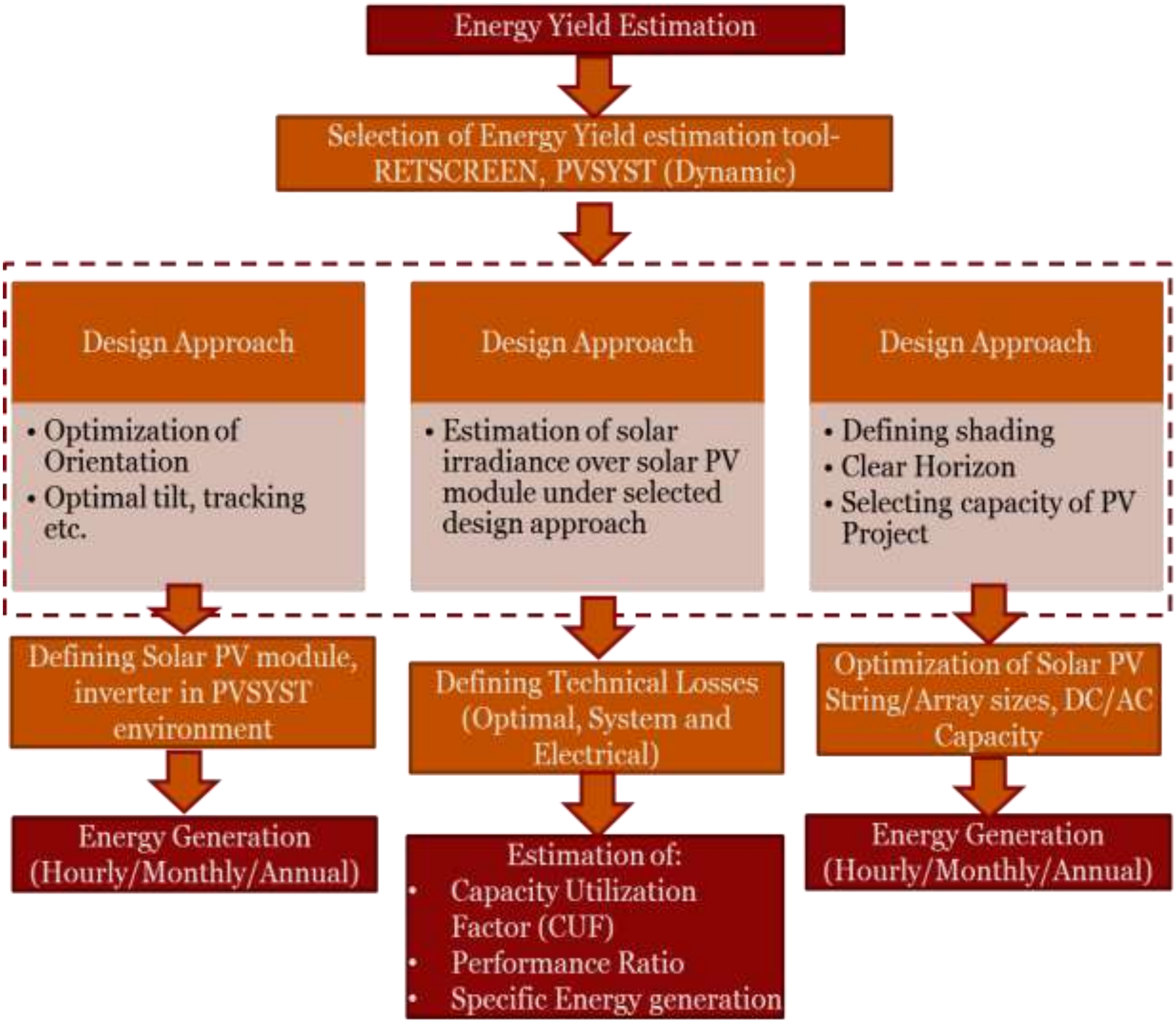


Figure 66. Energy yield estimation of solar PV power project using PVSYST

In order to make authentic hourly simulation, the state of the art simulation tool (PVSYST-6.2.6) has been used to estimate energy yield from the power plant at the proposed site of Tumkur, Karnataka using optimized solar radiation and meteorological database along with the optimized set of solar PV module combinations using multi-crystalline solar PV technology. The assumptions made while calculating annual energy yield from the proposed PV Power plant are indicated in the following software screen shot.

From the detailed solar radiation resource assessment exercise, the global solar radiation, diffuse solar radiation and mean hourly temperature data from Meteonorm 7.0 have been used for estimation of energy yield for the proposed power plant in Tumkur, Karnataka. The solar radiation data from all available sources near to meteorological centres, relevant to the site have been collected and compared for the proposed site. The optimum and most relevant value of GHI have been considered for the energy yield calculation through above sections. Figure 67 shows the PVSYST snapshot after simulation of 50 MW solar PV power project using multi-crystalline and Thin Film solar PV technologies.

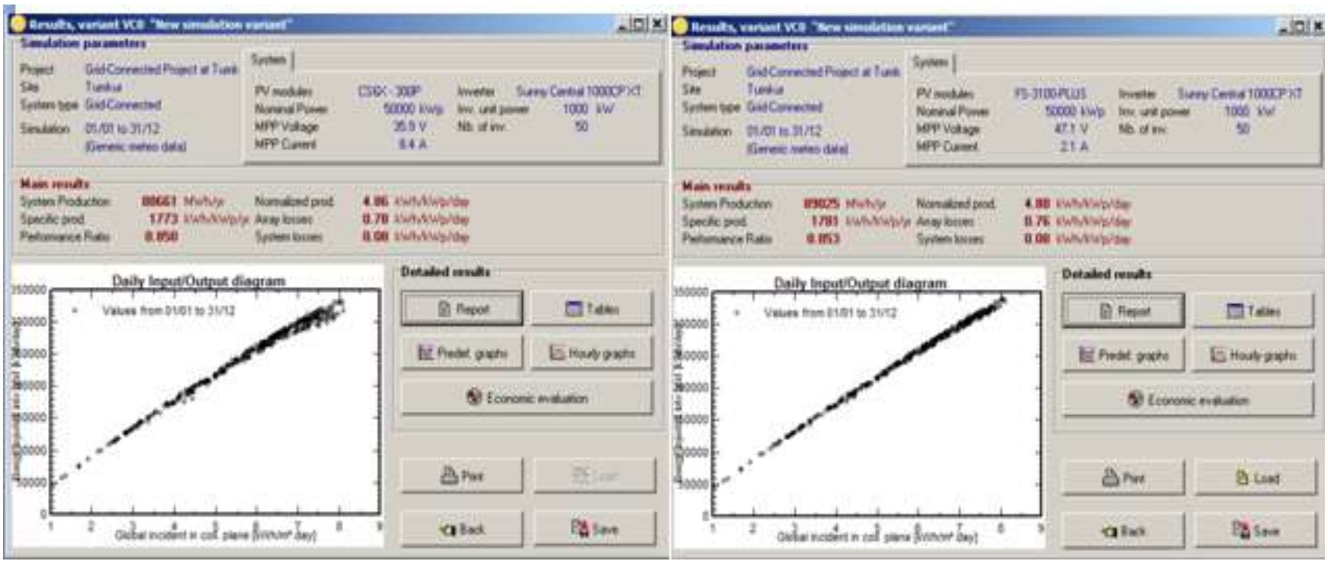


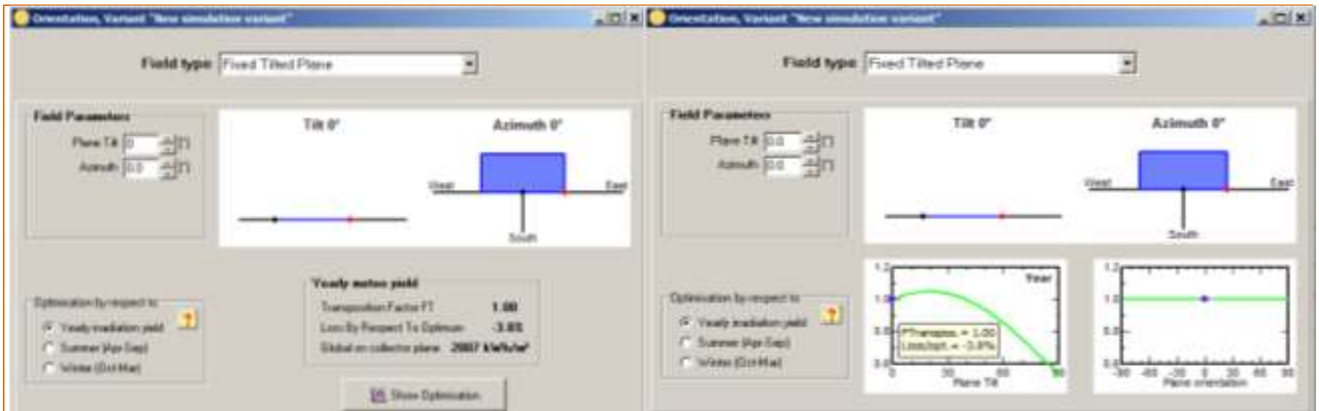
Figure 67. PVSYST Simulation of Solar PV Power Plant at Tumkur, Karnataka

6.3. Orientation and tilt angle of solar PV Modules

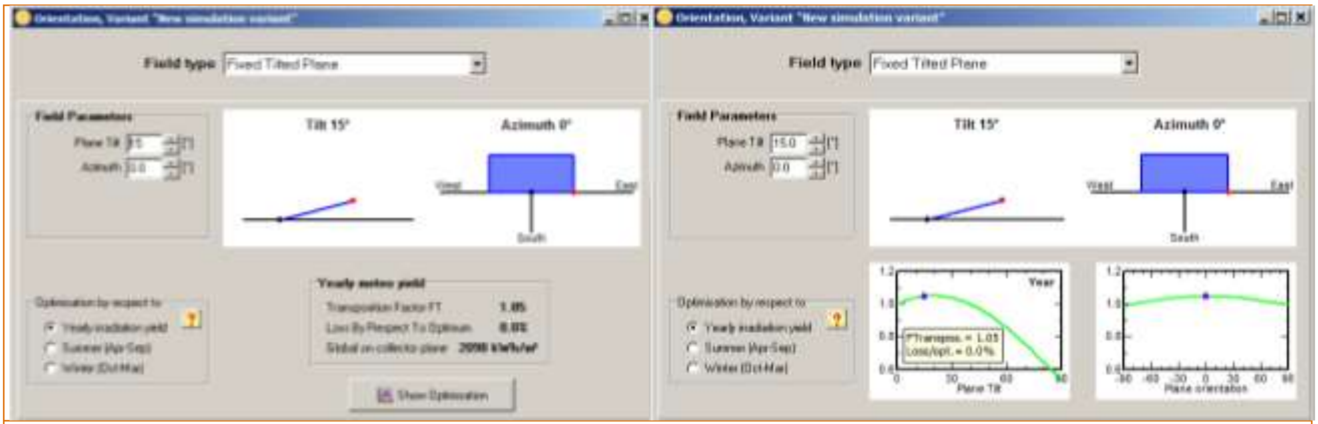
It is well established that the energy generation through solar PV module is essentially govern by the amount of incident solar irradiance over its surface. In order to augment the incident irradiance over the solar PV modules; the solar PV modules are arranges in inclined, seasonal adjustment, single or double axis tracking mode especially to reduce the angle of incidence of solar irradiance over the surface of the module and increase in the incident solar irradiance. Hence the benefit of the tilt angle or tracking depends upon the geography (latitude and longitude) of any location.

In order to reduce the operation and maintenance activities and auxiliary energy consumption; the fixed axis (without tracking and any seasonal adjustment) is mostly preferred. In this project the fixed axis and fixed tilt angle has been adopted for entire solar PV power project of 2000 MW capacity. The optimum tilt angle has been optimized through PVSYST computer software. The south facing (equator facing) tilt angle of 15 degree has been observed as optimum for the project location as at this angle the optical energy losses becomes zero. Table 26 presents the approach of optimization of the tilt angle of solar PV module while Figure 68 presents the horizon sun path at project location under this design approach. Using the approach of 15 degree tilt due south the annual solar irradiance over solar PV modules increases from 2007 kWh/m² to 2098 kWh/m².

Table 26. Optimization of tilt angle of solar PV Modules



When tilt= 0.0 degree, GHI = 2007 kWh/m², Optical losses are 3.8%



When tilt= 15.0 degree, Solar Irradiance = 2098 kWh/m², Optical losses are 0.0%

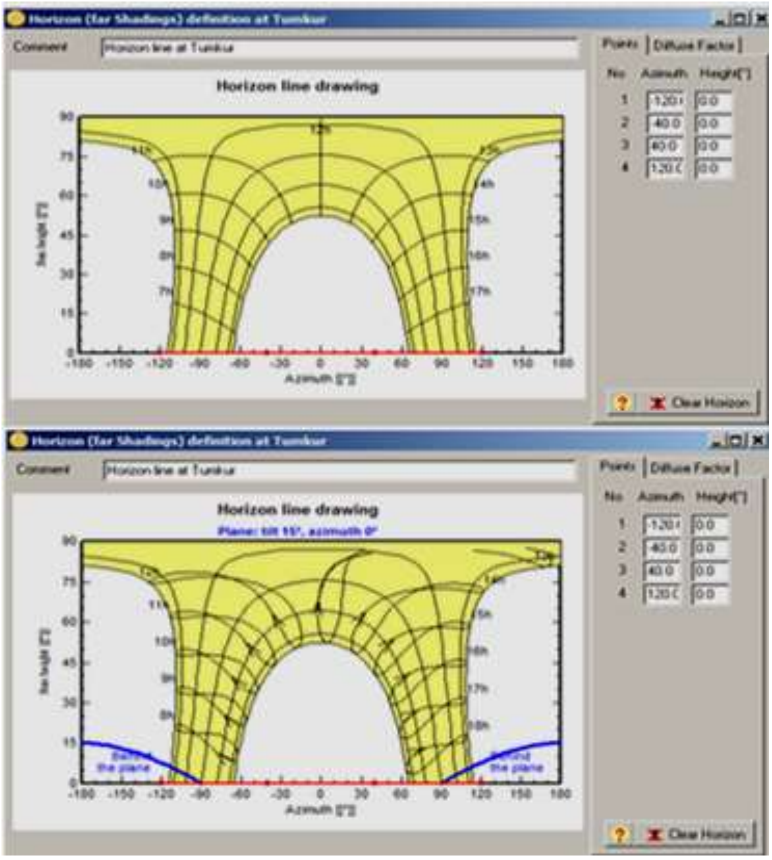


Figure 68. Horizon sun-path under seasonal adjustment at Tumkur, Karnataka

This approach (fixed axis) has been adopted for entire solar park of 2000 MW capacity; however the design approach of solar field might be done with various stationary and tracking options as following;

- Fixed axis plane
- Several orientations
- Seasonal tilt adjustments
- Unlimited sheds
- Unlimited sin-shields
- One axis tracking plane
  - Tracking tilted or horizontal N-S axis
  - Tracking horizontal axis E-W
  - Tracking Vertical axis
  - Tracking Sun-shields
- Two-axis tracking planes
  - Tracking Two-axis frame NS

- Tracking Two axis frame EW

The energy generation of the solar PV power project effective increases with the tracking designing approach; however the area requirement and other balance of plant also increases. As in the present solar power scenario of the country the solar PV power projects are given the tariff through biding under the specific solar power policies; there is always a higher limit of energy generation supplied to the grid on which the tariff is applicable n the power purchase agreement. Hence taking in to the account the business as usual scenario (BAU) only fixed axis tilt angle has been taken in to account for energy yield estimation and the plant technical design.

6.4. Major Components

Technical details of Solar PV modules and Inverters are essential for energy yield estimation along with solar and meteorological data. Following paragraphs indicate the specification of solar PV module(s) and inverter which have been used for the simulation and energy yield estimation of 2000 MW solar PV power project at Tumkur, Karnataka.

6.4.1. Solar PV Module(s)

From the technology assessment multi-crystalline and thin film solar PV technologies have been optimized at the location of Solar park Tumkur, Karnataka. Using the TIER-1 manufacturers of the key components following models have been chosen for energy yield estimation and project design.

- CS6X-300P of Canadian Solar (multi-crystalline)
- FS-3100 of First Solar (CdTe based Thin Film)

Project developers may choose the technology/ supplier/ manufacturer etc. using their own techno-commercial approach at the project implementation stage. The key technical specifications of the selected solar PV modules are presented in Table 27.

Table 27. Technical characteristics of Solar PV Modules

S. No	PV Module Parameters	Multi-crystalline solar PV	Thin Film Solar PV
1.	Model	CS6X-300P	FS- 3100
2.	Technology	Multi-crystalline	Thin Film
3.	Module peak power W	300	100
4.	Open Circuit voltage, Voc,V	44.6	58.8
5.	Short Circuit current, Isc, A	8.87	2.33
6.	Maximum voltage, Vmp, V	36.1	46.8
7.	Maximum current, Imp, A	8.30	2.18
8.	Fill Factor	0.76	0.73
9.	Module Efficiency	15.6	13.89
10.	Temperature coefficient of Voc (%/ °C)	-0.34	-0.28
11.	Temperature coefficient of Isc (%/ °C)	0.065	0.04
12.	Temperature coefficient of Pmax (%/ °C)	-0.43	-0.29
13.	Operating Temperature Range (°C)	-40 to +85	-40 to +85
14.	Number of modules in plant	166668	499995
15.	**Plant Capacity (kWp)**	**50000**	**50000**

6.4.2. Solar Inverter

From the technology assessment section the central inverters with outdoor arrangements have been optimized for the location of Solar Park. The outdoor inverters may effectively reduce the project implementation duration and cost. Project developers can take the decision of inverter selection at the implementation stage; however in order to carry out the energy yield estimation the 1 MW rating outdoor inverter of SMA (the world largest inverter manufacturer) has been selected. The key technical details of the selected inverter model are presented in Table 28.

Table 28. Technical Parameters of Inverter (Model – Sunny Central 1000CPXT)

S. No	Inverter Technical Parameters	Data/ Values
1.	Inverter	Sunny Central 1000CPXT
2.	Maximum DC power, kW	1120
3.	Maximum DC voltage, V	1000
4.	MPPT voltage range, V	596-850
5.	Rated Input Voltage	688
6.	Maximum Input DC current, A	1635
7.	Maximum Input DC current short circuit, A	2000
8.	Nominal AC power, kW	1000 (PF-1)
9.	Nominal output current, A	1568
10.	Nominal AC voltage, V	405
11.	AC grid frequency, Hz	50/60
12.	Power Factor range	1/0.9 lagging to 0.9 leading
13.	Harmonic Distortion	<3
14.	Maximum efficiency, %	98.7
15.	European Efficiency %	98.4
16.	Normal Ambient temperature range, °C	-25 to 62
17.	Degree of Protection	IP 54
18.	Enclosure material	Steel
19.	Type of Cooling	Opticool
20.	Warranty, years	5
21.	No of Inverter	50

6.5. Losses in SPV System

The loss in the Solar PV System depends on the Solar PV Module and Inverter technology used, efficiency and quality of PV Modules, Inverter, Junction Boxes and cables, workmanship of installation and scheduled maintenance and cleaning. The models of Solar PV Module as well as the Inverter selected for the simulation process comply with relevant international standards. The simulation results for different associated losses in the solar PV power project under the conditions of fixed tilt at the proposed location are given in Table 29. The technical loss tree of the project (50 MW each capacity) have been presented in Annexure 2: and Annexure 3: along with the performance results for both solar PV technologies.

Table 29. Various technical losses in Solar PV Power Plant of 50 MW capacity at Tumkur, Karnataka

S. No.	Technical Losses	Solar PV Modules (Model)	
		Multi-Crystalline	Thin Film
1.	IAM Losses	0.1	0.1
2.	Shading Losses	1.0	1.0
3.	Soiling losses	2.0	2.0
4.	Irradiance level losses	0.0	0.2
5.	Temperature losses	9.8	7.0
6.	Module quality losses	+0.4	2.0
7.	Module mismatch losses	1.0	1.0
8.	DC Ohmic wiring losses	1.1	1.0
9.	Inverter losses	2.1	1.7
10.	AC Losses (transformer,	3.5	3.5

	Ohmic losses)		
11.	Auxiliary Consumption	0.5	0.5
12.	First year degradation	0.65	0.70
13.	Plant availability	0.5	0.5
14.	Grid availability	0.5	0.5

All above technical losses have been taken in to account as per the best industrial practices. The temperature driven losses are drastically low at the project location which is most dominating under the Warm and Humid locations. The shading losses due to topography might be more dominating at the location; hence taken as 1.0%. The AC losses (transformer and Ohmic losses) have been taken as 2.0% via assuming that the metering will be done at the end of 400 kV switchyard. The plant availability and grid availability has been considered 0.5% each; however the first year degradation of 0.65% (multi-crystalline) and 0.70% (thin film) is considered towards energy yield estimation as per the best references for both solar PV technologies.

6.6. Capacity Utilization Factor (CUF)[24]

The Capacity Utilization Factor (CUF) is defined as the ratio of net electrical generation for the time considered to the energy that could have been generated if the system were generating at continuous full power during the same period. As Solar PV Modules converts solar radiation into electricity only during the time when sun is available, the CUF is rather low in comparison to conventional power plants. The average monthly energy generation calculated using the optimized Meteonorm 7.0 weather database for the 50 MW Solar PV power project with multi-crystalline solar PV technology (300 Wp solar PV Modules manufactured by Canadian Solar) at the selected project location, is presented below in Table 30.

Table 30. Monthly energy generation of the 50 MW at Solar Park, Tumkur, Karnataka using multi-crystalline solar PV Modules

Month	Hours	Ambient Temp. (°C)	GHI (kWh/m²)	Inverter Output [25](MWh)	Grid Output [26](MWh)	Grid Output (MU)	CUF (%)
Jan	744	170.9	24.2	8642	8067	8.07	**21.69**
Feb	672	164.4	26.7	7689	7178	7.18	**21.36**
Mar	744	202.8	29.6	8656	8080	8.08	**21.72**
Apr	720	195.1	30.6	7859	7336	7.34	**20.38**
May	744	192.7	30.1	7547	7045	7.05	**18.94**
Jun	720	156.2	27.2	6259	5843	5.84	**16.23**
Jul	744	149.4	26.5	6101	5695	5.70	**15.31**
Aug	744	148.8	25.9	6241	5826	5.83	**15.66**
Sep	720	155.9	15.8	6738	6290	6.29	**17.47**
Oct	744	159.4	25.7	7311	6825	6.82	**18.35**
Nov	720	152.8	23.9	7480	6983	6.98	**19.40**
Dec	744	158.4	23.2	8140	7599	7.60	**20.43**
Total				**88663**	**82767**	**82.77**	
Average First Year CUF (%)							**18.90**

In case of multi-crystalline solar PV modules the CUF of the project varies from 15.31% in July to 21.72% in March. Taking in to account all technical losses the annual CUF has been estimated as 18.90%; which is closer to the benchmark value of 19% considered by central electricity Regulatory Commission (CERC), Government of India for annual tariff determination for grid connected solar PV power projects.

[24] Capacity Utilization Factor= Total Energy generated (kWh)/ Plant Capacity (MW)*8760
[25] Inverter Output is Total(Gross) Energy Generated at Inverter End (Inverter converts DC Power of Modules to AC)
[26] Grid Output is Total(Gross) Energy Generated at Grid End

Table 31. Monthly energy generation of the 50 MW at Solar Park, Tumkur, Karnataka using Thin Film solar PV Modules

Month	Hours	Ambient Temp. (°C)	GHI (kWh/m²)	Inverter Output (MWh)	Grid Output (MWh)	Grid Output (MU)	CUF (%)
Jan	744	170.9	24.2	8651	8071	8.07	21.70
Feb	672	164.4	26.7	7762	7242	7.24	21.55
Mar	744	202.8	29.6	8863	8269	8.27	22.23
Apr	720	195.1	30.6	8024	7486	7.49	20.80
May	744	192.7	30.1	7611	7101	7.10	19.09
Jun	720	156.2	27.2	6222	5805	5.81	16.13
Jul	744	149.4	26.5	6048	5643	5.64	15.17
Aug	744	148.8	25.9	6195	5780	5.78	15.54
Sep	720	155.9	15.8	6745	6293	6.29	17.48
Oct	744	159.4	25.7	7317	6827	6.83	18.35
Nov	720	152.8	23.9	7469	6969	6.97	19.36
Dec	744	158.4	23.2	8118	7574	7.57	20.36
Total				**89025**	**83060**	**83.06**	
Average First Year CUF (%)							**18.96**

In case of Thin Film solar PV technology; the CUF of the project varies from 15.17% in July to 22.23 % in March. Taking in to account all technical losses the annual CUF has been estimated as 18.96% using CdTe based Thin Film Solar PV Technology.

6.7. Annual degradation

The estimated life of PV modules is considered as 25 years. Performance of solar PV modules degrades over its specified lifetime. Normally, PV module manufacturers provide a performance guarantee and indicate the rate of degradation over the module lifetime. Essentially the solar PV modules used in grid connected solar power plants are warranted for output wattage which should not be less than 90% at the end of 10 years and 80% at the end of 25 years. In the present exercise, the annual degradation has been taken as 0.65%; linear for entire project life of 25 years as per the best industrial practices. Considering all technical losses including inverter & auxiliary losses as well as an annual degradation of PV modules, exportable annual electrical energy yield from the 2000 MW (40X50 MW) solar PV power plant at the location Tumkur Karnataka for a projected period of 25 years is given in Table 32. The average CUF of the solar PV plant over its life time has been obtained as 18.47%.

Table 32. Life cycle annual yield and CUF of 50MW Solar PV Power project at Solar Park in Tumkur, Karnataka using Multi-Crystalline and Thin Film Solar PV Technologies

Year	Multi-Crystalline			Thin Film		
	Energy supplied to grid MWh/Year	Energy supplied to grid MU/Year	Annual CUF (%)	Energy supplied to grid MWh/Year	Energy supplied to grid MU/Year	Annual CUF (%)
1	82767	82.8	**18.90**	83060	83.1	**18.96**
2	82229	82.2	**18.77**	82479	82.5	**18.83**
3	81694	81.7	**18.65**	81902	81.9	**18.70**
4	81163	81.2	**18.53**	81328	81.3	**18.57**
5	80636	80.6	**18.41**	80759	80.8	**18.44**
6	80112	80.1	**18.29**	80194	80.2	**18.31**
7	79591	79.6	**18.17**	79632	79.6	**18.18**
8	79074	79.1	**18.05**	79075	79.1	**18.05**
9	78560	78.6	**17.94**	78521	78.5	**17.93**

10	78049	78.0	**17.82**	77972	78.0	**17.80**
11	77542	77.5	**17.70**	77426	77.4	**17.68**
12	77038	77.0	**17.59**	76884	76.9	**17.55**
13	76537	76.5	**17.47**	76346	76.3	**17.43**
14	76039	76.0	**17.36**	75811	75.8	**17.31**
15	75545	75.5	**17.25**	75281	75.3	**17.19**
16	75054	75.1	**17.14**	74754	74.8	**17.07**
17	74566	74.6	**17.02**	74230	74.2	**16.95**
18	74082	74.1	**16.91**	73711	73.7	**16.83**
19	73600	73.6	**16.80**	73195	73.2	**16.71**
20	73122	73.1	**16.69**	72682	72.7	**16.59**
21	72646	72.6	**16.59**	72174	72.2	**16.48**
22	72174	72.2	**16.48**	71668	71.7	**16.36**
23	71705	71.7	**16.37**	71167	71.2	**16.25**
24	71239	71.2	**16.26**	70669	70.7	**16.13**
25	70776	70.8	**16.16**	70174	70.2	**16.02**
Life Cycle Average	**76622**	**76.6**	**17.49**	**76444**	**76.4**	**17.45**

The energy generation and CUF reported above is at the confidence level of P50; however at the stage of project engineering and technical due diligence the energy generation at P75, and P90 could be explored via taking in to account the respective uncertainties.

7. Environmental and Social Impact Assessment

Every infrastructure or development project is espoused with multiple risks and hazards. In order to mitigate the associated risks; it is necessary to undertake a details study of environmental and social impact of any proposed project (solar park) under the Environment Protection Act 2006 of Government of India. The Solar Park is essentially being developed for Solar PV power projects which work on solar energy which is non-polluting source of energy; however there might be several dimensions of project implementation where ESIA and SIA aspects are essential to address as per the applicable acts. The initial ESIA / SIA aspects of the Solar Park project are briefly addressed in this section.

KSPDCL needs to appoint any agency (viz. NEERI, AECOM etc. or any one empanelled by MoEF for carrying out ESIA of infrastructure projects) to carry out the details ESIA of the entire Solar Park area. This exercise will be helpful for project developers to get the loan for their projects from international financial institutions like IFC, ADB etc. which gives significant emphasis on ESIA of solar PV power projects as per their guidelines.

7.1. Environmental Impact Assessment

In India, The Ministry of environment and Forest (MoEF) has excluded solar PV based power projects from their purview of environmental clearance and EIA as such projects are based on clean energy source and do not cause any pollution especially air pollution. Further the use of water for operation of the project is very small as compared with the conventional (thermal power projects). The water used for cleaning of solar PV modules (dust removal) dimply discharge on the ground; hence there is no effluent from solar field.

In most of the solar power policies in India (states) and Jawaharlal Nehru National Solar Mission (JNNSM) the project developers need to obtain;

- No Objection Certificate (NOC)
- Consent to Establish from State Pollution Control Board (SPCB)

In order to dump the material especially broken solar PV modules the arrangements of decomposition of the material is done with the supplier/ manufacturer and the project developer.

The land related pollution aspects come in to existence mainly with CdTe based thin film solar PV modules. The largest manufacturer of CdTe based thin film solar PV modules i.e. First Solar (USA) facilitates of recycling of the modules after project life in the supply agreement.

It will be ensured by KSPDCL (back to back from project developers) that there will not be dumping of any type of waste in the premises of Solar Park.

7.2. Categorization of Projects

As mentioned above that there are so specific guidelines developed by MNRE/ MoEF for solar PV power projects for ESIA of solar PV power projects and Solar Parks. However International Finance Corporation (World Bank) and Asian Development Bank (ADB) have developed their guidelines for all types of power projects categorize the project primarily according to the significance and nature of its impacts.

7.2.1. IFC's Categorization of Projects

As part of its review of a project's expected social and environmental impacts, IFC uses a system of social and environmental categorization. This categorization is used to reflect the size of impacts understood as a result of the social and environmental assessment and to specify IFC's institutional requirements. The categories used by the IFC are:

- **Category A Projects:** Projects with potential significant adverse social or environmental risks or/and impacts that are diverse, irreversible or unprecedented;

- **Category B Projects:** Projects with potential limited adverse social or environmental risks or/and impacts that are few in number, generally site-specific, largely reversible and readily addressed through mitigation measures;
- **Category C Projects:** Projects with minimal or no adverse social or environmental risks or/and impacts, including certain financial intermediary (FI) projects with minimal or no adverse risks;
- **Category FI Projects:** All FI projects excluding those that are Category C projects.

The Performance Standards (PS) established stipulates that the project shall meet the following throughout the life of an investment by IFC or other relevant financial institution:

- ✓ Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts;
- ✓ Performance Standard 2: Labour and Working Conditions;
- ✓ Performance Standard 3: Resource Efficiency and Pollution Prevention;
- ✓ Performance Standard 4: Community Health, Safety and Security;
- ✓ Performance Standard 5: Land Acquisition and Involuntary Resettlement;
- ✓ Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources
- ✓ Performance Standard 7: Indigenous Peoples; and
- ✓ Performance Standard 8: Cultural Heritage.

These performance standards and guidelines provide ways and means to identify impacts and affected stakeholders and lay down processes for management and mitigation of adverse impacts. A brief on the requirements as laid down in the performance standards is described in Annexure 4: of the DPR.

7.2.2. ADB's Environment Categorization of Projects

The project classification system of ADB is used to reflect the significance of potential environmental impacts understood as a result of the client's impact assessment and to establish ADB's safeguard requirements. The categories used by ADB are:

- **Category A Projects:** Projects which are likely to have significant adverse environmental impacts, involuntary resettlement impacts or impacts on indigenous peoples that are irreversible, diverse, or unprecedented.
- **Category B Projects:** Projects with potential adverse environmental impacts that are less in number, involuntary resettlement impacts or impacts on indigenous peoples, generally site-specific, mostly reversible and readily addressed through mitigation measures;
- **Category C Projects:** Projects with minimal or no adverse environmental impacts; involuntary resettlement impacts or impacts on indigenous peoples;
- **Category FI Projects:** Projects which involve investment of ADB funds to or through a financial investment.

The categorization of projects is done based on Equator principles mentioned in the Annexure 5: .

7.3. Social Impact Assessment

The site is essentially the barren land and comprises scattered vegetation mainly scrubs of dry agro area. There is few water bodies present within the premises of the Solar Park along with a State Highway which is connecting Anantpur district to Tumkur. The presence of state highway in between the selected land for solar park successfully addresses the connectivity and accessibility aspects of the site. It will save the cost of major road from highway to side along with its RoW. Hence only connecting and internal roads are required for developing the park.

One of the positive aspects of the selected land is the site if free of habitation and does not comprise any permanent structure in its premises. Hence there is no associated issue of resettlement and rehabilitation. However the development of the land will involve acquisition of the land which belongs to all private owners. The land is non-irrigated; however at few places scattered cultivation is in practice.

In order to avoid any local agitation; KSPDCL needs to manage an amiable manner for land acquisition process. This will provide a bid support to project developers and reduce the project implementation time.

7.3.1. During Construction Phase

During the construction phase of Solar Park and further the multiple solar power projects; there will be lot of employment generation which will provide employment and livelihood to the local people. The construction would also result in the development of socio-economic activities in the villages/ town in the vicinity of the selected site of Tumkur District. Un-skilled labour will be required at various civil, mechanical and electrical activities associated with the implementation of Solar Park and further the projects.

Nevertheless, during the construction phase following key activities will done which will make some negative impact on the top soil during slope grading activity.

- Construction of external and internal roads
- Drainage system and fire fighting arrangements
- Water pipe line network and reservoir
- Power evacuation facilities (towers, foundations and switchyard etc.)
- Administrative buildings and warehouses etc.

As a preliminary estimate grading of the proposed site will approximately generate waste soil of 88000 cum which need to be disposed off. Adequate arrangements for the labours/ engineers and other workers at the site during project implementation phase need to be provided at the site along with suitable health and safety measures.

7.3.2. During Post Commissioning Phase

It is proposed that the solar park will be of the cumulative capacity of 2000 MW which will be in multiple fractures of minimum 50 MW capacity based on the multi-crystalline or thin film solar PV technology. Frequent cleaning of solar PV modules is one of the major operation and maintenance activity associated with solar PV power plant which is essentially done manually in order to minimize the auxiliary energy consumption of the plant.

It has been estimated that a 50 MW capacity solar PV power plant will comprise following solar PV module area; which needs to be clean at least twice in a month;

- Multi-crystalline - **319807 m^2**
- Thin Film - **359996 m^2**

There will be such 40 projects in the Solar Park. There is involvement of around 8-10 technical manpower in each 50 MW capacity (plant management and technical operation) and more than 25 people for regular cleaning and security (i.e. 20 for cleaning and 5 for security[27]). Hence there will be around 400 technical manpower (skilled for solar PV power projects); however around 1000 semi-skilled jobs will be created in the Solar Park for cleaning applications and post commissioning services. Similarly the jobs on other fronts viz. Security, transportation will also evolve. The implementation of the solar PV power projects will also create off site infrastructure (hotels, restaurants, canteens, guest houses, rent houses, water tankers, vehicles etc.) in the vicinity.

The adequate facilities for workers need to be provided at the site towards accommodation and health during post commissioning phase.

7.3.3. Corporate social responsibility

In order to mitigate the social and environmental impacts of the project i.e. Solar Park; following actions have been suggested as a part of corporate social responsibility of M/s KSPDCL;

- Setting up man power capacity building facility for servicing in solar park for operation and maintenance activities

[27] Figures are based on the actual plant operation experience in India (Rajasthan and Gujarat).

- Setting up a vocational and training institute in the vicinity
- Training for skilled and semi-skilled activities involved in solar park and further in the plants
- Support the self help group in the vicinity
- Make a provision to use the recycling material for livelihood i.e. the packing material of solar PV modules could be used for furniture preparation for the schools and small institutions etc.
- On site hand on training of the students and skilled professionals of near vicinity
- Amenities for the workers population and local residents in terms of ;
    - Residence (housing)
    - Basic infrastructure i.e. water supply, sewerage, drainage etc.
    - Medical facilities
    - Educational facilities

- Employment to the local residents for unskilled and semi-skilled achievements
- Betterment and proper maintenance of the water bodies within the Solar Park vicinity
- Betterment of local roads within and near the vicinity from connectivity of locals
- KSPDCL should also take up another social benefit schemes of the state Government for sustainable development of the people
- Exploring the development of green belt/ corridor
- Rain water harvesting
- Solarification of the hospitals, panchayat bhawans, primary school buildings, computer facilities of the schools, street lighting etc.

As per the secondary data availability, observations through site visit and socio-commercial information collected from various sources the selected region for development of Solar Park falls under 'Category C Projects' which indicates that the projects with minimal or no adverse environmental impacts; involuntary resettlement impacts or impacts on indigenous peoples in the vicinity.

Apart from the conventional practices; KSPDCL may develop the Solar Park as a benchmark in the project where several visitors may come for exploring the solar PV power generation at multi MW scale. The vicinity could be developed from such a point of view in which the land owners and villagers may get long term secure employment and benefits. Furthermore it is recommended that KSPDCL needs to carry out a detailed ESIA of the entire Solar Park via addressing all key aspects like R&R and Green Belt. During the capacity allotment it could be declared that any project developer could use the ESIA carried out by KSPDCL for their procedures of project finance and other clearances.

8. Concept Plan of Solar Park

Development of Solar Park provides an integrated approach for addressing some of the key issues related to the development of solar projects. This is also results in reduced cost related to power evacuation, water availability owing the large scale solar project development in the solar park. In the present approach of developing the solar park of around 2000 MW capacity in the state of Karnataka only solar PV technology has been considered and No addressing of Concentrating Solar Power (solar thermal) systems.

It is well established in India that the solar PV power projects are given only 13 month time for execution from the date of signing of the power purchase agreement (PPA) under any solar power policy. Development of infrastructure, and land acquisition are two most important and time taking processes towards project development. Using the approach of Solar Park the emphasis could be given on the common infrastructure and enhancing the techno-commercial viability of the project. Following dimensions of the solar power projects development are addressed through developing the solar parks;

- **Land Availability and Acquisition:** Availability of land is a major issue faced for the development of solar power projects. Efforts need to be undertaken for identification of land for solar power development in the State. The land acquisition process takes long time which makes adverse impact on the techno-commercial performance of the solar PV power project.

- **Solar Resource:** The locations with annual global horizontal irradiance (GHI) of more than 1900 kWh/m² are recommended for best locations for implementing large solar PV power projects. Automatic Weather Systems need to be installed at the selected location or the data measured by the AWS of C-WET could be used for the solar resource and climatic assessment over the selected location towards development of Solar Park.

- **Infrastructure:** The accessibility, connectivity, logistics, off-site facilities, arrangement of construction power, water for construction and power evacuation facilities etc. Are addressed under this dimension;

    - **Power Evacuation:** The availability & capacity of power evacuation infrastructure in the remote areas can be a major issue for development of solar projects, as it could result in additional burden on solar project developer on grid connectivity infrastructure. The desired voltage level for power evacuation is also an important aspect.

    - **Availability of water:** Solar PV power projects require water for mainly the cleaning application of solar PV modules. Presently manually cleaning is preferred by most of the developers. Hence water of good quality is essential for effective plant operation.

- **Financing:** The project agreements like PPA, VGF (if applicable), transmission agreement and land acquisition etc are pre-requisites to the financing and developers are supposed to utilize equity (for payment of charges/fees etc) till debt disbursements are available. This at times affects the project development as the fees/charges paid by the developers in preparatory steps are quite high. Technical capability of commercial banks in understanding the solar technology and relatively higher risks of solar projects in comparison to conventional power projects act as barrier to financing. Financial institutions perceive solar energy in India as a riskier investment because it is a fledgling industry without a proven track record in meeting commissioning deadlines, performance benchmarks, and delivering power.

- **Project Implementation:** Development of projects needs to go through various administrative steps which are under various departments.

8.1. Vision

The proposed solar park will comprise around 2000 MW solar PV power projects of cumulative capacity in which the minimum project size will be of 50 MW. There will be only solar PV technology used in the entire solar park and no provision for deployment of solar thermal power generation as it is site specific. The park will comprise multi-crystalline and thin film solar PV technologies under the stationary and fixed axis tilt (due south) approach.

8.2. Basis of planning

The key focus of the Solar Park is to develop common infrastructure for multiple solar PV power projects in the state of Karnataka, India. The park designing is proposed in phase wise. The basic approach of the solar park designed aims to achieve the sustainable and renewable power generation interface which will not only ensure infrastructure availability but will also have the provision for the worker population for the worker population in terms of living space and other off site facilities in the vicinity etc. In order to attain the above tasks following approach has been adopted;

- Adequacy of connectivity and accessibility
- Optimization of land use
- Environmental sustainability through adequate buffers
- Adequacy of the basic infrastructure
    - Water supply
    - Sewerage and drainage system
    - 24 x 7 power supply
    - Provision for telecommunication
- Provisions for amenities for the worker population viz. Residential areas with adequate commercial and institutional segments
- Cost minimization/optimization – Identification and augmentation approach for existing infrastructure viz. Roads, water supply, power supply etc.

8.3. Factors for Planning

The designing capacity of Solar Park is framed taking in to account several factors, policies, obligation and private sector investors for captive power generation etc.

- **Jawaharlal Nehru National Solar Mission –** Government of India has revised the target of 20000 MW grid connected solar power till year 2022 are increased up to 100000 MW. Already around 3700 MW solar power in the country has been installed. However Government of India is in process to allocate around 5000 MW capacity projects shortly through Solar Energy Society of Indi a (SECI). Under this policy the project developer could implement the project in any state of the county. Till date the maximum project size under JNNSM was of 20 MW which might be increased by 50 MW under Batch-II of Phase-II, JNNSM.

- **Solar Power Policy (Karnataka) – 2014** – The state of Karnataka is running its Solar Power Policy of developing 2000 MW solar PV based power generation till 2021. At present various solar power projects are under implementation in Chitradurga, Gulbarga, Hubbali etc. districts of the state. There are few projects which are coming under REC mechanism and for captive consumption in the state.

- **Environmental considerations -** The site identified for developing Solar Park lies in the district Tumkur and adjacent to Tumkur-Ananatpur state highway. The fundamental approach of the park is in line with the industrial park where buffer zone is essential to safeguard such critical ecological areas. In case of Solar Park no such provision is applicable due to zero emission associate with solar PV. In addition Solar Park does not require environmental clearance from MoEF along with no applicability of EIA study. However, to ensure availability of green spaces, buffer areas will be provided.

- **Technology –** Only solar PV technology has been considered for Solar Park. The project will be implemented with multi-crystalline and Thin Film based solar PV modules.

- **Land requirement –** In case of fixed tilt (south facing) solar PV technology per MW land requirement has been estimated as 4.5 acres[28] per MW.

- **Roads –** The State Highway cross the site of Solar Park across the length; hence so separate connectivity road is essential. This road will play major role towards transportation material of the projects at development stage. From this road only the connecting roads inside the park will be developed. There are few other connecting roads present on the selected location. The strengthening of such roads is essential.

- Infrastructure – Till data no infrastructure is available at the site except few roads. Specific provision is required towards infrastructure development.

- Utility area - In order to evacuate around 2000 MW solar power a 400 kV substation needs to be provided within the site which will require around **30 acres** of land.

- Residential area – It has been observed that the direct and indirect employment is associated with the Solar Park; hence a residential block for 400-500 workers to accommodate their 100% population.

- Administrative block – The entire Solar Park and inside projects will be maintained through remote monitoring, therefore administrative block is essential.

- Site boundary – Site boundary along with entry gate of each block of the Solar Park from main road head is essential from the safety point of view of the park.

8.4. The Concept

The entire capacity of Solar Park i.e. 2000 MW is proposed with solar PV technology only where the minimum project size of 50 MW is proposed. The technologies are identified as multi-crystalline and CdTe based thin films; however project developers may explore mono-crystalline technology which will comprise less area as compared with other option.

8.4.1. Plot Sizing

In order to make the project designing it has been benchmarked that;

- Each plot of minimum plant size (50 MW) capacity must receive the road connectivity; however internal roads needs to be develop by the developer
- Each plot will comprise the connectivity for power evacuation. The routing of the cables (66KV) will be done via poles or on the cable tranches.
- Each plot will be provided drainage along with the major connecting road. Project developer need to ling internal drainage with the provided one.

The footprints of 50 MW solar PV power project has been estimated (through layout) as 200 Acres (4 acres per MW). Hence the minimum size of the plot will be of 200 acres. Entire available land will be divided in to 8 blocks each of 250 MW capacity and of around 1100 acres. The eight blocks will be comprises a cumulative of 8000 acres of land; however the area of major and internal roads of the parks, drainage, water supply, and other facilities will be separately taken in to account in project design.

8.4.2. Approach of Circulation

The Solar Park has been designed using a grid road network plan. The eight blocks of 250 MW capacity i.e. around 1000 Areas are segregated through one major road of 8.5 meters of RoW. This road will be started from State Highway and make a boundary road of two adjacent blocks.

[28] The area per MW has been estimated through developing a plant layout for 50 MW solar PV power project using the optimized technology for the location from previous sections. The approach design uses the inter row spacing of 3 meters and tilt of 15 degrees due south. The layout is given in Annexure-7.

8.4.3. Network

The park has been developed using a network plan of road. The grids have been branched from the State Highway which passes in between the land selected for Solar Park. As the land is of zigzag boundary; hence the road pattern adopted will not only ensure the optimum use of the land but will help extract rectangular or isometric plots which are conductive for setting up solar PV power projects. It has been kept in the mind that the vehicular movement will mainly till the commissioning of the Solar Park and solar projects only; however during the operation and maintenance phase very small number of vehicles will be moving within the Solar Park region.

8.4.4. Roads

The entire Solar Park is proposed with Solar PV technology which essentially not generates any short of vehicle traffics subsequent to its implementation. The traffic would be generated only during construction phase when solar PV modules, inverters, foundation and structure material, transformers etc. have to be implementing in the Solar Park and projects. During this phase traffic would mainly comprises of trucks. The electrical equipments especially transformers of 200/400 kV switchyards will be the most bulky items in the Solar Park. For free movement of trucks and other heavy vehicles road width of around 8.5 meters is amiable. As the state highway is well connected with the Solar Park; there is no need to create any road of large width. Following two types of roads will be constructed within the Solar Park ensuring that connectivity must be given to each plot of 200 acres.

- Approach road from State Highway to Block Boundaries of 8.5 meter width
- Internal road Network of around 6.5 meter width

8.4.5. Water Pipeline

As surface water availability is a big challenge within the vicinity; hence the ground water option has been explored. There will be at least two bore wells associated with each capacity of 50 MW (minimum project capacity), which are to be developed by the respective project developers.

8.4.6. Drainage

The drainage system is also proposed in parallel with the roads. 1 meter space is kept for drainage system parallel with the major and internal roads. However the drainage system will follow the natural drain. A detailed terrine map is required towards designing of the drainage system.

8.4.7. Fire Fighting

The isolate fire distinguishers at each solar PV plot will be implemented by the respective Project Developer. However in the premises of 220/66KV and 400/220 kV substations the fire fighting will be addressed as per the National Fire Protection Advisory (NFPA) guidelines.

8.4.8. Utility Area

In order to evacuate 2000 MW solar power, a substation of 400 kV is required within the site. A plot of around 50 acres is reserved for the said substation adjacent to the state highway. The approach road from the state highway to 400 kV substation will be separately provided. From this point onwards the 400 kV transmission live will be developed by Power Grid Corporation of India till the nearest grid substation of the state.

8.4.9. Facilities in the Solar Park

The key amenities and facilities at the proposed Solar Park are presented in Table 33 below; which gives the requirement of the land for such facilities.

Table 33. Amenities and facilities at Solar Park

Land use	Area (m^2)	Area (acres)
Residential	-	-
Administrative building	558	0.1

Warehouse	2224	0.55
Training center cum hostel	-	-
Parking	2000	0.50
Total	**4782**	**1.15**

8.4.10. Provision for Green Belt

It could be explored from site map that there are few natural water bodies existing nearby which are used by the local farmers for cultivation. Till date no declared guidelines for development of greenbelt by the state of Karnataka for solar power projects; however the concept of green belt could be explored later. At the present stage no consideration has been made for green belt in Solar Park.

8.5. The Land Use

The proposed land side use is presented in Table 34.

Table 34. Overall land use at Solar Park

Land use category	Sub land use	Area (m^2) /	Area (Acres)	Percentage (%)
Solar Field	40 blocks of 50 MW capacity	36421707.8	9000	
Electrical Sub Stations	220 kV (Eight numbers)	180000	44.80	
Electrical Sub Station	400 kV	122500	30	
220 kV transmission lines Including 35 mtr ROW)	70 number of Towers approx	95000	23.45	
Roads	8.5 meter width	268890	66.44	
	4.5 meter width	222255	54.92	
Utility	Residential			
	Administrative building	558	0.10	
	Ware house	2224	0.55	
	Training center cum hostel	465	0.11	
	Parking	2000	0.50	
Drainage				
Water supply				
Existing objects	Roads (SH)	96123	23.75	
	Water bodies			
	Natural drains			
	Internal roads	22793	5.63	
	Other objects			
Total area			**9250.31**	

9. Infrastructure Plan of Solar Park

This section deals with the detailing of preliminary infrastructure required towards developing 2000 MW capacity Solar Park at the selected location. The preliminary infrastructure consists of the roads, power evacuation facilities, water supply and other facilities.

9.1. Site Preparation

The land identified for the project is fairly flat and does not have significant undulations, however some portion of land may require leveling and grading. The site preparation shall include all work as required for installation of a utility scale solar PV plant as per good industry practices. This shall essentially include but not be limited to:

- Clearing of weeds, chopping down of small bushes and trees.
- If required leveling of land with excavation and back filling and disposal of excess soil. Backfilling soil may be required and shall have to be sourced from outside, if excavated soil has expansive potential.
- Movement of soil for leveling within the site.
- Grading the soil with south slope, if required.
- Construction of culverts on cross flow, if required.
- Rock blasting, wherever required.
- Wall and Gate Complex

9.1.1. Levelling of the Site

From the site assessment and site visit it has been noticed that

- Most of the land is stable (no loose soil on top surface)
- The terrain is flat relatively and less amount of levelling is essential
- The state highway is passing in between the land hence water and power evacuation facilities will cross the road which will be requiring approvals and clearances from concern departments
- South facing approach within the tolerable tilt angle of 15-20 degree will be accommodated through design; hence levelling will be negligible

As indicated the levelling will mainly be done in those area where undulation is higher than 15-20 degree except south direction. If the land comprises south facing tilt angle than the design approach will be adopted in line with the contour of the land. The object shading or shading due to geotechnical aspects of the land will be identified and minimized. It has been estimated that in order to make site levelling for minimization of major undulations the process will require disposal of around 88000 cum of soil.

9.1.2. Cleaning of the Site

The site is essentially un-irrigated and barren land which contains scattered vegetation mainly bushes etc. In order to develop Solar Park; such plantation or bushes need to be removing from the site.

9.1.3. Plantation for Dust Deposition

The selected location is essentially in hot and dry belt of Tumkur district where dust level is already high. Once the levelling work will cause the loose soil will make significant dust in the local environment. The high dust in the environment is adverse for performance of solar PV power project;

- Increase the soiling losses
- Increase the scattering in the atmosphere and reduce the fraction of direct (effective with high intensity) irradiance
- Reduction in the energy generation
- Increase the cleaning cycle (water requirement)
- Increase operation and maintenance expenses (more man power for cleaning)

In order to minimize the impact of dust the concept of plantation of xerophytic shrubs all across the site (boundaries) may be planned. The approach may ensure minimal concretisation of the land and contribute towards ground water recharge.

9.1.4. Boundary wall and Gates

As the state highway is in between the land and across the site hence boundary wall of the Solar Park from all sites is essential from the point of view of safety measures. In order to delineate the boundaries a 1.5 meter high masonry wall will be constructed.

The entire park external boundary will have compound wall. The gates will be required at both sites of the State Highway. The approach of gates is established in similar line of the blocks of 250 MW each i.e. around one gate for 1200 acres area. The entry within the site will be regulated by centrally monitored an Entry-Exit complex.

9.2. Land Survey, Soil Investigation & Geotechnical Study

KSPDCL has to carry out the Preliminary Soil Investigation & Geotechnical Study conducted along with Topographic Survey of the selected land of Solar Park. Further the project developers may, on their own responsibility, proceed on the basis of the Report for submission of the bid. For the final design of the Solar Park of multiple solar PV projects, the project developers need to carry out their own investigations under supervision of KSPDCL Authorities and shall take the full responsibility about the safety and stability of all buildings and structures upon award of the Contract about the safety and stability of all buildings and associated structures.

The Geo-technical study to be conducted shall consist of Field & Laboratory investigations conforming to applicable standards, Soil Electrical resistivity measurements (IEEE-81). The Report shall furnish the allowable safe bearing capacity, shear strength parameters and modulus of sub grade reaction for different sizes of foundations at different founding strata for shallow foundations. The investigation shall also address corrosion /chemical attack on account of dissolved chlorides, sulphates and other minerals in sub soil & ground water.

In general, small micro piles / ramming using either RCC or steel with adequate length will be adopted for erection of the Solar Module Support Structures. Accordingly the report shall address the recommendations comparing the adoption of conventional shallow foundations against RCC piles / Steel ramming sections of shallow depth considering the field implementation of large number of foundations.

9.3. Roads and Network

The selected site comprises good connectivity and adjacent to the State Highway (Figure 69).

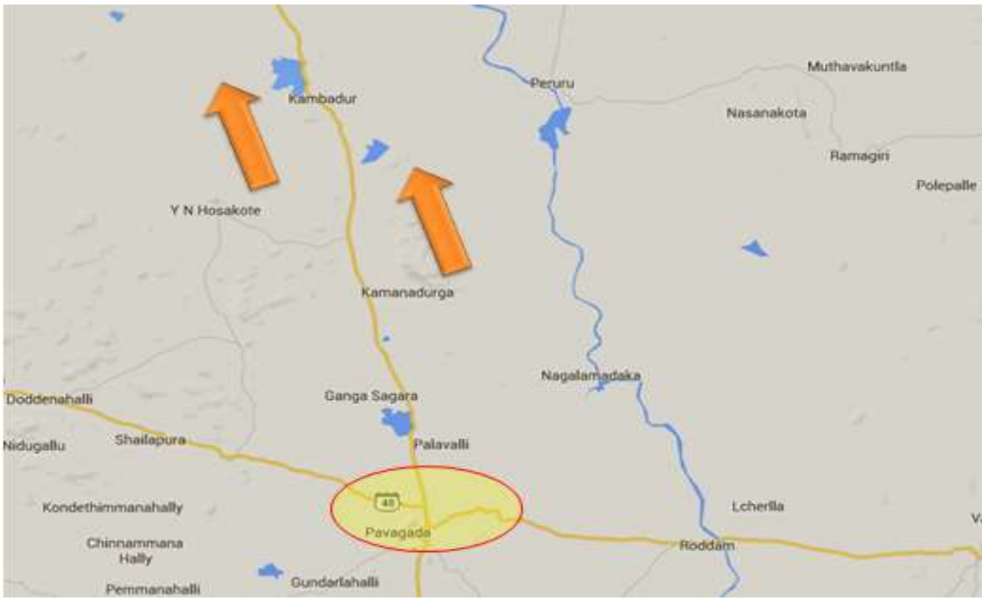


Figure 69. Satellite image of road infrastructure at selected location of Tumkur, Karnataka

The Solar Park site is located near the existing highway and the length of access road is minimal. The access road of each blocks of 250 MW will be of 8.5 m width with 2.0m shoulders on either side. The internal roads for connecting the blocks of 50 MW will be of the width of 5.5 meters with 2.0 shoulders on either side. The

RCC Hume pipe culvert shall be provided with adequate number, size and invert levels for cable crossings and water drains. The proposed hierarchy of the road is presented in Table 35.

Table 35. Proposed road network plan of Solar Park

S. No.	Types of Roads	RoW (m)	Lane	Length (km)	Remarks
1	Approach road (block level)	8.5	2		New Construction – Road will segmenting the blocks of 250 MW i.e. around 1200 acres land of Solar Park
2	Internal Truck Road (sub arterial road)	5.5	2		New construction – Roads inside the each block of 250 MW
3	Internal branch roads	3.5	1		New Construction – Roads inside the each block of 50 MW (will made by Project Developer based on its design approach)

The plot plan and project layout has been developed in such a way that separate roads to switchyard (220 kV and 400 kV) will be minimize and will be as per the roads mentioned in Table 10.1 depending upon the requirement. The switchyard will be developed adjacent to the state highways in order to address the RoW issues for power evacuation which can reduce specific road construction as well. In the mean time the maintenance of the state highway road needs to be done at the stage of Solar Park development.

9.4. Power Evacuation & Transmission Arrangement

The key assumptions for power evacuation are as following;

- The Solar Park will be of 2000 MW capacity in which 100% technology component will be of solar PV not solar thermal
- The minimum generation capacity for individual project developer will be 50 MW
- For solar PV projects; the land requirement has been considered as 4.5 acres per MW (through the project layout)
- From Solar Park the entire power will be evacuated at the grid substation constructed by POWERGRID which is in process.

The Power Evacuation from the proposed Solar Park shall be through 400/220 kV Grid Substation of POWERGRID constructed within the Solar Park. The Grid Substation of POWERGRID shall be connected to POWERGRID's 765KV Station at Madhugiri through Double Circuit Line having ACSR Moose conductor.

The proposed 2000 MW Solar Park would be developed as eight blocks of 250 MW capacity. For each 250 MW Solar Power capacity block, one pooling substation of 66/ 220 kV is proposed in which 2 x 150 MVA step-up transformers are considered. The 250 MW block is further subdivided into 50 MW sub blocks. Thus, these 5 X 50 MW sub blocks shall be connected to pooling substation through 66KV underground cables. The voltage will again be stepped up to 220kV at the Solar Project Pooling Station and again stepped up to 400kV at the proposed 400kV Grid Substation by POWERGRID at Solar power. Karnataka Solar Power Development Corporation Private Limited (KSPDCL) (JV of SECI and KREDL) will establish 8 Nos. of 220/66kV pooling stations at Pavagada site to evacuate 2000MW solar power generated at the Park

The 400 kV works would be implemented by Power Grid Corporation of India (POWERGRID) and 220 kV Works up to 66KV pooling stations would be carried out by Transmission Corporation of Karnataka (KPTCL). The proposed site for 400/220kV grid substation to be established by POWERGRID falls in Pavagada taluk, Tumkur district. The nearest station of Power Grid Corporation of India Limited is 765KV station at Madhugiri which is under construction. The power evacuation approach of entire solar park is presented in Single Line Diagrams in Annexure 11: Annexure 12: Annexure 13: ;

- Indicative Single Line Diagram of 50 MW Solar PV Power Plant
- Indicative Layout 50 MW Solar PV Power Plant
- Indicative Single Line Diagram of 220/66KV Pooling Substation

The Power Evacuation arrangement is shown in Indicative Single Line Diagram of 220/66KV Pooling Substation attached annexure, however **Error! Reference source not found.** below is also representing the ower Evacuation arrangement of complete Solar Park of 2000 MW capacity.

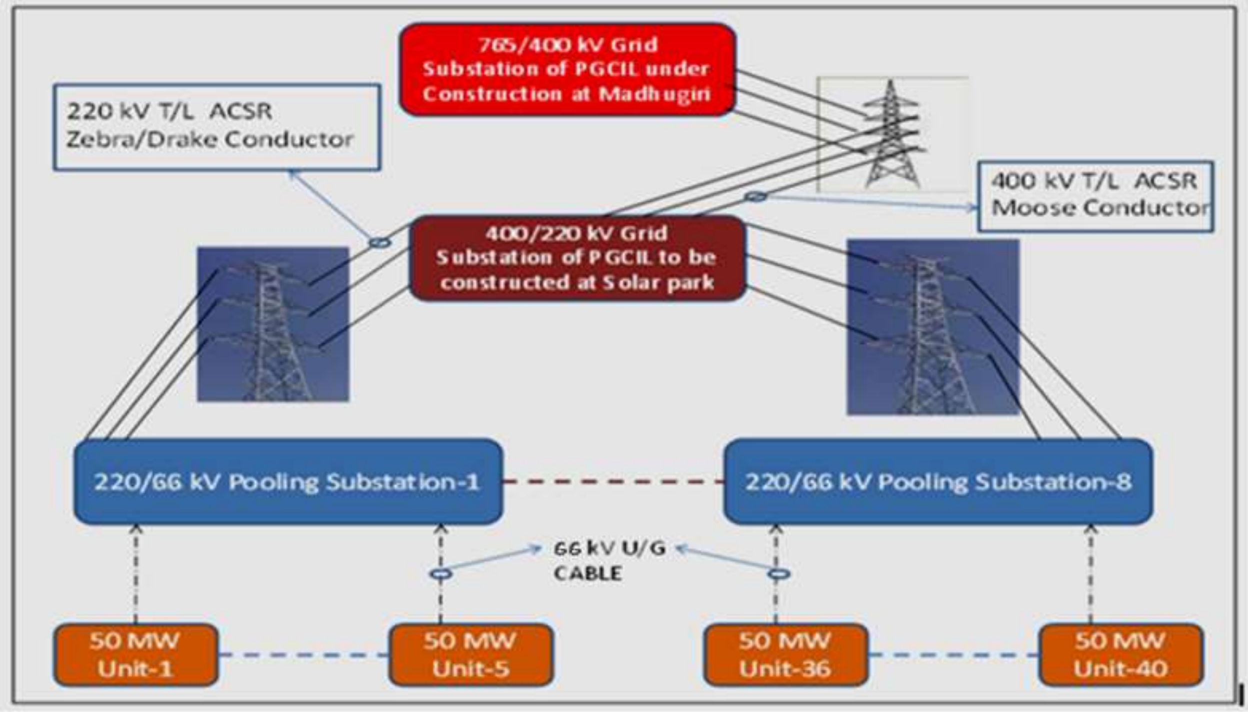


Figure 70: Power Evacuation plan of 2000 MW Solar Park

9.4.1. Metering system

The metering system will be confining to Indian Grid Code and Requirement of KPTCL. It is proposed to install electronic energy meters (Main and Check) of class 0.2s accuracy at interconnection point (220/66KV Pooling Substation). However tariff meters (Main and Check) shall also be installed at Plant end as well. The tariff meter shall be ABT type. The associated current transformers (CTs) and potential transformers (PTs) shall also be of class 0.2s accuracy. Remote Transmitting Unit (RTU) shall also be installed at 220/66KV Pooling Substation for transferring real time data to SLDC for its monitoring purpose.

9.4.2. Construction Power Arrangement

Construction Power arrangement shall be the responsibility of respective developer. The Construction Power shall be arrange either by DG set or through the Construction Power connection from the Discom. In order to avoid the Transmission Line within the Solar Park, the DG Set arrangement shall be preferable.

9.4.3. Transmission Substation

The Transmission Substation for evacuation of complete 2000 MW Power shall be 400/220 kV Substation of POWERGRID. POWERGRID will construct the 400/220 kV Substation. The 8 nos. 220 kV Line from 8 nos. 220/66KV Pooling Substation (one from each 220/66KV Pooling Substation) shall be connected to 400/220 kV Substation of POWERGRID. The POWERGRID Substation shall be further connected to 765/400 kV Grid Substation which is planned to be constructed at Madhugiri. The 400/220 kV Substation shall have 4 nos outgoing 400 kV Line Bays, 8 nos. 220 kV Incoming Bays, 4 nos 500 MVA Transformer bay and Reactor bay(optional).

9.5. Water Supply System

The water requirement is to be catered to trough separate borewells installed by respective project developers. Water requirement for a solar park shall depend on the water requirement of the Solar Power Projects to be located in the proposed solar park. Water requirement for a solar PV projects are lesser as compared to the conventional power projects viz. thermal power projects and nuclear power projects etc. The consumption of water in case of solar PV projects is mainly on account of module washing.

9.5.1. Basis of Design

Water Requirement for Module Washing

While considering water requirement for the solar park, consideration were given for both PV technology i.e. crystalline and thin film technology. Cleaning frequency which solely depends on the climatic parameters is considered as twice in a month for the present case. Table 36 presents water requirement for the cleaning of PV modules of 2000 MW solar PV projects.

Table 36. Water Requirement for Module Washing

Capacity of the Park	MW	2000	2000
No. of 250 MW Block	Nos.	8	8
Solar PV Technology		Crystalline	Thin Film
PV Module Area Requirement	sqm	12792280	14399840
Water requirement[29]	**ltr/ sqm/ cleaning**	**1**	**1**
Cleaning frequency	no/ month	2	2
Monthly Water Requirement for cleaning	kl / Month	25584.56	28799.68
Annual Water Requirement	**kl/ year**	**307015**	**345596**
Daily Water requirement- Subtotal -A	**kl/day**	**841**	**947**

Water Requirement for Other Purposes

As indicated in the preceding section, that during operation and maintenance of the solar power projects, a total of 35 manpower including technical, skilled, semi-skilled and un-skilled shall be required which will result in 1400 manpower working for the operation and maintenance of entire park capacity of 2000 MW.

Table 37. Total water requirement at Solar Park

Total No of Manpower	**1400**
Water Requirement (ltr. / head/ day)[30]	45
Total Water Requirement (kl / day)	63

Water Requirement for 2000 MW Solar Park

Based on the demand estimation of the Water requirement for the operation and maintenance of the Solar Projects, it is estimated that there would be a 904 kl /day in case of crystalline technology and 1010 kl/ day in case of thin film technology project on account of module washing and other requirements. An additional 10% of the water requirement is estimated considering water requirement for the electrical operation of different pooling substations and marginal availability. In view of this, total water requirement for a solar park of 2000 MW is estimated in the range of **995-1110 kl/ day.**

Source and storage of Water

As indicated in the preceding section, underground water can be sourced through suitability sized bore well to meet the water requirement of the solar parks. Based on the design optimization of the Project, it is recommended to have at least two bore wells for every 50 MW capacity block of the Solar Park which translates into total of eight (80) nos. of bore well for entire Solar Park. In case of bore wells the storage for raw water and storage for treated water through individual RO plant will be developed by Project Developers within their premises taking in to consideration of autonomy of few days.

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[29] As per prevailing industrial practices for the similar kind of Projects; practically it might be lesser than this.

[30] IS (1172: 1993)code of basic requirement for Water supply, drainage and sanitation

Requirement of Water Treatment

In view of non-availability of groundwater test report, requirement of water treatment plant cannot be assessed. In case of subsequent to groundwater test report, if it is found the quality of water is suitable for module cleaning and usage by the manpower, installation of water treatment and RO plant shall be required.

9.6. Social Infrastructure

Along with the site plan for 2000 MW capacity Solar Park; the land has been reserved for following social infrastructure as well;

- Parking area
- Warehouses (block wise)
- Administrative building
- Residential buildings
- Training institute for capability development

10. Project Cost Estimates

This section address the entire cost of Solar Park of 2000 MW capacity comprising various infrastructures. There will be 40 solar PV power projects each of 50 MW minimum capacity. The block costs are based on the selected solar PV technology and associated engineering inputs in line with the previous sections.

It has been observed from the cost detailing of 5 MW to 100 MW solar PV power projects in the country implemented during last 5 years; the civil cost of solar PV power projects is nominal as compared with the other costs viz. Solar PV modules & inverters, electrical and other heads. The breakup of civil cost consists of 10-12% of the total project cost including the structure of mounting the solar PV modules is inclusive. Following technical aspects are the benchmark of solar PV power projects in the country;

- In case of multi-crystalline solar PV technology modules the per MW structure requirement is around 45-50 tonnes
- In case of Thin Film solar PV technology modules the per MW structure requirement is around 65-40 tonnes.
- In case of constructing the solar field of 1 MW solar PV power project using multi-crystalline technology around 300-350 piles are essential with single support structure (depending upon the location)
- In case of thin film solar PV based solar field the number of piles varies from 650-700 nos. per MW capacity with single support.
- The concrete requirement for 1 MW capacity solar field varies from 70-75 cubic meters with the reinforced steel.
- Ramming and casting; both piles are common in solar PV field. Casting is cost effective however ramming is time effective.

10.1. Major Heads of Project Cost

The Cost of entire Solar Park shall have the following major heads:

- Land Acquisition for complete Solar park
- Site Development
- Roads
- Drainage System
- Water Piping/Supply System / Bore wells
- 40 nos. 50 MW Solar PV Plants (Project Developer cost)
- 8 nos., 220/66KV Pooling Substation
- 8 nos. Single Circuit 220 kV Transmission Line from 220/66KV Pooling Substation to 400/220 kV Main Substation of POWERGRID
- Admin Building and other establishment

The project cost estimates excludes the followings costs;

- Cost of developing greet belt
- Survey and soil testing
- Geotechnical investigations

10.2. Basis of Project Cost

This cost estimate are based on the following data/inputs

- Quotation of Various Bidders for other Contemporary projects
- Consultant in house database
- Benchmark costs of CERC/ SERCs for solar PV power projects
- Project cost of similar 50 MW Solar PV Projects
- Rates of Land in Karnataka for solar PV power projects under implementation
- Discussion with professionals of EPC companies of solar PV projects

10.3. Project Cost

10.3.1. Land Acquisition

The Land requirement for 2000 MW Solar Park including solar field (i.e. solar PV plants), Roads, Transmission and Distribution Network will be of around 11,000 acres. Out of which 4.4 acres per MW i.e. around 8800 acres of the land will be solely required for 40 nos. 50 MW Solar PV Plants; however the and balance land will be required for Roads, Water Supply system, Admin Building, ware house, training centre and Transmission and Distribution Network etc.

The selected land for Solar Park by KSPDCL is totally private land which is proposed to acquire on annual lease basis. In order to estimate the project cost at First Year a cost figure of Rs 23100 per acres with 5% escalation on base year lease every second year has been taken for project cost estimates. The lease mechanism and associated cost needs to be finalized by KSPDCL with land owners.

In case the lease model is not applicable the present land price within the vicinity is around 4.5 lacs per acre[31]. In this mode the land cost will be around Rs. 630 Cr.

10.3.2. Site Development

The site development activities shall include the following:

- Site Cleaning leveling and Grading[32]
- Boundary/ Wall of Solar Park
- Main Gate and other gates
- Main Security Complex and Porta Cabin for Security
- Green Belt area for 220 kV Transmission Line and CSR work

It has been experienced that the site work is given to the local subcontractors on fixed price basis in which the contractor makes the surface cleaning only through JCB but do not takes care of the leveling of the land. The leveling of land is presently not preferred by the developers and the natural slope is adjusted through the structures only.

- The cost of site cleaning has been taken as **Rs 10000.00 per acres** from best market practices (i.e. Rs 750-800 per hour and 6-7 hours for one cleaning)
- Further if project developer is willing to make full leveling (ideal) of the land; the cost will be taken care by the respective project developer.
- The wall is essential from the point of view of security and operation of the projects.
- There will a main gate near the administrative building and 400 kV grid-substation. As the land is separated by the state highway; hence the entry gates are required at both end. The approach has been developed in such a way that there will a main gate and fours small gates at the point of connecting roads from state highway.
- 5% contingency will be considered over capital cost calculation.

Table 38 below indicates the tentative cost required for site development.

Table 38. Cost of Site Development

Dimensions	Quantity	Rate (in INR)	Estimated Cost (INR in Cr.)
Site Cleaning levelling and Grading	14000 acres	10000.00 per acres	14.0
Boundary wall of Solar Park	96 km	2,000,000.0 per km	19.2
Main Gate, other gates and Security Complex/cabins	1 nos Main Gate and 4 other gate	Rs 30 lakhs for Main gate Rs 15 lakh for other gate	0.90

[31] Based on the cost data of a solar PV power project under implementation in Chitradurga, Karnataka

[32] Few years back the site leveling was very common and the project developers/ EPC contractors was working within 0-4 degree tilt due south. Presently most of the developers are following the tilt of terrain and making the structures accordingly. In solar PV project up to 15 degree tilt due equator is acceptable hence the approach of following the natural tilt of land save project cost.

		including security cabins	
Total Cost (INR in Crore)	**34.1**		

10.3.3. Road and Drainage System

The selected site for developing the Solar Park of 2000 MW (8 x 250 MW) capacity comprises established road connectivity and adjacent to State Highway. Hence there is no requirement to construction multi-lane road at the site. The heaviest components will be associated with the 400 kV grid-substation which will be developed adjacent to state highway. There will be mainly two types of the road;

- The roads of 8.5 meter width which will comprise two lanes. These roads will be also work as the boundaries of each block of 250 MW capacity (i.e. each block). Similar roads will be connecting the pooling substations (220/66KV) and grid substation of 400/200 kV.
- The roads which will be sub-sectioning the blocks will be of 4.5 meters of width[33].
- The internal roads will be of 3.5 meters of the width which will be developed by the respective project developer.
- The drainage system of solar PV power projects is essentially not a well standardized package as it depends upon the terrine of the selected project location. Essentially the natural slope and drain is maintained for drainage in the solar field.
- The selected location is essentially located in the Hot and Dry region where the annual rainfall is low and no history of flooding and water logging has been reported.
- The cost of 8.5 meter road could be taken as **Rs 50 lacs per km** which will be use as diversion between the each block of 250 MW and transportation of heavy equipment
- As per the best practices the drainage cost could be taken as 1.0 % of the civil cost involve in the solar power project. The internal drainage of each project will be developed by the project developer; however the cost of major drains could be taken as **Rs 3.0 Cr.** one time lump sum cost.
- In the project layout preparation the consideration of the drainage system has already been made and a meter of length is kept along with the roads for drainage system.
- 5% additional cost will be considered to over capital cost calculation.

The tentative Cost of Roads and Drainage system is described in Table 39 below.

Table 39. Cost of Road and Drainage System

Dimensions	Quantity	Rate (INR in Crore/km)	Estimated Cost (INR in Cr.)
Roads (8.5 m)	27 kms	2.12	57.24
Roads (4.5 m)	34 kms	1.1	37.4
Drainage system	Entire park	-	3.0
Total Cost (INR in Crore)	**97.64**		

10.3.4. Street Lighting System

KSPDCL needs to provide street light within the Solar Park. In the present approach the lightning of substations (220/ 400 kV) have been addressed in their respective BoQ. However the street lights needs to be provided on major roads of 8.5 meters and 4.5 meter width. The internal arrangement for street lights will be developed by the specific project developers for their specific projects.

As per the best industrial practices the street lights are provided at every span of 30 meters (specifications attached in Table 40). The road of 8.5 width will comprise two fixtures however the 4.5 meter width road will have single fixture per pole. 5% contingency will be considered over capital cost calculation.

Table 40. Cost of Street lights

Description	Nos. of Lights	Span (meter)	Cost (in Cr)
8.5 meter Road (27 kms)	1800 (2 fixtures per Pole	30	2.70

[33] The internal roads might be of 3.5 meters as well. At the stage of project implementation the higher width has been taken it has from the point of view of the easy transportation as multiple projects will be simultaneously under construction.

4.5 meter Road (34 kms)	1150 (1 fixtures per Pole	30	1.38
Total Cost-			**4.08**

10.3.5. Water Supply System

The water requirement has been estimated in previous section which is mainly required for operation and maintenance (cleaning) and other applications at the Solar Park. KSPDCL has confirmed that the underground water will be used to fulfil the requirement as there is scarcity of surface water within the vicinity.

- As per the report of central ground water board for the district of Tumkur, Karnataka the groundwater level varies from 350-500 feet in the vicinity of Pavagada.
- In case of using the groundwater; the centralized facility is not recommended as the Solar Park comprises a large solar field area for cleaning.
- As per the best industrial practices one bore well is essential for a solar PV power project capacity of 25 MW. As the minimum project size of the project is 50 MW; hence at least two bore wells and required[34] with one solar PV power project of the said Solar Park.
- At least one bore well is essential at each 220/66KV substation for supplying the water to the workers at the Solar Park and other applications. However one bore well is essential at the 400/220 kV grid substation.
- Each bore well needs to attach with RO system for the treatment of groundwater before use.
- The intermediate reservoirs for raw water and the treated water from RO plant with few days' autonomy will be developed by the individual project developers at the site.
- 5% contingency will be considered over capital cost calculation.

The tentative cost of Water Supply System is mentioned in Table 41 below.

Table 41. Cost of water supply system

Dimensions	Total number of systems	Cost per System (Lacs)	Estimated Cost (INR in Cr.)
Bore well system[35]	10	3.0	0.3
RO Plant	10	10.0	1.0
Total Cost			**1.3**

Solar park owner will install 10 bore well and RO system for general maintenance requirement. For solar projects, bore well system and RO plant system is in developer scope of work.

10.3.6. Power Infrastructure Cost

There will be involvement of Inside and Outside cost of power infrastructure associated with the Solar Park of 2000 MW capacity. As per the present scenario; KSPDCL will be developing the 8 poling substations and connect it with 400 kV grid substation in the premises of Solar Park from which the power transmission and evacuation will be the scope of work of POWERGRID; Government of India. Hence Solar Park will comprise the Inside Cost of power infrastructure.

10.3.6.1. 220/66KV Pooling Substation (8 Nos.)

There will be 8 nos. of 220/66KV Pooling Substation within the Solar park to collected and further transmit the entire 2000 MW Solar Power generated from the Solar Park. The 220/ 66KV Pooling Substation work shall be executed based on the lump sum turnkey basis i.e. complete EPC Work shall be awarded to the contractor. The major heads contribute to 220/ 66KV Substation are Transformer, Bay Equipment, Substation Automation System etc. The Cost of 1 no 220 /66kV Pooling Substation is mentioned in Table 42below. 5% contingency will be considered over capital cost calculation.

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34 At least one bore well at 125-150 area of the area. This will be easy for the cleaning of the solar field (modules) as well.

35 The cost of bore well system has been taken from best references in operational solar PV projects in India which comprises Rs 2.0 lacs for bore well (depending on the depth), Rs 15000 for casing, Rs 30000 for HVP pipe, Rs 10000 for electrical cabling, etc.

Table 42. Cost of a 220/66KV Pooling Substation

Dimensions	Unit	Rate (INR in Crore)	Nos of Bays/ Transformer	Estimated Cost (Cr.)
220 kV Bays	Nos	2.8 per bay	8	22.4
Transformer 150 MVA	Nos.	9.4 per Transformer	2	18.87
66KV Bays	Nos	0.50 per bay	10	5
Station Transformer	Nos	0.25	2	0.50
Cost for ONE no 220/ 66KV Pooling Substation (Rs in Crore)	46.77			
Total Cost of 8 Nos. of 220/ 66KV Pooling Substation (Rs in Crore)	**374.16**			

The Total Cost of 8 nos. 220/ 66KV Pooling Substation shall be 8 x 46.67 i.e. INR **374.16 Crores**. The detailed cost break-up of 220/66KV pooling substation (reference BoQ) has been presented in Annexure 14: .

10.3.6.2. 220 kV Transmission Line (8 nos.)

From each 220/66KV Pooling Substation the power shall be evacuated through 1 no 220 kV Transmission Line. The Transmission Line shall connect the 220/66KV Pooling Substation to 400/220 kV Grid Substation of POWERGRID. The 3 nos Transmission Line from 3 nos 220 kV Pooling substation shall share common towers, and another 3 nos Transmission Line from 3 nos 220 kV Pooling substation shall share common towers and balance 2 nos. Transmission Line from 2 nos 220 kV Pooling Substation shall share common tower. Therefore there shall be 2 nos. of triple circuit Line and 1 no double circuit line shall be connected to 400 kV Grid Substation Station. 5% contingency will be considered over capital cost calculation.

The Transmission Line Work shall also be awarded on Lump sum Turnkey basis. The Major Contributors to Transmission Line cost are Tower[36], Tower Foundation and Conductor[37]. The Cost of 220 kV Transmission Line is mentioned in Table 43 below.

Table 43. Cost of 220kV Transmission Line

Dimensions	Unit	Rate(INR in Crore)	Total Kms for 8 nos	Estimated Cost
220 kV Transmission Line	kms	0.50 per kms	100 approx.	50
Total Cost for all 8 nos 220kV Transmission Line (INR in Crore)	**50.0**			

10.3.6.3. 400/220 kV Grid Substation of POWERGRID

There shall be 1 no 400/220 kV Grid Substation of POWERGRID within the Solar Park to collect and further transmitted the entire 2000 MW Solar Power generated from the Solar Park. One and a half breaker scheme shall be adopted for 400/220 kV Grid Substation. The Grid Substation works shall be awarded on Lump sum turnkey basis. The major contributor towards 400 kV Grid Substations are 400 and 220 kV Equipment, Power Transformer and civil works. The Cost 400 kV Grid Substation is mentioned in Table 44 below.

Table 44. Cost of 400/220 kV Pooling Substation

Dimensions	Unit	Rate (INR in Crore)	Nos	Estimated Cost
220 kV Bays	Nos.	3 per bay	8	24
Transformer Bay	Nos.	4.0 per bay	4	16
Transformer 500 MVA	Nos.	36.0 per	4	140

[36] There are four tower of tower available for 200 kV Transmission Line DA, DB, DC and DD type , while computing the Cost of Transmission Line total 50 towers of different combination have been selected.
[37] 220 kV Zebra Conductor has been considered for Transmission Line.

		Transformer		
400 kV Line Bays (including civil work and Auxiliary System works)	Nos.	4.5 per bay	4	18
Middle Circuit Breaker bay	Nos	3.5 per bay	4	14
Reactor Bay	Nos.	3.0 per bay	1	3
Auxiliary System				1.5
Total Cost for one no 440/ 220 kV Pooling Substation (INR in Crore)	**215.3**			

The detailed cost break-up of 400/220 kV pooling substation (reference) has been presented in Annexure 15: .

10.3.7. Admin Building and Other Establishment

The Solar Park shall have an Administrative Building, Warehouse and Parking Space. It is envisaged that each 250 MW capacity block will be having a separate warehouse. 5% contingency will be considered over capital cost calculation. The tentative Cost of Admin Building and other establishment are mentioned in Table 45 below:

Table 45. Cost of building and other establishments

Dimensions	Area	Unit rate (INR)	Estimated Cost (INR in Crore)
Admin Building (3 storey building with built up area 6000 sq ft on each floor)	18000 sq. ft.	2000 per sq. ft	3.6
Ware House 8 nos of 1000 sq m each (one in each block)	8000 sq. mt.	8000 per sq m	6.4
Training centre building	5000 sq. ft.	2000 per sq. Ft.	1.0
Total Cost (INR in Crores)	**11**		

10.3.8. Power arrangement for solar park use

The solar park shall have separate arrangement for power consumption at admin building and other facilities. 28 Kms Transmission line from Discom station to Pavagadata and Substation will be installed with 8 MVA 66/11 Kv transformer. 5% contingency will be considered over capital cost calculation.

Dimensions	Unit	Unit rate (INR)	Length	Estimated Cost (INR in Crore)
28 Kms line from Discom station to Pavagada	Km	25 Lakhs/Km.	28 Kms	7
Substation with 8MVA 66/11 KV transformer	Rs	75 Lakhs	-	7.75
Total Cost (INR in Crores)	**7.75**			

10.4. Summary of Project Cost

The summary of Solar Park development cost is mentioned in Table 46 below.

Table 46. Total Project Cost of Solar Park (2000 MW)

Dimensions	Cost (INR in Crore)
Land (Lease for the first 2 years) 23,100 Rs per acre per year with 5% escalation on base year (Escalation in every 2nd year)	65.85
Site Development	35.81

Roads and Drainage System	102.52
Cost of street lights	4.28
Water Supply System	1.37
220 kV Pooling Substations	392.87
220 kV Transmission line	52.5
400/220 kV Grid Substation of POWERGRID	215.3 (In POWERGRID Scope)
Cost of transmission link line to Devanahalli hardware park	360 (In POWERGRID Scope)
Administration buildings and others	11.55
8 MVA Transformer and 28 KM transmission line from distribution S/S	8.14
One time Expenditure towards consultancy for ESIA, LTA	107.3
'One time expenditure towards land lease	27.84
Total hard cost	**1385.33**

The total cost of developing Solar Park has been estimated around Rs. 1385.33 Crores in which the power evacuation comprises effective component. After the successful completion of the construction of the solar park, lease of Rs. 23100/acre/year is payable every year with non-compounded 5% escalation every second year and the same shall be chargeable from the developers; and thus not considered part of the project cost.

10.5. Cost of Solar PV Power Projects

The cost details of solar PV power projects (along with the key break-up) recently commissioned (2014-15) in India based on Multi-crystalline and Thin Film solar PV technologies in India are presented in Annexure 16: . This cost will be invested by the various project developers for the respective capacities.

11. Financial Analysis

11.1. Formation and Functions of the Joint Venture Company

The implementing agency for the Solar Park is Karnataka Solar Power Development Corporation Ltd. (KSPDCL),- a Joint Venture Company (JVC) floated by Solar Energy Corporation of India (SECI) and Karnataka Renewable Energy Development Limited (KREDL) under the Companies Act, 2013. The JVC has been formed as per Mode 2 of the MNRE Scheme wherein 50% equity is held by SECI, 50% equity by KREDL. The MD, KREDL has been appointed as Chairman of the Board of the Company for the first 3 years and thereafter the role would be rotated every two years between the nominees of SECI and KREDL.

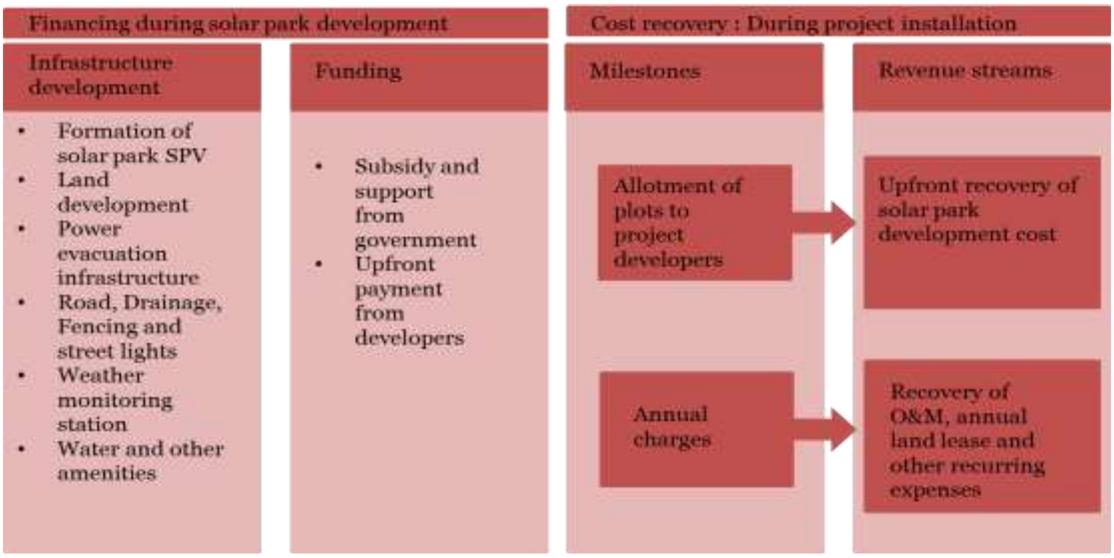
The key functions of Solar SPV are detailed below:

- Land Purchase: The Solar JV will acquire the land for setting up the proposed Solar Park following the leasing out of land by farmers
- Land Development & Civil Works: To undertake land development and civil work in the proposed site for setting up the Solar Park. This will include leveling & grading, building external boundary wall, access roads, roads within Solar Park, common utility buildings and warehouse.
- Evacuation Arrangement: In coordination with KPTCL, set-up the evacuation infrastructure for the Solar Park.
- Water Supply Arrangement: Set-up water supply network infrastructure to meet the water requirement for the solar projects to be set-up in the Solar Park.
- Entering appropriate contracts/agreements : A provisional list of contracts which the Solar Park SPV entity is likely to enter is:
    - Solar Park Construction contracts
        - Grid Connection Agreement between the Solar Park and STU
        - Construction of the internal access road and civil works
    - Solar past post construction agreements
        - License Agreement with each solar project on allotment of plots
        - Services Agreement with each solar project for providing various services (water, power evacuation)

11.2. Overall Framework for Project Development

The established Solar Park JV shall undertake the infrastructure development for the setting up of the Solar Park and allot the plots to the project developers eligible for participating in the schemes identified for promotion in the Solar Park. The figure below details the overall framework for setting up the Solar Park and allotment of the plots to solar project developers.

Figure 71: Overall framework for setting up solar park



Phase 1: Solar Park Development
The key steps related to the Phase – 1: Solar Park developments are:

- Solar Park Development: The Solar Park JV would be responsible to undertake infrastructure development for setting up the Solar Park. This shall include land acquisition, land development, power evacuation infrastructure and water supply infrastructure.
- Funding: The Govt. of Karnataka may provide the initial funding for meeting the funding requirement for setting up the Solar Park. A budget allocation from Government of Karnataka can be earmarked for providing the funds for undertaking the preparatory work for development of the Solar Park. Also, the fund could be sourced from the grant provided by MNRE under the 'Scheme for Development of Solar Parks'. The grant could be of up to Rs.20 lakhs/MW or 30% of the project cost including Grid-connectivity cost, whichever is lower

Phase 2: Solar Project Development
The key steps related to Phase-2 i.e. Solar project development are:

- Registration Fees: A one-time registration fee (per project or per MW) may be collected by inviting applications from the prospective buyers when the scheme is finalized.
- Allotment of projects to the solar project developer: The plots in the Solar Park can be allotted to developers after charging a one-time charge or a combination of the following:
  - ✓ Upfront Allotment Fee – One time
  - ✓ Service Charge with annual escalation
- Charges for other services: It can be expected that Solar Park JV will continue operating as an entity and having separate service agreements with project developers for providing various services (water, power evacuation)

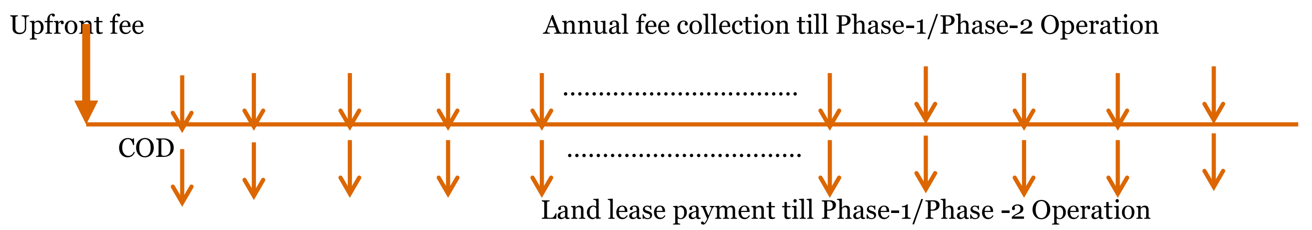
11.3. Project Level assumptions

A large scale grid connected solar park has been proposed in the state of Karnataka. The size of the proposed plant is 2000 MW. There will be 40 solar PV power projects of 50 MW minimum capacities each. Infrastructure for plant will be built in 2 Phases, each of 1000 MW capacity. Scope of this financial analysis is limited to infrastructure and facilities required for solar park.

11.3.1. Revenue and expense Timelines

It has been considered that solar park owner will pay annual land lease to farmers. For construction time in Phase- 1 and Phase -2 i.e. till Phase -1 COD and Phase -2 COD, Land cost is considered as capital cost. After COD, Land cost is considered as lease expense.

Upfront + Annual fee collection by park owner from developer



In this mode, developer pays upfront fee and annual fee to solar park owner. Solar Park is envisaged to be developed in two phases e.g. Phase-1 and Phase-2. Both phases will have different CODs as well as different operation closure dates. Upfront fee will be paid to Solar park owner at solar park zeroth date (Date of award) and annual fee as well as other annual charges are paid to park owner every year from Phase-1/Phase-2 COD till the year respective phase of solar park ceases to operate.

11.3.2. Capital Cost

400/220 KV Grid substation is considered in POWERGRID scope of work and lease is 23,100 Rs/Acre with 5% escalation every second year on base year (Not compounded).

The project cost of infrastructure and facilities for solar park are described in table 46.

Table 47 : Capital cost of a solar Park

Capital Cost Components	Unit	Cost (Phase 1)	Cost (Phase 2)
Total Solar park Cost	**Rs Crores**		
Land cost[38] 23,100 Rs per acre per year with 5% escalation on base year (Escalation in every 2nd year)	Rs Crores	32.70	33.15
Site Development	Rs Crores	18.38	17.43
Road and Drainage	Rs Crores	82.89	19.64
Street lighting system	Rs Crores	3.56	0.72
Water Supply system	Rs Crores	0.68	0.68
Pooling[ii] substations	Rs Crores	196.43	196.43
400/220 kV substation cost[39]	Rs Crores	-	-
220 KV Transmission line cost	Rs Crores	26.25	26.25
Admin Building	Rs Crores	11.55	-
Substation and Transmission line for Solar park use	Rs Crores	8.14	-
Expenditure towards consultancy for ESIA, LTA	Rs Crores	53.65	53.65
One time expenditure towards land lease	Rs Crores	13.92	13.92
Total Costs	Rs Crores	**448.15**	**361.87**
Total costs (P1+P2)	Rs Crores	**810.02**	
IDC	Rs Crores	-	-
Total IDC (P1+P2)	Rs Crores	-	
Total cost (Phase 1 + Phase 2)	Rs Crores	**810.02**	
Subsidy Component (Subsidy[40] on project cost+ NPV of Land lease)			
	Rs Crores	**264.57**	
Project cost after subsidy (For solar park agency)			
Total cost (P1+P2)	**Rs Crores**	**545.45**	

It is considered that 400/220 KV GRID Substation and transmission line to Devanahalli hardware park is in POWERGRID scope. 20 Lakh/MW subsidy is considered for total solar park infrastructure cost. Total subsidy of 400 crore will be distributed in proportion to capital expenditures + NPV of land lease expenditure borne by solar park owner and capex borne by POWERGRID. For subsidy calculation, Net present value of land lease is included in project cost to have benefit of subsidy on land cost. Land lease is discounted at 9% to arrive at NPV of total land lease expense. After subsidy, Total cost of the solar Park (Phase 1+ Phase2) comes out to be Rs. 545.45 Crores or Rs. 27.27 Lakh /MW.

[38] Land lease is considered in capital cost only during construction period till Phase-1 COD and Phase-2 COD. After COD, Land cost is considered as an annual expense. For first 6 months, No land lease is considered as financial closure is attained after 6 months of project award.
[39] 400/220 KV Substation is in POWERGRID scope of work.
[40] Subsidy has been distributed between POWERGRID and solar park owner in proportion to capital cost of POWERGRID and (Capital cost + NPV of land lease) of Solar park owner

11.3.3. Financing assumptions

The proposed solar park has been assumed to be financed by upfront fee charged from developers. No debt is considered for solar park development activities.

11.3.4. Solar park assumptions

The solar park assumptions which have been discussed above along with other assumptions required to undertake financial feasibility of the proposed project has been summarized in the table below.

Table 48 : Base case assumptions for proposed solar Park project

Assumption Head	Sub-Head	Unit	Value
Installed Power Generation Capacity	Project capacity	MW	2000
Time-lines	Life of the project	Years	25
	No. of construction phases		2
	Capacity/Phase	MW	1000
	Project reward	Month	0th (For Timeline reference)
	Financial closure (Phase 1)	Month	6 (0th to 6th Month)
	Phase 1 Construction	Month	12 (6th Month to 18th Month)
	Solar Park construction (Phase 1)	Month	12 (18th Month to 30th Month)
	Financial closure (Phase 2)	Month	6 (6th to 12th Month)
	Phase 2 Construction	Month	12 (12th Month to 24th Month)
	Solar Park construction (Phase 2)	Month	12 (24th Month to 36th Month)
Financing Assumptions	Debt	%	0%
	Upfront fund (Investment by park agency from advance received)	%	100%
Returns expectation by solar park owner	Returns expectation	% p.a	16%
Taxes	Income Tax [41]	%	34.61%
	MAT	%	21.34%
Depreciation Rates (WDV) IT Act	Site Development (Only civil work)	%	10%
	Road and Drainage	%	10%
	Street light system	%	12.77%
	Water supply system	%	100%
	220 KV Substation	%	15%
	220KV Transmission line	%	15%
	400/220 KV Substation	%	15%
	Admin building	%	10%
	S/S and Transmission line for Solar park use	%	15%
	Transmission/Land rights	%	10%
	Salvage value for WDV	%	5%
'Depreciation rates (SLM) Company Act[42]	Site Development (Only civil work)	%	19%
	Road and Drainage	%	19%

[41] 'Basic tax to be reduced by 1.25% every year starting from FY2017 until Basic tax becomes 25%. Tax holidays have been considered as per section 80IA of income tax act.
[42] Depreciation rates for Straight line method have been calculated as per useful life given in company Act,2013.

	Street light system	%	9.5%
	Water supply system	%	6.3%
	220 KV Substation	%	4.3%
	220KV Transmission line	%	3.8%
	400/220 KV Substation	%	4.3%
	Admin building	%	9.5%
	S/S and Transmission line for Solar park use	%	4.3%
	Transmission/Land rights	%	3.8%
	Salvage value for SLM	%	5%
	Total expenses on wages	Rs. Crore/Yr	2.21 in FY 2018 (Escalated at 4% per annum)
	Substation O&M	Rs. Lakh /Year	48.1 in FY 2019 (Escalated at 5.72% per annum)
	Recurring logistic charges	Rs. Crore/Yr	1.08 in FY2018 (Escalated at 4% per annum)
	One time logistic charges	Rs. Crore/Yr	0.79
Land Lease Rs 23100 per acres with 5% escalation every second year on base year lease	Phase 1	Crores	32.7
	Phase 2	Crores	33.15
Revenue Inflation & Escalation	Appreciation in annual fee	%	5%
	Inflation in Annual fee (Base year – 2016-17)	%	8%
Working Capital	O&M Payables	Months	1
	Receivables for Debtors	Months	2
	Inventory	%	15% of O&M expenses
	Interest On Working Capital	%	13.5%
Return Expectation	Returns to solar park agency	%	16%

11.4. Sensitivity analysis of the proposed solar project Profitability and financial feasibility analysis

Sensitivities have been run on the proposed 2,000 MW solar park, by changing the returns expectations of Solar park owner.

Table 49 : Analysis of different scenarios for the proposed solar Park project

Returns expected by solar park agency (%)	Total Annual fee	Advance payment by developer
	Lakh/MW	Lakh/MW
14%	2.54	27.27
14.5%	2.57	27.27
15%	2.59	27.27
15.5%	2.62	27.27
16%	2.65	27.27

In all the sensitivity analyses, return expectations are taken as Input and highlighted in tables. Upfront payment and annual fee required to achieve returns expectations by solar park agency in base case scenario are highlighted as well. Advance payment by project developers is 27.27 Lakh/MW. Annual fee is considered with 5% annual escalation.

11.5. Conclusion

In the above financial analysis, Project cost to solar park agency and fee charged from project developer are calculated for 2000 MW solar park. In base case, Calculations are furnished to meet returns expectation of solar park agency i.e. 16%. Sensitivity analyses are done for returns expectations of 14%,14.5%,15%.15.5%,16% In base case scenario, Per MW cost for solar park owner and Fee collection from developer are as per table below:

Table 50 : Fee collection from developer

Expected Returns by solar park agency	Annual fee paid by developer (5% Annual escalation)	Upfront payment by developer to solar park agency
%	Lakh/MW	Lakh/MW
16%	2.65	27.27

Upfront payment from project developer will be utilized in solar park development expenditure, expenditure towards consultancy for ESIA, LTA and one time expenditure towards land lease by solar park agency. Annual fee will cater to recurring expenses over the project life. An annual escalation of 5% is also applicable on the annual fee.

Upfront payment and Annual fee payment from developer is 27.27 Lakh/MW and 2.65Lakh/MW at 16% returns expectation by solar park agency. NPV of annual and upfront payment is 62.36 Lakh/MW (Annual fee paid by developers is discounted at 10% for NPV calculation purpose).

For solar park implementation agency, Cost/MW for solar park infrastructure (Excluding annual land lease payment) is 27.27 lakh/MW. Additionally, advance payment from developers will contribute to 100% of the capital cost requirement after subsidy. Upfront payment and annual payment figures are subject to change as per changes in assumptions.

12. Implementation Schedule

Taking in to account the experience of setting up large scale solar PV power projects in India (i.e. up to 100 MW capacity); it has been observed that the land acquisition is the most important dimension which governs the project implementation schedule. In India; the current market practice for setting up of solar PV power projects is around 13 months from the date of signing of the Power Purchase Agreement.

The Implementation of Solar Park can be done in Phases i.e. Block wise completion (250 MW each) which will allow to use common manpower and facilities at the Solar Park for the contractors. A cumulative duration of Two Years could be taken for developing the complete Solar Park of the capacity of 2000 MW. The activities could be segmented in 8 quarters of three months each.

The Level-1 project implementation schedule has been presented in Table 51 below.

Table 51. Level-1 Project Implementation Schedule of Solar Park of 2000 MW Capacity

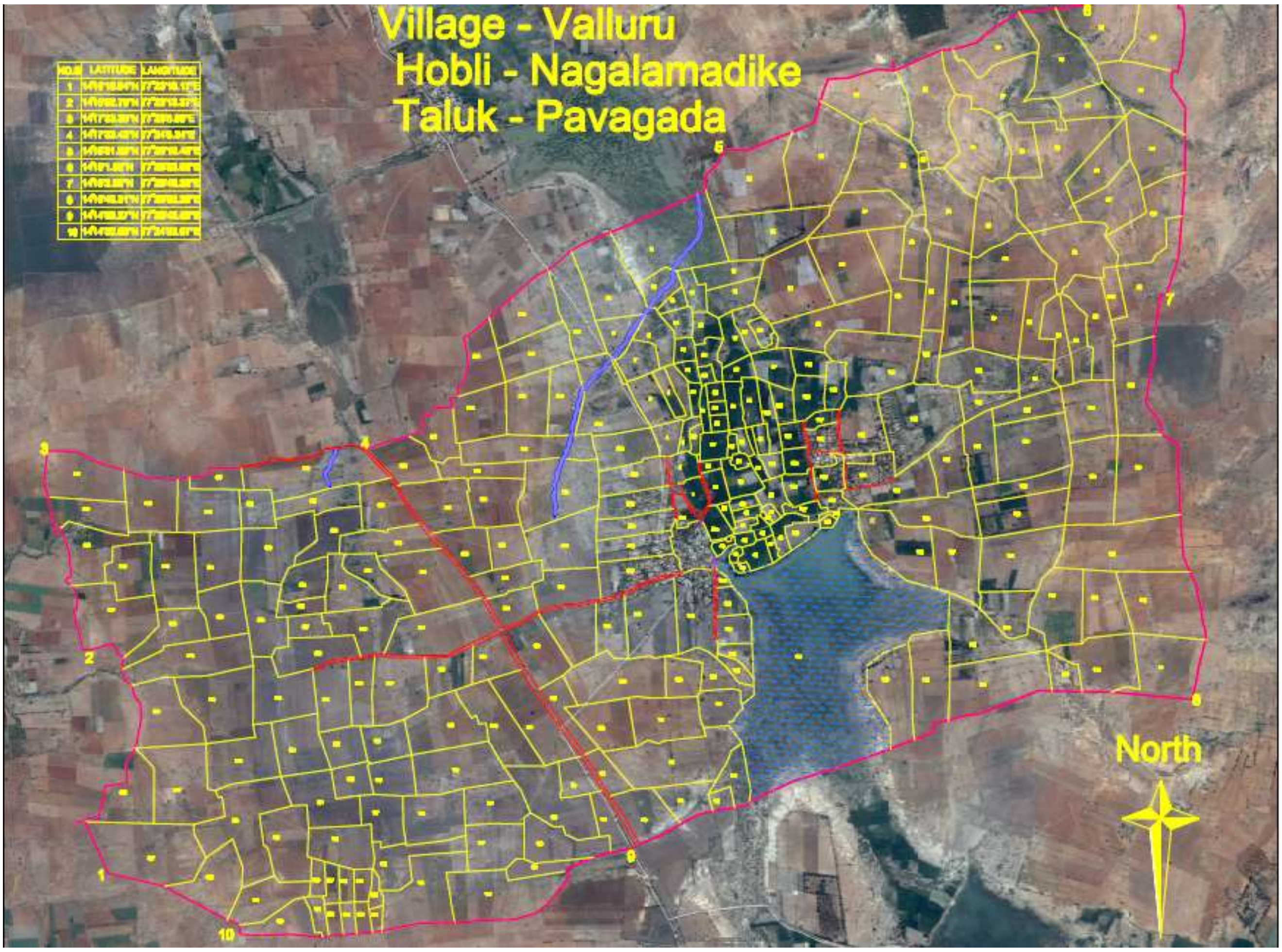
Milestones	Q-1	Q-2	Q-3	Q-4	Q-5	Q-6	Q-7	Q-8	Q-9	Q-10	Q-11	Q-12
Land acquisition and financial closure												
Park Planning and Feasibility Study												
Due Diligence Study by Lender engineer												
Solar park development Phase -1												
Solar park development Phase -2												
Construction of 1000 MW (4 x 250 MW)Plants Phase 1												
Construction of 1000 MW (4 x 250 MW)Plants Phase 1												

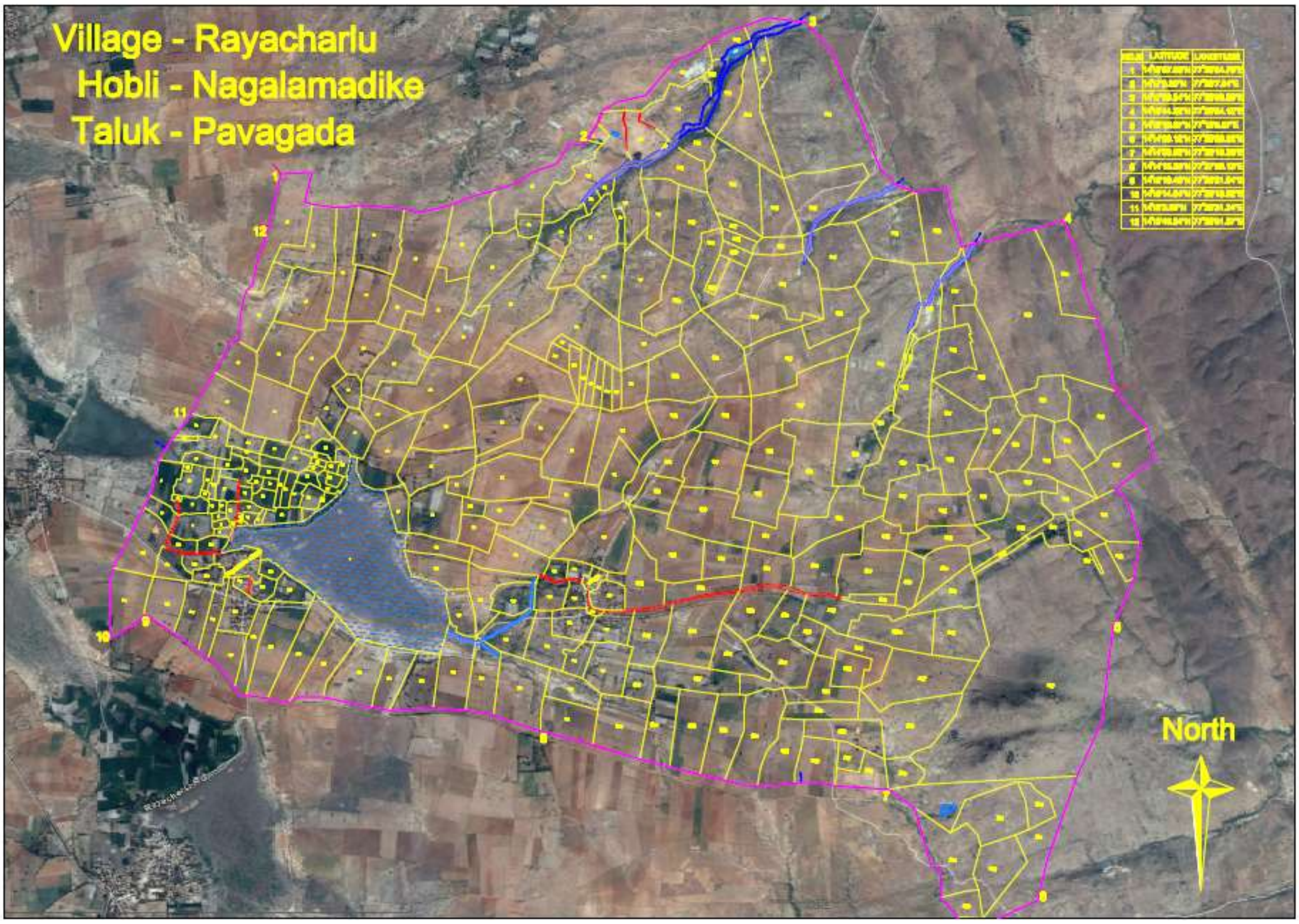
13. Key Recommendations

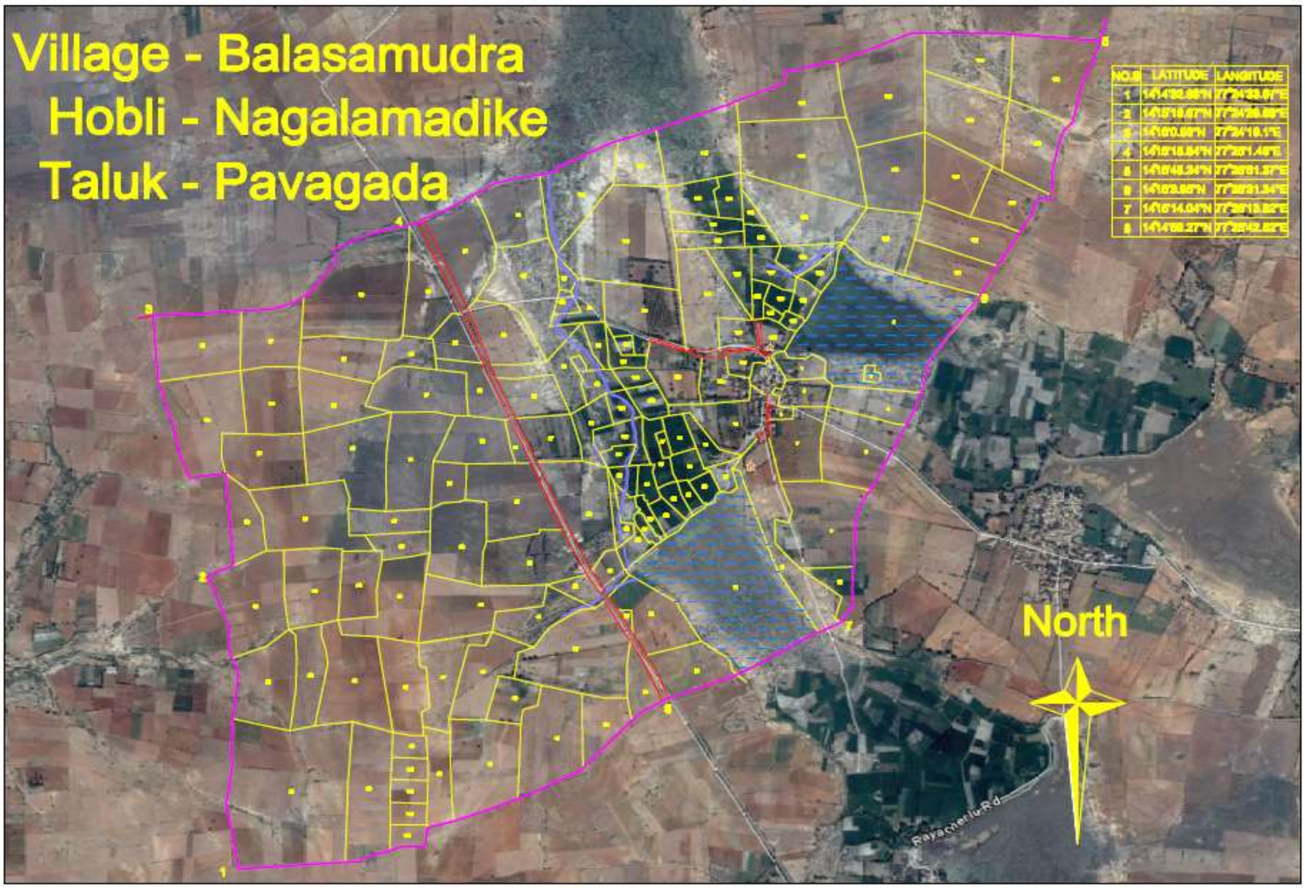
At the present stage the report is based on the Level-1 data of the site hence there are several considerations taken for development of the Detailed Project Report of the Solar Park of 2000 MW capacity. The phase wise development approach (in the lot of 500 MW each) will be techno-commercially viable. Following considerations are essentials to address at the stage of detailed engineering and implementation of the Solar Park;

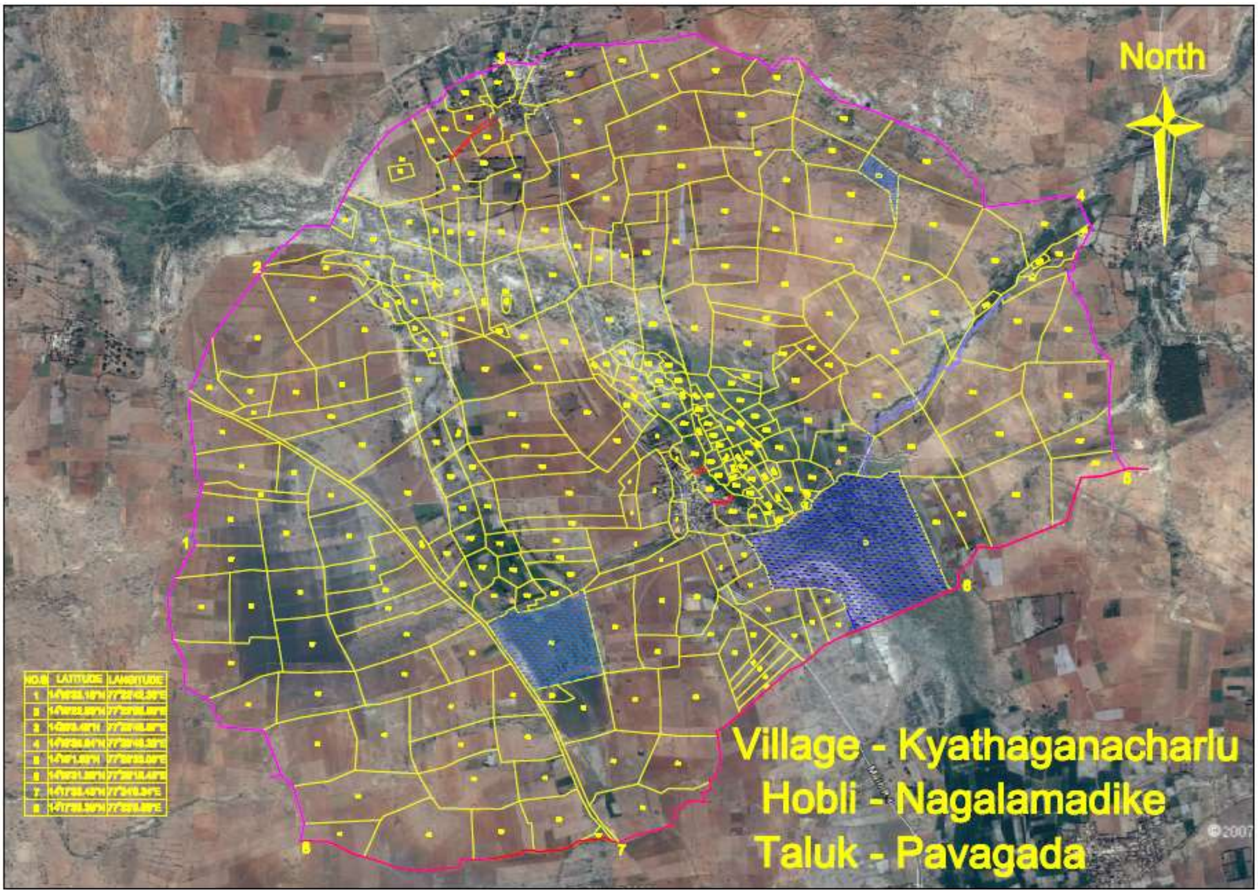
- Detailed geo-technical investigations of the entire land selected for development for Solar Park need to be done
- Soil testing at multiple locations (minimum one bore within the area of 50 acres) is essential towards designing of the civil structures along with the selection of the construction material required
- At least one Automatic Weather Station need to be implement at the site at the stage of starting the work for development of Solar Park at the site from which Project Developers can get realistic clarity about the incident solar irradiance at the site along with associated meteorological parameters.
- The details of high and low flood level is essential from the point of view of reviewing the flooding or water logging history within the premises of the selected land for Solar Park
- The geotechnical assessment is essential to develop the drainage system over the Solar Park
- More clarity on the water source is essential. At present the ground water has been considered for development of Solar Park and has been laid out in developer scope of work.
- In case the ground water is selected the detailed hydrological study of the vicinity is recommended which needs to address the ground water levels along with its quality (TDS) from the point of view to use for module cleaning without or with less treatment.
- KSPDCL needs to explore the possibility of arrange surface water for operation and maintenance arrangement of the project from the point of view of environmental sustainability.
- Few innovative ideas could be explored at Solar Park in order to showcase the approach of clean energy production for sustainable development;
    - Use solar street lighting across the solar park. This could be made a mandatory condition to project developers during the stage of project allocation
    - Use of solar energy powered vehicles (autos and cars) using batteries in the park premises. Once the park is implemented; the inside transportation could be shifted to solar powered vehicles. The charging stations for the batteries of the vehicles could be developed at the stops of the outer roads of the park. This approach will create direct employment generation as well.
- Dimensions of further cost optimization;
    - Warehouses could be eliminated as each solar PV power project will be comprising its own warehouse
    - Cost optimization is possible in case of the execution of bore wells for water supply

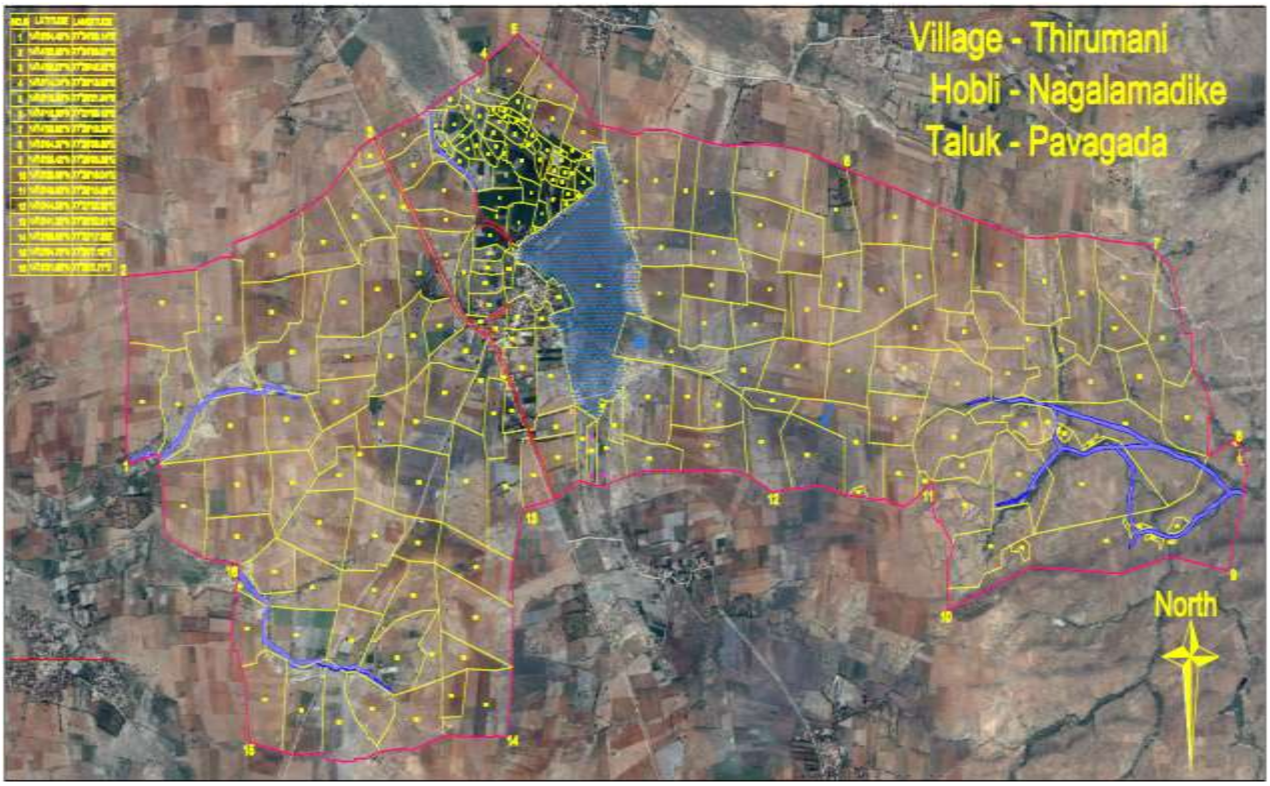
Annexure 1: Satellite Images of the Villages under Solar Park




Village - Rayacharlu
Hobli - Nagalamadike
Taluk - Pavagada
North


Village - Balasamudra
Hobli - Nagalamadike
Taluk - Pavagada
North


North
Village - Kyathaganacharlu
Hobli - Nagalamadike
Taluk - Pavagada


Village - Thirumani
Hobli - Nagalamadike
Taluk - Pavagada
North

Annexure 2: PVSYST Simulation of 50 MW Solar PV Plant using Multi-Crystalline Solar PV Technology

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Grid-Connected System: Simulation parameters

Project :	**Grid-Connected Project at Tumkur**			
Geographical Site	**Tumkur**		Country	**India**
Situation	Latitude	14.3°N	Longitude	77.4°E
Time defined as	Legal Time	Time zone UT+6	Altitude	571 m
	Albedo	0.20		
Meteo data:	**Tumkur**	Synthetic - Meteonorm file		

Simulation variant :	**New simulation variant**			
	Simulation date	10/06/15 17h35		

Simulation parameters

Collector Plane Orientation	Tilt	15°	Azimuth	0°
Models used	Transposition	Perez	Diffuse	Erbs, Meteonorm
Horizon	Free Horizon			
Near Shadings	No Shadings			

PV Array Characteristics

PV module Si-poly	Model	**CS6X - 300P**		
	Manufacturer	Canadian Solar Inc.		
Number of PV modules	In series	19 modules	In parallel	8772 strings
Total number of PV modules	Nb. modules	166668	Unit Nom. Power	300 Wp
Array global power	Nominal (STC)	**50000 kWp**	At operating cond.	44553 kWp (50°C)
Array operating characteristics (50°C)	U mpp	604 V	I mpp	73705 A
Total area	Module area	**319807 m²**	Cell area	292082 m²
Inverter	Model	**Sunny Central 1000CP XT**		
	Manufacturer	SMA		
Characteristics	Operating Voltage	596-850 V	Unit Nom. Power	1000 kW AC
Inverter pack	Nb. of inverters	50 units	Total Power	50000 kW AC

PV Array loss factors

Array Soiling Losses			Loss Fraction	2.0 %
Thermal Loss factor	Uc (const)	29.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	0.14 mOhm	Loss Fraction	1.5 % at STC
Module Quality Loss			Loss Fraction	-0.4 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Incidence effect, ASHRAE parametrization	IAM =	1 - bo (1/cos i - 1)	bo Param.	0.00

User's needs : Unlimited load (grid)

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Grid-Connected System: Main results

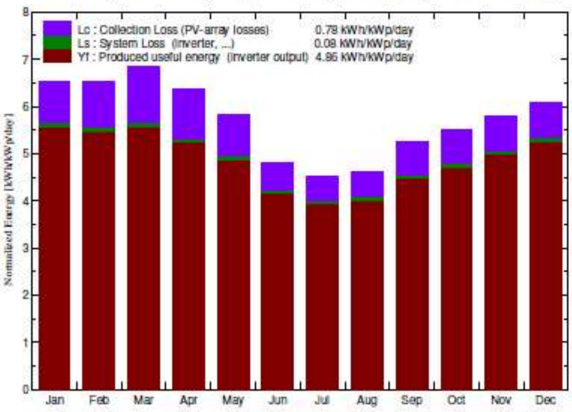
Project : **Grid-Connected Project at Tumkur**

Simulation variant : **New simulation variant**

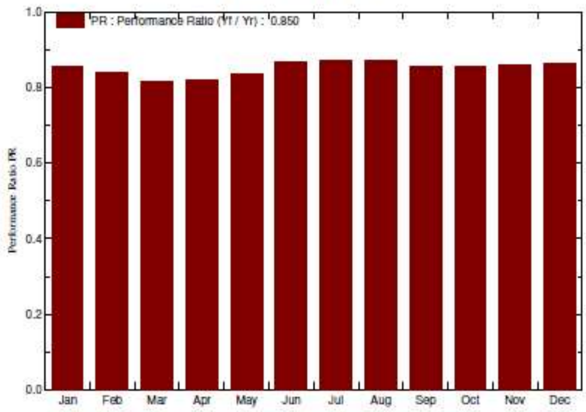
Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	15°	azimuth	0°
PV modules	Model	CS6X - 300P	Pnom	300 Wp
PV Array	Nb. of modules	166668	Pnom total	**50000 kWp**
Inverter	Model	Sunny Central 1000CP XT	Pnom	1000 kW ac
Inverter pack	Nb. of units	50.0	Pnom total	**50000 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**88661 MWh/year**	Specific prod.	1773 kWh/kWp/year
	Performance Ratio PR	85.0 %		

Normalized productions (per installed kWp): Nominal power 50000 kWp



Performance Ratio PR



New simulation variant

Balances and main results

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	EffArrR %	EffSysR %
January	170.9	24.19	201.9	197.9	8788	8642	13.61	13.38
February	164.4	26.68	183.1	179.4	7818	7689	13.35	13.13
March	202.8	29.55	211.9	207.4	8802	8656	12.99	12.77
April	195.1	30.59	191.6	187.6	7994	7859	13.04	12.82
May	192.7	30.05	180.1	176.4	7675	7547	13.32	13.10
June	156.2	27.15	144.5	141.5	6364	6259	13.77	13.54
July	149.4	26.54	139.9	136.9	6204	6101	13.87	13.64
August	148.8	25.85	143.4	140.3	6346	6241	13.84	13.61
September	155.9	25.75	157.5	154.2	6854	6738	13.61	13.38
October	159.4	25.70	171.0	167.5	7441	7311	13.61	13.37
November	152.8	23.88	173.8	170.2	7612	7480	13.70	13.46
December	158.4	23.22	188.4	184.6	8280	8140	13.74	13.51
Year	2006.9	26.59	2087.1	2044.1	90178	88661	13.51	13.28

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

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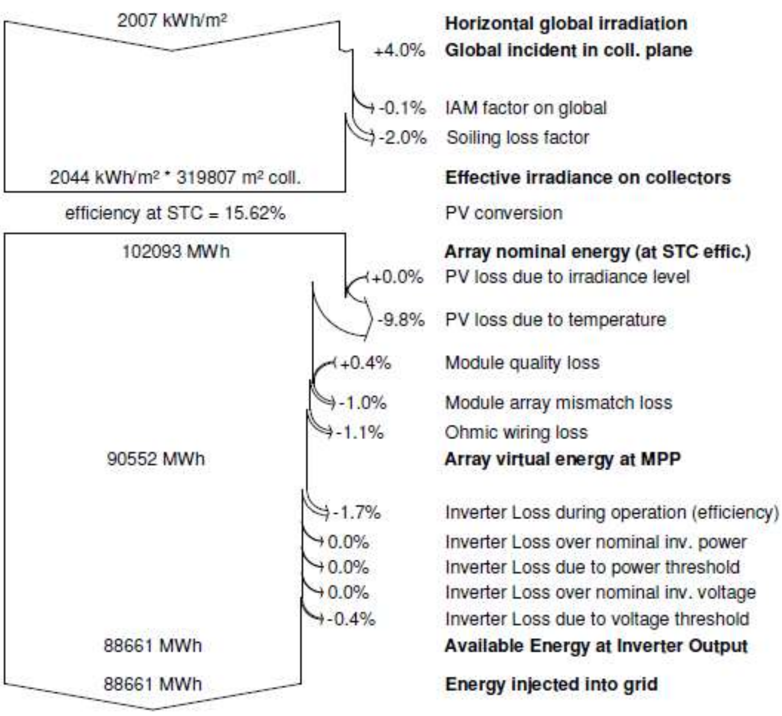
Grid-Connected System: Loss diagram

Project : **Grid-Connected Project at Tumkur**

Simulation variant : **New simulation variant**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	15°	azimuth	0°
PV modules	Model	CS6X - 300P	Pnom	300 Wp
PV Array	Nb. of modules	166668	Pnom total	**50000 kWp**
Inverter	Model	Sunny Central 1000CP XT	Pnom	1000 kW ac
Inverter pack	Nb. of units	50.0	Pnom total	**50000 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



Annexure 3: PVSYST Simulation of 50 MW Solar PV Plant using Thin Film (CdTe) Solar PV Technology

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Grid-Connected System: Simulation parameters

Project :	**Grid-Connected Project at Tumkur**			
Geographical Site	**Tumkur**		Country	**India**
Situation	Latitude	14.3°N	Longitude	77.4°E
Time defined as	Legal Time	Time zone UT+6	Altitude	571 m
	Albedo	0.20		
Meteo data:	**Tumkur**	Synthetic - Meteonorm file		

Simulation variant :	**New simulation variant**			
	Simulation date	10/06/15 17h45		

Simulation parameters

Collector Plane Orientation	Tilt	15°	Azimuth	0°
Models used	Transposition	Perez	Diffuse	Erbs, Meteonorm
Horizon	Free Horizon			
Near Shadings	No Shadings			

PV Array Characteristics

PV module CdTe	Model	**FS-3100-PLUS**		
	Manufacturer	First Solar		
Number of PV modules	In series	15 modules	In parallel	33333 strings
Total number of PV modules	Nb. modules	499995	Unit Nom. Power	100 Wp
Array global power	Nominal (STC)	**50000 kWp**	At operating cond.	46283 kWp (50°C)
Array operating characteristics (50°C)	U mpp	651 V	I mpp	71122 A
Total area	Module area	**359996 m²**	Cell area	326307 m²
Inverter	Model	**Sunny Central 1000CP XT**		
	Manufacturer	SMA		
Characteristics	Operating Voltage	596-850 V	Unit Nom. Power	1000 kW AC
Inverter pack	Nb. of inverters	50 units	Total Power	50000 kW AC

PV Array loss factors

Array Soiling Losses			Loss Fraction	2.0 %
Thermal Loss factor	Uc (const)	29.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	0.14 mOhm	Loss Fraction	1.4 % at STC
Module Quality Loss			Loss Fraction	2.5 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Incidence effect, ASHRAE parametrization	IAM =	1 - bo (1/cos i - 1)	bo Param.	0.00

User's needs : Unlimited load (grid)

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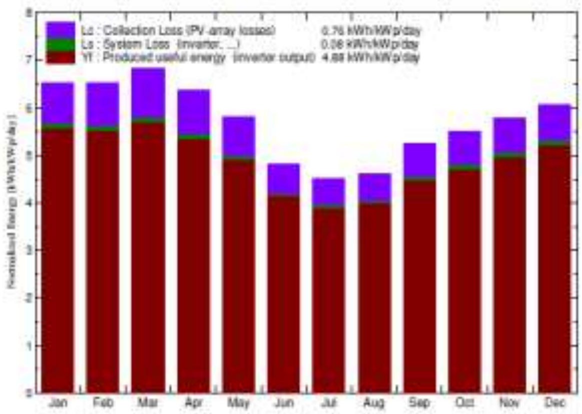
Grid-Connected System: Main results

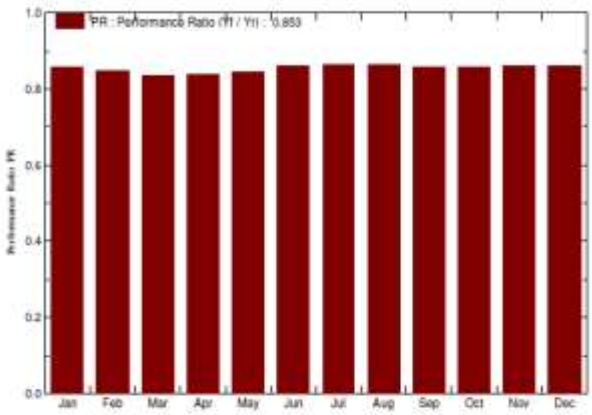
Project : **Grid-Connected Project at Tumkur**

Simulation variant : **New simulation variant**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	15°	azimuth	0°
PV modules	Model	FS-3100-PLUS	Pnom	100 Wp
PV Array	Nb. of modules	499995	Pnom total	**50000 kWp**
Inverter	Model	Sunny Central 1000CP XT	Pnom	1000 kW ac
Inverter pack	Nb. of units	50.0	Pnom total	**50000 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**89025 MWh/year**	Specific prod.	1781 kWh/kWp/year
	Performance Ratio PR	85.3 %		





New simulation variant

Balances and main results

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	EffArrR %	EffSysR %
January	170.9	24.19	201.9	197.9	8799	8651	12.10	11.90
February	164.4	26.68	183.1	179.4	7894	7762	11.98	11.77
March	202.8	29.55	211.9	207.4	9014	8863	11.82	11.62
April	195.1	30.59	191.6	187.6	8164	8024	11.83	11.63
May	192.7	30.05	180.1	176.4	7740	7611	11.94	11.74
June	156.2	27.15	144.5	141.5	6326	6222	12.16	11.96
July	149.4	26.54	139.9	136.9	6150	6048	12.21	12.01
August	148.8	25.85	143.4	140.3	6300	6195	12.20	12.00
September	155.9	25.75	157.5	154.2	6861	6745	12.10	11.90
October	159.4	25.70	171.0	167.5	7448	7317	12.10	11.89
November	152.8	23.88	173.8	170.2	7601	7469	12.15	11.94
December	158.4	23.22	188.4	184.6	8259	8118	12.18	11.97
Year	2006.9	26.59	2087.1	2044.1	90556	89025	12.06	11.85

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

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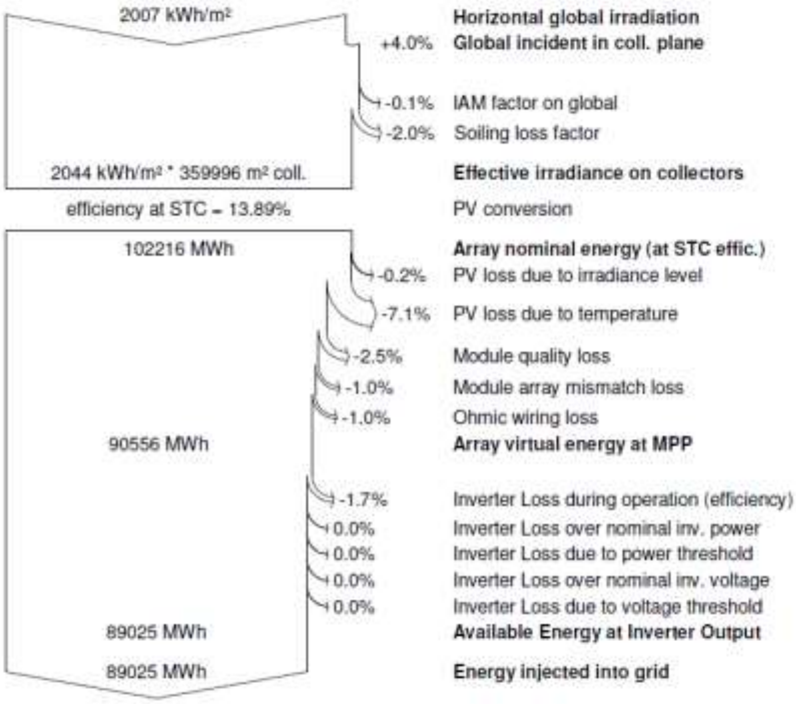
Grid-Connected System: Loss diagram

Project : **Grid-Connected Project at Tumkur**

Simulation variant : **New simulation variant**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	15°	azimuth	0°
PV modules	Model	FS-3100-PLUS	Pnom	100 Wp
PV Array	Nb. of modules	499995	Pnom total	**50000 kWp**
Inverter	Model	Sunny Central 1000CP XT	Pnom	1000 kW ac
Inverter pack	Nb. of units	50.0	Pnom total	**50000 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



Annexure 4: IFC Performance Standards and Applicability with Solar Park

Performance standard	Description	Applicability	Requirements
PS 1: Assessment and Management of Environmental and Social Risks and Impacts;	PS 1 establishes the importance of integrated assessment to identify the environmental and social impacts, risks, and opportunities of projects; effective community engagement through disclosure of project-related information and consultation with local communities on matters that directly affect them; the client's management of environmental and social performance throughout the life of the project.	The PS 1 is applicable to projects with environment and/or social risks and/or impacts. The proposed project is a solar power project and will have environmental and social impacts such as stress on existing water resources, generation of noise, construction activities etc . ***PS 1 is therefore applicable for the project.***	KREDL shall conduct a process of environmental and social assessment. There is already an established Environment and Social Management System (ESMS) incorporating the following elements: • Policy; • Identification of risks and impacts; management programs; • Emergency preparedness and response; • Stakeholder engagement; and • Monitoring and review.
PS 2: Labour and Working Conditions	PS 2 recognizes that the pursuit of economic growth through employment creation and income generation should be accompanied by protection of the fundamental rights of workers. The objectives of the PS:2 are: • To promote the fair treatment, non-discrimination, and equal opportunity of workers. • To establish, maintain, and improve the worker-management relationship. • To promote compliance with national employment and labour laws. • To protect workers, including vulnerable categories of workers such as children, migrant workers, workers engaged by third parties, and workers in the client's supply chain. • To promote safe and healthy working conditions, and the health of workers. • To avoid the use of forced labour.	The PS:2 applies to workers directly engaged by the client (direct workers), workers engaged through third parties (contracted workers), as well as workers engaged by the client's primary suppliers (supply chain workers). The proposed project will involve employment of direct and contracted workers during construction and operation phases. ***PS 2 is therefore applicable for the proposed project.***	The project proponent will formulate HR policies and procedures and grievance redressal mechanisms for management of worker relationship in compliance with IFCs requirements. KREDL shall provide reasonable working conditions and terms of employment for both direct and contracted workers through contractor agreements. The proponent shall ensure measures to • Prevent child labour, forced labour, and discrimination. Freedom of association and collective bargaining shall be provided. • Wages, work hours and other benefits shall be as per the National labour and employment laws.
PS 3: Resource Efficiency and	PS 3 recognizes that increased economic activity and urbanization often generate	The PS-3 is applicable to projects resulting in increased levels of pollution and requires	KREDL shall assess the impacts and risks associated with the

Pollution Prevention	increased levels of pollution to air, water, and land, and consume finite resources in a manner that may threaten people and the environment at the local, regional, and global levels.	project to avoid, minimize, or reduce adverse impacts on human health and environment by adopting pollution preventive and control technologies throughout the Project life cycle The proposed project is a clean energy project and will not have major pollution sources associated with it. The construction works for the development of project will result in generation of wastes like wastewater, waste oil and construction debris .The operation phase will result in generation of minor quantities of waste such as transformer oil. ***PS 3 is therefore applicable for the proposed project.***	generation, use, storage, release, and/or disposal of pollutants during the ESIA, planned as part of the ESMS, and implement them as per the Action Plan The project proponent shall plan and implement pollution control measures right from the conception stage. Practices like minimal release of waste, handling of hazardous waste, safe disposal of waste, waste water management etc. shall be considered prior for each phase.
PS 4: Community Health, Safety, and Security	PS 4 recognizes that project activities, equipment, and infrastructure can increase community exposure to risks and impacts. Its main stress is to ensure that the safeguarding of personnel and property is carried out in accordance with relevant human rights principles and in a manner that avoids or minimizes risks to the Affected Communities.	This performance Standard is applicable to projects which entail potential risks and impacts to the health and safety of affected communities from project activities. The proposed project will involve transportation of construction material and movement of construction machinery which may pose safety risks to the affected communities. ***The PS 4 is therefore applicable for the proposed project.***	The proponent shall evaluate the risks associated with the project activities and will devise measures to address these impacts through the Environment and Social Management System.
PS 5: Land Acquisition and Involuntary Resettlement	PS 5 recognizes that project-related land acquisition and restrictions on land use can have adverse impacts on communities and persons that use this land. Its main aim is to anticipate and avoid, or where avoidance is not possible, minimize adverse social and economic impacts from land acquisition or restrictions on land use by providing compensation for loss of assets at replacement cost and ensuring that resettlement activities are implemented with appropriate disclosure of Information, consultation, and the informed participation of those affected.	The PS 5 is applicable when there is physical and/or economic displacement because of the project. The land for the proposed project comprises of uncultivable revenue land which has been leased by the Government. The land was not being used by the community for any purpose and no encroachments were observed on the land. *PS 5 is therefore NOT applicable for the proposed project.*	

PS 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources	PS 6 recognizes that protecting and conserving biodiversity, maintaining ecosystem services, and sustainably managing living natural resources are fundamental to sustainable development. This standard is aimed to promote the sustainable management of living natural resources through the adoption of practices that integrate conservation needs and development priorities.	PS 6 is applicable to projects located in modified, natural, and critical habitats; or projects that potentially impact on or are dependent on ecosystem services or that include the production of living natural resources . The proposed project does not involve any diversion of forest land. The plant sites are devoid of vegetation. The project activities are not likely to have any impact on the ecology. The proposxed project will involve additional traffic movement which may impact the higher fauna. ***PS 6 is applicable to the project.***	The proponent shall evaluate the risks associated with the project activities and will devise measures to address these impacts through the Environment and Social Management System.
PS 7: Indigenous Peoples	PS 7 recognizes that Indigenous Peoples, as social groups with identities that are distinct from mainstream groups in national societies, are often among the most marginalized and vulnerable segments of the population. In many cases, their economic, social, and legal status limits their capacity to defend their rights to, and interests in, lands and natural and cultural resources, and may restrict their ability to participate in and benefit from development.	This Performance Standard applies to communities or groups of Indigenous Peoples whose identity as a group or community is linked, to distinct habitats or ancestral territories and the natural resources therein. The project area or its surroundings does not support indigenous people. No material degradation or adverse impact is expected on land resources on which indigenous peoples are dependent ***PS 7 is therefore NOT applicable for the proposed project.***	
PS 8: Cultural Heritage	PS 8 recognizes the importance of cultural heritage for current and future generations. Consistent with the Convention concerning the Protection of the World Cultural and Natural Heritage, this Performance Standard aims to ensure that clients protect cultural heritage in the course of their project activities. In addition, the requirements of this Performance Standard on a project's use of cultural heritage are based in part on standards set by the Convention on Biological Diversity.	This PS is applicable when tangible forms of cultural heritage, unique natural features or tangible objects that embody cultural values and certain instances of intangible forms of culture are impacted or are proposed to be used for commercial purposes. There are no culturally important sites in or around the project site. ***PS 8 is therefore NOT applicable for the proposed project.***	

Annexure 5: Equator Principles

- **Principle 1: Review and Categorization of the Project -** Equator Principles Financial Institutions (EFPIs) are required to categories projects according to the magnitude of its potential impacts based on the environmental and social screening criteria of IFC. Projects are designated as Category A, B or C when it represents, respectively, a high, medium or low level of risk.

- **Principle 2: Social and Environmental Assessment -** Projects Categorized as A or B requires the borrower to conduct an ESA to assess all possible environmental and social impacts and risks.

- **Principle 3: Applicable Environmental and Social Standards -** For projects located in non-OECD countries, the assessment should refer to the IFC Performance Standards and then the applicable industry specific guidelines, i.e. the World Bank Group EHS Guidelines.

- **Principle 4: Action Plan (AP) and Management System -** For all Category A or B projects located in non- OECD countries, the borrower must prepare an Action Plan which addresses the relevant findings of the ESA.

- **Principle 5: Consultation and Disclosure -** For all Category A projects and where appropriate Category B, the borrower or third party expert must have consulted with project affected communities in a structured and culturally appropriate manner. In projects with significant impacts on affected communities, the process must ensure their free, prior and informed consultation (FPIC) and facilitate the informed participation.

- **Principle 6: Grievance Mechanism -**For all Category A projects and where appropriate Category B, located in non-OECD countries, the borrower has to ensure that the consultation, disclosure and community engagement continues throughout the construction and operation of the project, scaled to the level of risks and impacts involved at different stages, and establish a grievance mechanism as a part of the management system.

- **Principle 7: Independent Review -** For all Category A projects and where appropriate Category B, an independent expert (environmental or social) not directly associated with the borrower will review the Assessment, Action Plan and consultation process to assist EPFI's Due-Diligence and EP compliance.

- **Principle 8: Covenants -** The borrower will covenant the following compliance requirements in the financing documents:
  - To comply with all the relevant host country social and environmental laws, regulations and permits in all material respects;
  - To comply with Action Plan (where applicable) during construction and operation of the project in all material aspects;
  - To provide periodic reports in a format agreed with EPFIs (frequency to be agreed, but not less than annually) that documents compliance against APs, as well as against local laws and permits; and
  - To decommission the facilities in accordance with an agreed decommissioning plan.

- **Principle 9: Independent Monitoring and Reporting -** To ensure ongoing monitoring and reporting over the life of the project, the EPFIs will, for all A Category projects and where appropriate Category B, require appointment of an independent environmental and/or social expert, or require that the borrower retain qualified and experienced external experts to verify its monitoring information, to be shared with the EPFIs.
- **Principle 10: EPFI Reporting -** Each EPFI is committed to issuing periodic public reports about project implementation processes and experience with due regard for appropriate project confidentiality.

Annexure 6: Plant Design and Layout- Sample 50 MW (Minimum Capacity Size Project in Solar Park)

The design of a PV plant involves a series of compromises aimed at achieving the lowest possible levelised cost of electricity. Choosing the correct technology (especially modules and inverters) is of central importance. Selecting a module requires assessment of a complex range of variables. At the very least, this assessment would include cost, power output, benefits / drawbacks of technology type, quality, spectral response, performance in low light, nominal power tolerance levels, degradation rate and warranty terms. The factors to consider when selecting inverters include compatibility with module technology, compliance with grid code and other applicable regulations, inverter-based layout, reliability, system availability, serviceability, modularity, telemetry requirements, inverter locations, quality and cost.

The electrical design of a PV project can be split into the DC and AC systems with DC system comprising of Array(s) of PV modules, Inverters, DC cabling (module, string and main cable), DC connectors (plugs and sockets), Junction boxes/combiners, Disconnects/switches, Protection devices, Earthing. The AC system includes AC cabling, Switchgear, Transformers, Substation, Earthing and surge protection. Selection of suitable technology and optimisation of the main electrical systems is clearly vital. Alongside, detailed consideration should be given to the surrounding infrastructure, including the mounting structures, control building, access roads and site security systems. While these systems should be relatively straightforward to design and construct, errors in these systems can have a disproportionate impact on the project.A thorough financial and technical analysis as well as prior experience with performance of solar PV plants is required to determine the most cost-effective technology options, suited to a particular site

Plant Layout

While preparing the layout of Solar PV Plant, the considerations which have been taken into account are site coordinates, size and topography of land, approach to the site, row to row distance, row to row shading of modules, wind directions, Seismic Zone, water supply, tracking arrangement (if opted), selection of modules, inverters, inverter transformers, selection of Power Transformer, other electrical equipments, optimization of cables, selection of Power evacuation voltage, power evacuation corridor, etc. The layout of the array structures shall be so designed that it shall occupy minimum space without sacrificing the output of solar PV modules. The Proposed Solar Park shall be having 50 MW units. For each 50 MW Plant the Modules with Multi-Crystalline Technology/ This film shall be selected; The DC Power generated from the DC Field shall be converted into 405V, 50Hz AC, three phase using solar Inverters and further stepped up to 66kV using Inverter Transformers. 66KV Switchyard /Double Pole Structure have been envisaged for evacuation of power from the plant.

DC Field Layout

The 2000 MW Solar park will be a combination of 40X50 MW units. Each unit shall consists 50 nos. solar Inverters, 25 nos., 2 MVA Inverter Transformer, and associated solar PV Array.. The DC and AC field layout shall be designed based on the these rating. In this section we are discussing about the AC and DC layout of 50 MW unit considering Multi Crystalline and Thin Film technology. Other unit may follow any of these technology.

Module and String

Table below represents the models and manufacturer of solar PV Modules selected for 50 MW plant for multi crystalline and thin file technology:

Table 52. Solar PV Modules Details

S No.	Manufacture	Model	kW Rating

1.	Canadian Solar Inc (mutli- Crystallaine)	CS6X - 300P	300 Wp
2.	First Solar (Thin film)	FS-3100 Plus	100 Wp

String Monitoring Boxes /Combiner Box

Since the total output current of all the strings shall be very high, these strings will be divided into several sub groups and connected to String Monitoring Boxes (SMB)/Combiner Box and the String Monitoring Boxes /Combiner Box will be connected to the inverter input.

Inverter

The Central Type Inverter of SMA Model no. Sunny Central 1000CPXT of rating 1 MW has been proposed for the 50 MW Plant. A total of 50 Inverters shall be used for 50 MW Unit. The summary of equipment used in DC Layout is summarized in Table 53.

Table 53. Summary of DC Field Layout

S No.	Parameters	Value
1.	Total Rated capacity of Solar PV Power Plant at STC	50 MW AC
2.	Rated capacity of module	300Wp for Multi Crystalline or 100Wp for Thin Film
3.	No. of Modules	166668 for Multi Crystalline/ 499995 for Thin Film
4.	Number of modules in series in a string	19 for Multi Crystalline/15 for Thin Film
5.	Total no of Strings	8772 for Multi-Crystalline(176 strings per inverter)/ 33333 for Thin Film (667 per Inverter)
6.	No. of String Monitoring Box (SMB)/Combiner Box	Shall be decided during Detailed Engineering Stage
7.	Total no. of inverter units	50 nos. of 1000 kW
8.	Type and Make of Inverter	Sunny Central 1000 CPXT of SMA

AC Field Layout

There shall be a total of 25nos. Inverter Stations and one (1) no Main Control Building for 50 MWp Unit. One no 66KV Switchyard / Double Pole Structure shall be provided for power evacuation.

Inverter Stations

Each Inverter station out of 25 nos. Inverter Stations, shall consist of 2 nos. of 1000kW Inverter, one (1) no LV Distribution Board, Inverter Transformer Protection Panel, UPS and Battery etc. Outdoor equipment adjacent to the Inverter Stations shall be three winding 2MVA, 66KV/0.405-0.405kV Inverter Transformer, 66KV Isolators, 66KV Circuit Breakers, associated Instrument Transformers, Lightning Arrestors & related hardware etc. LT cables shall be provided to interconnect LV winding of Inverter Transformer and Solar Inverters. The ventilation system with air ducts shall be provided in the Inverter Room. Fire protection and Detection system shall be provided in Inverter Room.

Main Control Building

There shall be one no Main Control Building for each 50 MW Plant. The Main Control Building shall consist of Control Room, 66KV Switchgear Room, Auxiliary Room, Battery Room and Toilets. The size of the Main Control Room Building shall be decided during detailed engineering stage. Air conditioning shall be provided in Control Room and Ventilation System shall be provided in 66KV Switchgear Room, Auxiliary Room, Battery Room and Toilets. Fire protection and Detection system shall be provided in Main Control Building.

66KV Switchyard/66KV Double Pole Structure

There shall be one no 66KV Switchyard or 66KV Double Pole Structure for each 50 Mw Unit for evacuation of Power generated from the Plant. The nos. of bay in case 66KV Switchyard shall be envisaged are as follows:

- 1 nos. incoming bays from 66KV Switchgear located in Main Control Room Building;
- 2 nos outgoing bays for 66KV underground cable
- 1 Bay for Common Auxiliary Transformer

The 66KV Switchyard shall be provided with following equipment and accessories;

- Circuit Breaker
- Current Transformers
- Voltage Transformer
- Lightning Arresters
- Isolators
- Aluminum Conductor Steel Reinforced (ACSR) Conductors/ Conductor Hardware & Connectors as required
- Bus Post Insulators as required
- Control, Metering and Protection system
- Tariff Metering Panel
- Common Auxilary Transformer

Location of the control building and transformers are optimized to reduce transmission loss in DC wiring and AC transmission from the inverters. Gatehouse has been provided at the entry to the site through the existing roads.

Table 54. Summary of AC Field Layout (1000 MWp)

S No.	Parameter	Value
1.	No of Inverter Station	25
2.	No of Inverter in Inverter Stations (1-165)	2
3.	Type of Inverter Transformer	Outdoor, three winding,
4.	No of Inverter Transformers	25
5.	No of Unit Auxiliary Transformer	1 for each Inverter Station or shall be decided during detail engineering

Plant Boundary and Roads

The plant boundary shall have wall for safety and to avoid the entry of animals in to the plant site. There shall be no trespass in to the power plant area except the security personnel, technicians and engineers on duty, permitted visitors and inspection team as and when required. The plant main entrance gate shall be 9m wide for vehicles provided with 1.75m wide wicket gate for pedestrians and visitors. However the final dimensions of Main Gate and wicket gate shall be decided during detail engineering stage. The height of gate shall be kept equal to the height of wall provided with double leafs and lean concrete surface at bottom for swing area including proper locking system. A 5m wide continuous road connecting all the Inverter Rooms, Main Control Building, Administration Building and Main Gate, Pump House and 400kV Switchyard is running across the plant.

Administrative Building

The Indicative size of various rooms for Administrative Building shall be as follows; however actual size shall be decided during detailed engineering stage.

- Store Room - 12.0mx8.0m
- Office Room - 15.0mx15.0m
- Meeting Room/Hall -10.0mx6.0m
- Document/Archive Room - 5mx4m
- Pantry Room - 4.0mx4.0m
- Toilet/Urinal - 4mx4m

The above mentioned dimensions shall be finalized during detail engineering stage.
An overhead tank of 2500 litre capacity of reputed make shall be provided for sanitation & plumbing.

Water Supply System

The plant shall be provided with proper water supply system for the purpose of sanitation, drinking and modules cleaning. The provision of deep well within the vicinity of plant area with necessary water treatment methods to be adopted including storage tanks shall be suitably made to meet the total water requirement of the plant. It is envisaged to provide sufficient nos. of storage tanks for module cleaning purpose. The size of tank for the storage of water shall be 4.5mx2.0mx2.0m (clear dimensions in two compartments).

Plant Electrical Design

The plant electrical design the DC and AC sides of the 50 MW sample solar PV power project.

Plant Single Line Diagram

Total generation of the 50 MWp unit shall be through 50 nos., 1000 kW Inverter. A total of 25 Inverter Stations have been envisaged for 50 MWp unit. The DC power generated by the photo voltaic modules associated with each Inverter Station shall be converted into 405V, 3 phase, 50Hz, AC power through suitable numbers of solar PV inverters. The 405V AC output from inverter terminals shall be further stepped up to 66KV by Inverter Transformers located near the Inverter Room.

DC Single Line Diagram

The DC side SLD shall present the scheme from Solar PV Module to Inverter Transformer. The Multi-Crystalline/ Thin Film Modules has been proposed for complete 50 MWp plant. Each 50MWp unit can be envisaged with any of the two type of module. The rating of each Module is 300 Wp (for Multi Crystalline) and 100 Wp (for Thin Film) and a total of nos. 166668 for Multi Crystalline/ 499995 for Thin Film of Modules have been proposed for each 50 MWp unit.

Type of Module	**CS6X - 300P Canadian Solar Inc**	**FS-3100 PLUS of First Solar**

Fifteen (15) modules in case of thin film while 19 nos of Module sin case of Multi Crystalline will be clubbed together in series to form a string. A Total of 8772 nos. of strings in case of Multi Crystalline /33333nos of strings in case on thin film have been envisaged for each 50 MWp unit. Number of strings shall be connected with String Monitoring Boxes (SMB)/Combiner Box in parallel. Each string shall be provided with DC dis-connector and fuse. Monitoring shall be done at string level. The SMB/Combiner Box output shall be connected with Inverter Individual input terminal. All the individual input terminals of Inverter shall have disconnection facility. Solar grade DC cables shall be provided for interconnection between Modules and SMB/Combiner Box and between SMB/Combiner Box and input terminals of solar inverter.

DC Side Protection

The Solar modules are made of Semiconductor material which will intern act as a Diode. These are connected in series to make the system desired voltage. The following protection equipments are provided:

- Fuses for short circuit protection.
- Surge Protection Device – To protect from Surges at the DC side.

AC Single Line Diagram

The AC side SLD shall present the scheme from Inverter Transformer to Power Evacuation point. The output of the solar inverter shall be 1000kW, 405V, 50 Hz AC with ± 10 % voltage variation. 25nos. three winding outdoor Inverter Transformer of rating 2MVA, 66KV/0.405-0.405 kV, are envisaged for each unit of 50 MWp. Two nos. 1000 kW Solar Inverters shall be connected to three winding Inverter Transformer i.e. one inverter per LV winding. The Inverter Transformer will step up the Inverter output voltage of 405V, 50Hz AC to 66KV, 50Hz AC.

The power output of the all inverter transformers i.e. total 50 MW approx. shall be connected in the 66KV Switchgear through 66KV MV Cables. From 66KV Switchgear Power shall be evacuated through 66KV Switchyard or 66KV Double Pole Structure. From 66KV Switchyard/ 66KV Double Pole Structure two no 66KV Cable shall be connected to 220/66KV Pooling Substation. The Pooling substation shall further connected to

400/220 kV Substation of POWERGRID through 200 kV single Circuit Line of 220 kV having Zebra Conductor. All bays of 66KV Switchyard shall consist of suitability rated Vacuum Circuit Breaker, Isolators, Instrument Transformers, LA, Wave Trap, PLCC and insulators as required. The grid interfacing bay shall be provided with dedicated CT/PT for energy metering purpose. The Indicative SLD s for DC and as well as AC side have been attached as Annexure 12: with this DPR.

Auxiliary Power Supply

The Auxiliary System Power Supply shall be through suitable nos. of Unit Auxiliary Transformer, the voltage rating of Transformer shall be 66KV/ 0.415kV Unit Auxiliary Transformer shall be envisaged. However the Capacity of Unit Auxiliary Transformer shall be finalized during detailed engineering stage based on proper sizing calculation. The Unit Auxiliary Transformer shall be connected with 415V LV Distribution Board for further distribution of auxiliary power. This LV Distribution Board shall be provided with a bus coupler and have provision for interconnection with 415V Diesel Generator (DG) Set. In order to ensure reliability in the Auxiliary Power Supply, a Ring Main Scheme shall be considered.

AC Side Protection

The followings protections shall be provided for solar Inverter.

- Over Voltage protection
- Grid Monitoring – Adjustable Voltage and Frequency range
- PV Generator connection – Insulation monitoring, polarity reversal protection.
- DC Filter.
- DC disconnect switch.
- AC side Insulation monitoring device
- Earth fault protection.

Power Transformer Protection

The Power Transformer shall be protected from the external faults by isolating through the outdoor SF6 Circuit breaker at 400kV and 66 kV end. The following electrical and mechanical protections for Transformers shall be provided:

- 50 – Instantaneous Over Current Relay
- 50N – Instantaneous Earth Fault Relay
- 51 – IDMT over current relay
- 51N – IDMT Earth Fault Relay
- 87- Differential Protection
- 49WT – Winding Temperature protection - Alarm / Trip
- 49OT – Oil Temperature Protection - Alarm
- OL – Magnetic Oil Gauge (MOG) - Alarm
- 63 – Buchholz Relay protection - Alarm / Trip
- PRV – Pressure Release Valve - Alarm / Trip

The all above relays will trip to VCB via Master Trip Relay (85). In addition, the SF6/VCB shall be provided with the following protections:

- 95 - Trip Circuit supervision protection
- 94 - Anti Pumping Relay

Inverter Transformer Protection

The Inverter Transformers shall be protected from the external faults by isolating through the outdoor VCB at 66 kV Switchgear and Air Circuit Breaker (ACB) in the LV side. The following electrical and mechanical protections for Transformers shall be provided:

- 87- Differential Protection
- 50 – Instantaneous Over Current Relay
- 50N – Instantaneous Earth Fault Relay
- 51 – IDMT over current relay
- 51N – IDMT Earth Fault Relay

- 49WT – Winding Temperature protection - Alarm / Trip
- 49OT – Oil Temperature Protection - Alarm
- OL – Magnetic Oil Gauge (MOG) - Alarm
- 63 – Buchholz Relay protection - Alarm / Trip
- PRV – Pressure Release Valve - Alarm / Trip

The Inverter Transformer Protections shall be in line with the CBIP requirements. The all above relays will trip to VCB via Master Trip Relay (85). In addition, the VCB shall be provided with the following protections:

- 95 - Trip Circuit supervision protection
- 94 - Anti Pumping Relay

66KV Switchyard Protection:

The Incoming feeders of 66KV Switchyard shall be provided with the following protections;

- 50 – Instantaneous Over Current Relay
- 50N – Instantaneous Erath Fault Relay
- 51 – IDMT Over current relay
- 51N – IDMT Earth Fault Relay

The all above relays will trip to Breaker via Master Trip Relay (85). In addition, the SF6 CB shall be provided with the following protections:

- 95 - Trip Circuit supervision protection
- 94 - Anti Pumping Relay

The Grid Interface will be provided with the following protection to prevent faults feeding from the Grid side.

- 59N – Residual Voltage Protection for Earth Fault using the Open Delta PT.
- 50 – Instantaneous Over Current Relay
- 50N – Instantaneous Erath Fault Relay
- 51 – IDMT overcurrent relay
- 51N – IDMT Earth Fault Relay
- 67- Distance Protection Relay

The all above relays will trip to CB via Master Trip Relay (85). In addition, the SF6 CB shall be provided with the following protections:

- 95 - Trip Circuit supervision protection
- 94 - Anti Pumping Relay

Along with this the Surge Arrestor with suitable rating shall be provided for the protecting from Surges from Grid.

Auxiliary Power Supply Protection

Moulded Case Circuit Breaker (MCCB) will be provided in Incomer, Bus coupler and Bus Tie for short circuit and over current protection. Outgoing feeders shall be provided with Miniature Circuit Breaker (MCB) for protection against short circuit and over load.

The design concept of the electrical system as a whole is based on the requirements for the safe and reliable operation of the Plant with provision for easy maintenance. The design and performance requirements of equipment will be generally as per the latest Indian Standards and the Codes of Practice, International standards like IEC. Indian Electricity Rules, wherever applicable will also apply. All electrical equipment for the proposed plant including 400kV switchyard equipment shall be designed based on the following limiting Power Supply Conditions.

Table 55. Technical Specification of Electrical Equipment

S. No.	Supply	Description	Variation	Load/System
1	**Modules**	300Wp	Power: 0 to +5%	**Each Module**
2	**Power Evacuation**	400 kV, 3-Phase, 3 wire, 50 Hz, Fault level	3. Voltage: +/- 5% 4. Frequency:+3/-5%	**400kV System**

	System	: 50kA (rms) for 1 sec	Combined volt. And freq.: 5% absolute	
3	**66KV Switchgear**	66 kV, 3-Phase, 3 wire, 50 Hz, Fault level : 31.5kA (rms) for 1 sec	5. Voltage: +/- 10% 6. Frequency:+3/-5% Combined volt. And freq.: 10% absolute	**66KV Switchgear**
3	**LT System**	400 V, 3-Phase, 4 wire, 50 Hz, solidly earthed, Fault level: 50 kA (rms) for 1 sec	7. Voltage: +/- 10% 8. Frequency:+3/-5% Combined volt. And freq.: 10% absolute	
4	**Uninterrupted AC supply System**	220 V, 1-Phase, 2 wire, 50 Hz, ungrounded system, 6 hour backup.	9. Voltage: +/- 1% Frequency: +/- 0.2%	**Inverter Room and SCADA**
5	**DC System**	**220 V (indicative), 2 wire, Ungrounded system, Fault level : 25 kA for 1 sec**	**10. Voltage:+10/-15%**	**Protection and control systems , emergency loads etc.**

Codes and Standards

All equipment of the PV power plant shall conform to international standards including IEEE for design and installation of grid connected PV system. The standards cover various aspects such as PV modules, cable types and selection, temperature considerations, voltage ratings, BOS wiring, inverter wiring, blocking diodes, bypass diodes, disconnect devices, grounding requirements, surge and transient suppression, load centre, power qualities, protection features and safety regulations. The following codes and standards will be followed while constructing the power plant:

- Indian Electricity Rules for design of the electrical installation
- National Fire Protection Association (NFPA) 70-1990(USA) or equivalent national standard
- National Electrical Safety Code ANSI C2 -1990(USA) or equivalent national standard
- IEEE 928 - 1986: Recommended criteria for terrestrial PV Power Systems
- IEEE 929 – 1988: Recommended practice for utility interface or residential and intermediate PV systems
- IEC 61646: Standard for PV Modules

Solar PV Array

The key components of solar PV array (DC field) are elaborated in this sub-section;

PV Module

Multi-crystalline/ Thin Film Solar PV technology has been selected for the 50 MWp Solar PV Power Project. The solar Modules offered should be fabricated according to international standard such as IEC, etc. Module shall be made of Transparent Toughened Safety Glass front surface giving high encapsulation gain and with edge sealant for module protection and mechanical support. All materials used shall have a proven history of reliable and stable operation in external applications. It shall perform satisfactorily in relative humidity up to 100% with temperatures between -10°C and +85°C and withstand gust as per IS 875 Part 3 for High Damage Risk Zone, Vb = 47 m/s from back side of the panel. PV Module must qualify to IEC 61215.

String Monitoring Boxes (SMB)/Combiner Box

The SM)/Combiner Box shall be dust, vermin, and waterproof and made of metal or thermoplastic. This will have suitable cable entry points fitted with cable glands of appropriate sizes for both incoming and outgoing cables. This will also have suitable surge protection devices. Degree of protection shall be IP 65 for panel enclosure. SMBs/ Combiner Boxes and shall be complete with the following features:

- 1000 Vdc fusible/ non-fusible DC Disconnector
- DC fuses in all strings in both positive and negative polarity with current sensing device.
- Surge Protection Device
- String Monitoring System

- Wired Communication System

The following parameters shall be monitored in the SMB/Combiner Box:

- Individual String current
- Voltage of strings
- Power generated by each string
- Status of fuses of each string
- Self check up on Power ON

Inverter and Control

The solar inverter is the link between the PV array DC system and the grid connected AC system. Its basic task is to convert the DC electricity generated by the PV module into AC by synchronizing itself to the frequency and voltage level of the Utilities Grid. The inverter receives varying DC input power from the module due to varying nature of solar radiation and motion of Sun throughout the day & year, which is converted into AC power by its highly efficient Power Electronics Circuit working based on Multi MPPT mode and synchronizing to the Grid Frequency and Voltage. Grid interconnection of PV systems is accomplished through the inverter which converts DC power generated from PV modules to high quality AC power to the utility system at reasonable cost. By means of high frequency switching of semiconductor devices with PWM (Pulse Width Modulation) technologies, high efficiency conversion with high power factor and low harmonic distortion power can be generated. Software controlled Maximum Power Point Tracking (MPPT) techniques are utilized in the control system to optimize the solar energy fed into the grid. The control system detects if the insolation level is above a predetermined value and the grid supply is within the preset limits in voltage and frequency, the inverter modules synchronise and connect to the grid supply and proceed to export the available solar energy. The unit will switch over to a low power sleep mode at night and during periods of low insolation and automatically wake up, when the insolation level rises above a preset point. Once the grid is back into its operating range, the inverter unit will synchronize and connect to the grid to export all the available energy generated by the PV array. The controller will have following control and automated functions.

- Inverter start up, shut off and disconnection sequence
- Over / under voltage & frequency protection
- Anti islanding protection
- Power tracking to match inverter to the arrays
- Adjustment of delay periods to customize system shutdown sequence
- Graphical user interface for real time communications, monitoring and control
- Optional remote monitoring via internet modem
- Faults notification via modem
- Data acquisition and logging
- DC monitoring

Cooling of Inverter

For cooling the solar inverter, the cooling air shall be taken in through the ventilation openings in the doors and blown out via the fans in the upper area of the inverter. Ventilation ducts shall be installed in order to prevent unnecessary heating of the service room, keep the ambient temperature within the permissible limits and prevent thermal short Circuits. Filters shall be provided at cooling air intake to ensure dust free supply of air.

Inverter Transformer

For 50 MWp plant, 25 nos. of 33/0.405-0.405 three winding, 2/1-1 MVA transformers, shall be suitably located in the layout to step up the voltage to 66KV level. Output of two nos., 405V, 3ph, 50Hz inverters shall feed to the LV side of the three winding Inverter Transformer. The interconnection between Inverter to Inverter Transformer shall be through Cables. The Transformers shall be conform to IS 2026 and IEC 60076. All Inverter transformers shall be oil type and located adjacent to the Inverter Room. HV side of these transformers shall be connected to the 66 kV Switchgear.

Unit Auxiliary Transformer

The suitable nos. of Unit Auxiliary Transformers shall be provided adjacent to the Inverter Stations to cater the Unit loads and Common Auxiliary loads. The voltage rating of Unit Auxiliary Transformer will be 66/0.415 kV at 50 Hz frequency. Auxiliary Transformer will be provided with off circuit tap changer (OCTC) having range of ±5% of nominal voltage @ 2.5% taps. The tentative rating of Unit Auxiliary Transformer shall be 250 kVA, however, final rating will be finalized during detail engineering stage based on the detailed calculation and actual loads.

66KV Switchyard/66KV Double Pole Structure

One ns.66KV Switchyard has been envisaged for evacuation of power. The switchyard shall be interconnected with the 220/66KV Pooling Substation by means of underground Cable. The 66KV Switchyard will be designed based on the parameters presented in Table 56.

Table 56. Technical details of 66KV Switchyard

Dimensions	:	Details
System operating voltage		66KV
Maximum operating voltage of the system(rms)		36kV
Rated frequency		50Hz
No. of phase		3
Rated Insulation Level		
Full wave impulse withstand voltage (1.2/50 microsec.)		170kV
One minute power frequency dry withstand voltage (rms)		95kV
One minute power frequency wet withstand voltage (rms)		75kV
Minimum creepage distance		31mm/kV
Minimum Clearances		
Phase to phase		500 mm
Phase to earth		500 mm
Sectional clearances		2800 mm
Rated short circuit current for 1 sec. duration		25 KA

Circuit Breakers

66KV Vacuum Circuit breakers each comprising set of 3 pole live/dead tank units with spring operated mechanism, and meeting the requirements as specified in IS, IEC standards, and the regulations
The following minimum ratings:

- Rated Voltage : 66KV
- Short time rating : 25 kA for 1 sec

Disconnecting Switches

Center rotating post horizontal double break triple pole disconnecting switch with or without earth switch will be provided. Operation of the disconnecting switch will be interlocked with associated breaker and earth switch. The isolator shall have the following minimum ratings:

- Rated Voltage : 66KV
- Short time rating : 25 kA for 1 sec

Current Transformers

Live or dead tank type single phase multi-core multi ratio current transformers (CTs) with 1 amp secondary will be provided for indication, metering and protection requirements. Accuracy of tariff metering cores shall be Class 0.2S. Separate CT cores will be provided for Main and Check Tariff Metering. The CT's shall have the following minimum ratings:

- Rated Voltage : 66KV
- Short time rating : 25 kA for 1 sec

Voltage Transformers

Voltage Transformers (VTs) with multiple secondary windings will be provided on lines, bus bars and step up transformers for metering and protection requirements. Separate cores with Class 0.2 accuracy will be provided for metering.

Lightning Surge Arresters

30 kV, 10 kA metal oxide (gapless) surge arresters of heavy duty station class (discharge class III) shall be provided. The arrester will include a digital impulse counter and leakage current detector.

Energy Metering

Dedicated CT and PT shall be provided in 66KV Switchyard for Tariff metering. Accuracy class of CT and PT shall be 0.2s and 0.2 respectively. Tariff metering panel to be located in the yard as per existing practice followed in India.

Switchyard Control Room Building

The Switchyard Control Room Building shall consist of Control, Metering and Protection Panels of Switchyard, LV Switchgears, Battery and Battery Charger system. Regarding Protection and Metering Bay Control Kiosk located inside the Switchyard itself can also be adopted. one nos. Building shall be envisaged for Completed 50 MWp Plant.

66KV Switchgear/66KV RMU

If 323 kV RMU scheme is adopted the RMU shall be located adjacent to Inverter Station with individual feeders connecting to Inverter Transformer which is further connected to the 66KV Switchgear located in Main Control Room Building. The 66KV switchgear will be provided with positive safety electrical interlocking and bus bar / Feeder earthing facilities for operational and personnel safety. The Technical Particulars of Major Electrical Equipment are given in the Table 57 below.

Table 57. Technical Particulars of 66KV Switchgear

S. No.	Parameter	Value
1.	Type	Metal Clad , horizontal draw out
2.	Service	Indoor
3.	Quantity	As required
4.	Enclosure	IP-4X
5.	VT and Relay Compartments	IP-52
6.	Voltage	66000 V
7.	Phase	3
8.	Frequency	50 Hz
9.	Interrupting/peak withstand	25kA rms
10.	Rated short circuit current for 1 sec. duration	25 kA

415V LV Switchgears

The 415V, 3 phase, 4 wire power for the 415V auxiliaries would be obtained from 66/0.415 kV Auxiliary transformers. The system will be a solidly earthed system. The 415V switchgear would be of metal enclosed design with a symmetrical short circuit rating of 50 kA for 1 sec. All power and motor control centres will be compartmentalized and will be of single/double front execution. They will be of fully draw-out design with all circuit components mounted on a with drawable sheet metal chassis. The circuit breakers would be of air break type. The LV switchboards shall be housed in the Main Control Building and each Inverter Rooms.

Table 58. Technical Particulars of LV Switchboard

S. No.	Parameter	Value
1.	Type	Metal Enclosed, horizontal draw out
2.	Service	Indoor
3.	Quantity	As required
4.	Enclosure	IP-4X
5.	Voltage	415 V
6.	Phase	3
7.	Frequency	50 Hz
8.	Short Circuit Interrupting/peak withstand current	50/125 kA (rms/peak)
9.	Short circuit withstand current for 1 Secs.	50 kA

Plant DC System

To supply power to various unit / loads, the following DC Systems (one main and one standby) have been envisaged for the each plant of 50 MWp and a separate DC system for 66KV Switchyard. The Battery and Battery Charger System shall consist of 220V battery and float & float cum boost charger for Main Control Building and as well as for 66KV Switchyard. The battery & charger shall cater to all the DC loads of each 50 MWp which mainly comprises of DC lighting load, Control supply for the switchgears etc.

Battery

The battery shall be of storage type Lead Acid Plante type. The Battery shall be high discharge performance type. The plates shall be designed for maximum durability during all service conditions including high rate of discharge & rapid fluctuation of load. For the purpose of design, an ambient temperature of 55°C and relative humidity of 100% shall be considered.

Battery Chargers

Battery charger will be float & float cum boost charger of suitable capacity for quick boost and trickle charging as well as supplying the DC loads. The battery chargers will be of silicon controlled rectifier type completely automatic and self-regulating type. The float charger will be capable of floating the battery and at the same time supply the continuous DC load. The boost charger will be capable of charging the fully discharged battery to full charge.

Table 59. Technical specifications of DC System

S. No.	Parameter	Value
1	Voltage	220 V
2	Type of Battery	Tubular Lead Acid
3	Quantity of Battery	One Battery Bank in Main Control Building
4	Minimum emergency period	60 minutes
5	Type of Battery Charger	Float cum Boost

DC Distribution Board (DCDB)

Each DCDB will receive power from its respective DC Battery/battery charger. DCDB incomers will be provided with positive mechanical interlocking facility to ensure that different power supply sources will not operate in parallel to avoid fault level exceeding their designated capability. Each DCDB will be of indoor, single front and non draw-out type. These will be sheet metal enclosed, assembled to form a rigid, free-standing floor mounted structure. Vertical units will be assembled to form a continuous line up of panels. Compartmentalized multi-tier configuration will be provided. The degree of protection will be IP4X. The DCDB will have short circuit ratings consistent with the available short circuit current.

Inverter Room

There shall be three nos. of inverters in Inverter stations 1-165, however Inverter Stations 166-167 shall consist of two nos. of Inverter, while inverter station 168 shall consist 1 no of inverter therefore the entire 1000 MWp unit shall consist of 168 nos. of Inverter Rooms. The 415V LV switchgear for auxiliary power distribution and Control & Protection Panels for the Inverter transformers shall also be located in the Inverter Room. Ventilation system with air ducts shall be provided in Inverter Room. Fire protection and Detection system shall be provided for Inverter Room. The Inverter Room shall be made of Pre-Engineered Building with proper heat insulation in it. The roof slope shall be kept at 1:25 with single sided slope. However the exact slope shall be finalized during detail engineering stage.

Main Control Building

The Main Control Building shall house SCADA system, 66KV Metalclad Switchgear, 415V LV Switchgear for feeding auxiliaries, DC System and other associated auxiliaries. The Main Control Building shall be made of Pre-Engineered Building with proper heat insulation in it. The roof slope shall be kept at 1:15 with single sided slope.

Cables and Accessories

As solar farms are exposed to varying atmospheres throughout its life cycle. The cables will be exposed to ultra violet radiations which would reduce the cable life span. Therefore, cables with Ultra Violet protection have to be used. Additionally, the cables should be flame, oil Ozone resistant halogen free complying with DIN standards. Cables shall be sized based on considerations like rated current of the equipment, voltage drop under full load condition, short circuit withstand capability, de-rating factors for various conditions of laying etc. The size of the cables for module/array interconnections, array to junction boxes and junction boxes to PCU etc. interconnection shall be selected to keep the voltage drop and losses to the minimum. The suggested cable is the bright-annealed 99.97% pure copper conductor which offers low conductor resistance and lower heating thereby increasing the cable life and making savings in power consumption. Table 60 and Table 61 present the technical specifications of the cables in solar PV area and Power and Control Cables respectively.

Table 60. Technical Specification of Cables in the PV Area

S. No.	Parameter	Value
1.	Working voltage	Up to 1100V
2.	Temperature range	-15°C to +80°C
3.	Specification	IS 694:1990 or equivalent
4.	Approvals	FIA/AC/ISI
5.	Sizes	Suitable size

Table 61. Technical Specification of Power and Control Cables

H.V. Power Cables		
1.	Voltage Grade	66KV
2.	Conductor	Stranded aluminium circular or compared circular shaped.
3.	Conductor Screen	Extruded semi-conducting compound
4.	Insulation	Extruded cross linked polyethylene (XLPE)
5.	Insulation Screen	Extruded semi-conducting compound with a layer of non-magnetic metallic tape
6.	Inner Sheath	Extruded PVC compound conforming to type ST2 of IS: 5831 for three core cables. Single core cables shall have no inner sheath. Filler material shall also be of type ST2 PVC.
7.	Armour	GI strip armoured as per Table -4(method a) of IS 7098
8.	Overall Sheath	Extruded FRLS PVC compound conforming to type ST2 of IS: 5831.
L.V. Power Cables		
1.	Voltage Grade	1100 V
2.	Conductor	Stranded and compacted plain aluminium of grade H2 and class 2 / stranded, high conductivity annealed plain copper, generally conforming to IS: 8130.
3.	Insulation	Cross linked polyethylene (XLPE)
4.	Inner Sheath	Extruded PVC compound conforming to type ST2 of IS: 5831 for multi-core cable. Single core cables shall have no inner sheath.
5.	Armour	as per Table -4(method a) of IS 7098
6.	Overall Sheath	Extruded FRLS PVC compound conforming to type ST2 of IS: 5831.
Control Cables		
1.	Voltage Grade	1100 V
2.	Conductor	Heavy Duty, stranded copper conductor
3.	Insulation	PVC
4.	Armour	Galvanized steel wire / strip armoured
5.	Overall Sheath	Extruded FRLS PVC of type ST1 outer sheathed

Lightning and Over Voltage Protection

The PV Power plant shall be provided with Lightning and Over Voltage protection connected to proper earth mats. The main aim of the protection is to reduce the over voltage to a tolerable level before it reaches the PV or other sub-system components. The source of over voltage can be lightning or other atmospheric disturbance. The Lightning Conductors shall be made as per applicable Indian or International Standards in order to protect the entire Array Yard Lightning stroke. Necessary concrete foundation for holding the lightning conductor in position will be made. The lightning conductor shall be earthed through flats and connected to the Earth mats as per applicable Indian/International Standards with earth pits. Each Lightning Conductor shall be fitted with individual earth pit as per required Standards including accessories, and providing masonry enclosure with cast iron cover plate.

Earthing System

Each Array structure/Trackers of the Solar PV area shall be grounded properly. The array structures are to be connected to earth pits as per Indian/International standards. Necessary provision shall be made for bolted isolating joints of each earthing pit for periodic checking of earth resistance. The earth conductor shall run through appropriate pipes partly buried and partly on the surface of the control room building. The complete earthing system shall be mechanically & electrically connected to provide independent return to earth. All electrical outdoor equipment structures will be grounded through the proper grounding conductor. All transformers neutral and Lightning Arrester shall be connected to the main grid through earth pits as per Indian/International standards.

Supervisory Control and Data Acquisition (SCADA) System

The PV power plant will be monitored through the SCADA system. This will enable monitoring the status of inverters to gather information on energy generation. Periodic reports of the plant's performance will be provided by the monitoring system. A suitable display system can also be installed suitably in the plant to access live data on the performance of the solar system. Remote data access will be provided through secured gateway connectivity. The status of all breakers shall also be monitored.

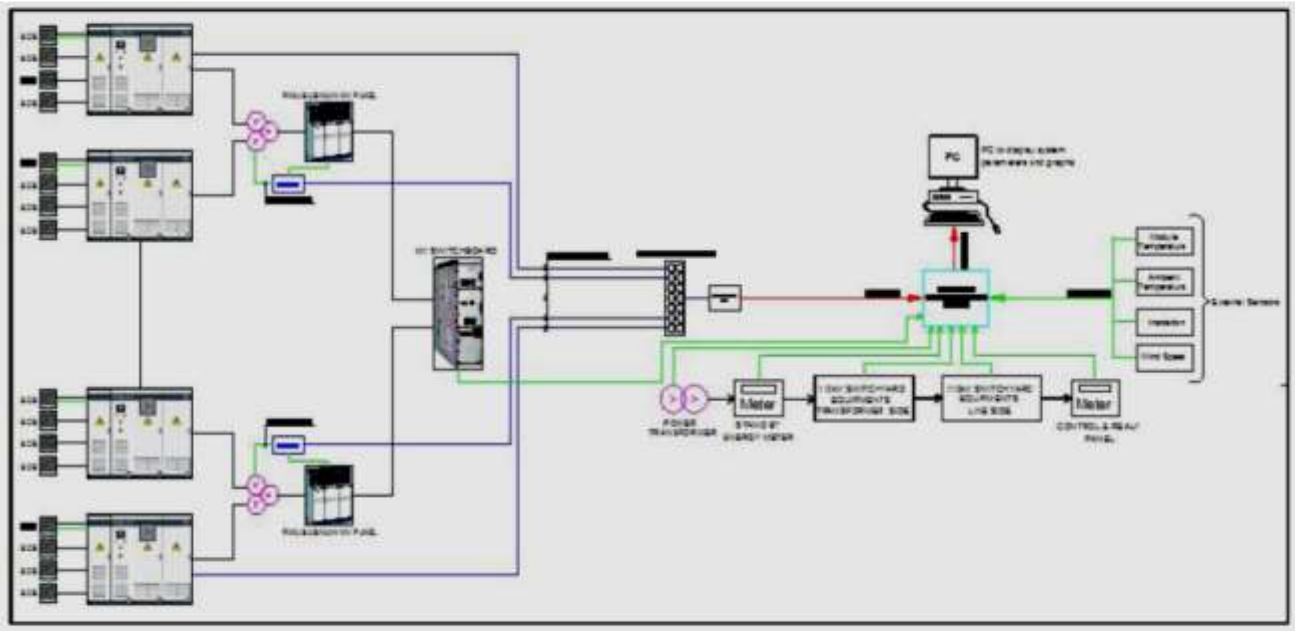


Figure 72. Indicative schematic of data monitoring

Automatic Weather Station (AWS)

An Automatic Weather Station (AWS) is required at the plant site in order to measure climatic parameters and global solar radiation periodically. The realistic climatic parameters are required for performance testing of the proposed solar PV power plant. Ambient temperature of 55 Deg. C and relative humidity of 95% shall be considered for equipment design. At least one AWS will be required with every 100-250 MWp capacity solar PV power plant in order to carry out the Performance Guarantee test of the projects.

Figure 73. Automatic weather station (AWS) at project site

The Automatic Weather Station (AWS) shall be provided with the following features:

- Measurement of Global, Horizontal & Background Irradiance.
- Measurement of Wind Speed, Wind Direction, Ambient Temperature and Relative Humidity.
- Measurement of Cell Temperature.
- Facility for Data Logging.
- The Transmitter and Data Logger must have certification from IMD for functional operation through INSAT / Kalpana satellites.
- Supports TCP/IP, DHCP configurations
- Supports serial (RS-232/485, MODBUS) and analog (0-1V, 0-5V, 4-20mA) output
- Modular and easily customized
- In-Built Memory for storing data for at least 12 months period.
- Graphical Display Software

The following points should be taken into account for the components of the AWS:

- Each component should have a detailed instruction manual.
- Each component should be highly durable.
- Each component should be easily maintainable.
- Standard devices and interfaces that are adaptable to technological progress should be used.

Civil Works, Site development & construction facilities

Civil works of the project have to be carried out looking ahead of the extreme conditions at the site. The sub soil conditions at site are to be taken care during design as well as during construction. The natural drainage conditions are to be maintained to the maximum extent so as to avoid flooding of site during rainy seasons and minimise the cost of land grading & levelling operations. Good quality controls have to be maintained at site during construction. Site may require filling at some patches to elevate the FGL depending upon the actual site condition.

Power and Water Requirements

Power for construction activities at site can be arranged with the help of DG set during construction period of the plant. The Water for the construction activities as well as potable water at site can be taken from tankers/ bore wells. Further distribution arrangement can be established during construction period of the plant.

Fire Fighting

The Fire Fighting system design shall conform to TAC/NFPA norms. The types of fire protection systems for the complete plant shall be including Portable Fire extinguishers and Wheel/Trolley mounted fire Extinguishers.

Adequate number of portable fire extinguishers of dry chemical powder and Carbon dioxide type shall be provided at suitable locations in different buildings. Wheel/Trolley mounted Mechanical foam type fire extinguishers, conforming to IS:13386 are proposed to be provided for protection of transformers. The design, construction & testing of fire extinguishers shall meet the requirements of relevant IS Codes. RCC water tank for clear water shall be located as per the requirement. The tank shall be partially embedded in the ground and covered with RCC slab. Pump house shall be located adjacent to the tank. Fire water pump shall be installed in this pump house.

Mounting Structure

A fixed module mounting system of 30° inclination has been chosen for the PV plant. The mounting structures to be selected shall comply with the appropriate industrial standards and shall be capable of withstanding on-site loading and climatic conditions. Material to be used shall be a combination of hot-dipped galvanised mild steel and pre-galvanised cold rolled sheets sheared to form structural members for module mounting. The pre-galvanised sheets post process shall be appropriately coated anti-corrosion compounds for the project life cycle. According to India wind zone map the Project lies in low damage risk zone with maximum wind speed in the range of 44 to47 m/s. The withstanding wind speed for mounting structure designs should be exceeding the upper limit of the maximum wind speed range. The modules shall be arranged in landscape orientation in seven rows to minimize the effect of shading. 16 modules are assembled per row of the mounting structure.
During the detailed designs, geotechnical analysis need to be done to determine the profile, size and class of the grounding piles or foundations required. The analysis will also determine the installation method. Load bearing capacity tests along with soil sampling and analysis will be done to ascertain the profile.

8.25 Inter-row spacing for PV mounting structures

In addition to optimizing the inter-row pitch for minimum shading, adequate inter-row spacing shall be maintained for cleaning of modules. Although this will depend on the strategy adopted for module cleaning, a minimum of 3.5 meters of inter-row space shall be maintained throughout the solar PV array area. However it will be decided on the basis of string design approach (portrait pr landscape placing of modules) at detailed engineering.

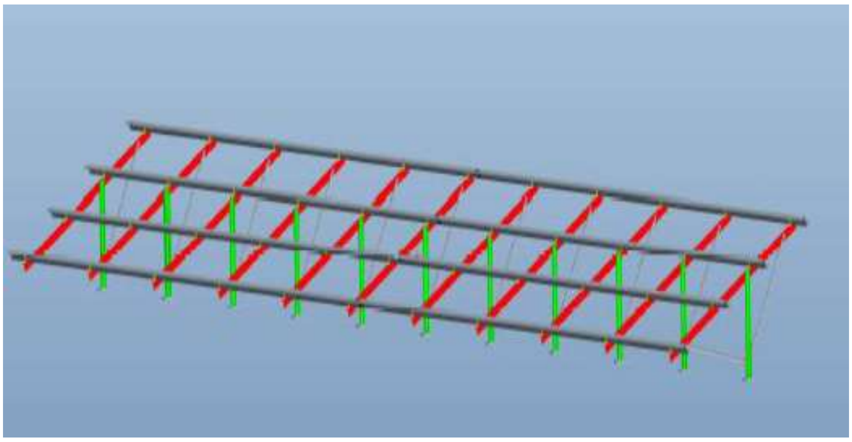


Figure 74. Indicative layout of typical mounting structure

8.26 Site Security

Installation of a security wall has been considered for the entire land boundary in order to reduce the risk of theft and tampering. Security cameras are sometimes specified for PV plants. Security cameras may be considered as an option in the detailed design phase.

Figure 75. Example of Security Systems used in PV power plants

Ventilation and Air-Conditioning System

Air Conditioning System

Air Conditioning Systemfor Control Room shall be provided with Package/Split type Air conditioners. The cooling load shall be calculated for the summer, monsoon and winter seasons for selection of the equipment accordingly. Air conditioned area shall be maintained at 24°C ± 1oC and relative humidity of 50 % ± 5%.
The indoor quality of air conditioned areas served by air conditioning units shall be as per ASHRAE Standard – 62. The bidder shall consider sufficient allowances for possible equipment heat loads and demonstrate the adequacy of system sizing through calculations. The occupancy shall be considered as per ASHRAE Standards. For proper ventilation of the air conditioned area, fresh air intake of 1.5 air changes per hour or 0.57 m^3/min of fresh air/person, whichever is higher shall be adopted. A minimum design margin of 15% is to be considered while selecting the AC equipment capacity for each area. Continuous motor rating should be selected with 10% more than maximum power requirement at any condition of the entire characteristic curve of the driven equipment. All the equipment shall be designed for continuous duty.

Ventilation System

Provision of ventilation system shall include but not be limited to the following areas.

- Switchgear Room
- Inverter Room
- Toilets, etc.

A minimum design margin of 10% is to be considered while designing the capacity of supply air fans, and exhaust air fans etc.

Annexure 7: Technical specifications 50 MW sample Solar PV plant

Electrical Requirement

Solar PV Module

The Bidder shall supply, install and commission the Solar PV Modules for the proposed 50 MW Solar PV Project. The Solar PV Module offered shall fulfill the technical requirements furnished in this section.

Code and Standards

The Solar PV Modules offered should be manufactured in conformance to the following IEC and other international standards.

- IEC 61646 and IEC 61215: Standard for PV Modules
- IEC 61730: Quality testing of SPV Modules
- IEC 61701: Quality test for Solar PV Modules to be used in a highly corrosive atmosphere
- IEC 60904: Photovoltaic Devices
- IEC 62446: Grid Connected PV systems- Min. Requirement for documentation, Commissioing tests and Inspection
- IEC 60634-7-712: Electrical Installation of Bulidngs, Requirements for special installations or locations- Solar PV power supply system
- EN 50380: Data sheet and Nameplate information for Solar PV Modules
- EN 50521:2008: Connectors for PV System

Equipment and material conforming to any other standard which ensures equal or better quality may be accepted. The manufactures shall have the quality certifications for example by TUV, CE, UL etc.

Technical Requirements

Solar PV Modules shall be made of Transparent Toughened Safety Glass front surface giving high encapsulation gain and hot butyl rubber edge sealant for module protection and mechanical support. Anodized Aluminum Frame shall be provided. The Solar PV Module shall be provided with RFID tag for identification. The Module shall perform satisfactorily in relative humidity up to 100% with temperatures between -10°C and +85°C and withstand gust as per IS 875 Part 3 for High Damage Risk Zone, Vb = 47 m/s from back side of the panel. The material and workmanship warranty of Solar PV Modules shall be of 10 years while the power output warranty shall be of provided for 25 Years. Module degradation shall be in the range of 0.5% to 0.7% linear per annum over the life span of 25 years. The Manufacturer shall provide the degradation data of Solar PV Modules. Module dumping procedure shall be provided by the Bidder for Owner/MNRE/ KSPDCL approval.

String Combiner Box (SCB)/Monitoring Box

Bidder shall supply, install and commission the SCBs. Sections herein present the technical requirements for the SCBs. SCBs shall be equipped with monitoring hardware so as to monitor status and performance of each string. The gateway protocol for communication shall be uniform throughout the system. The power supply to SCB's shall be external. The enclosure for SCBs shall be dust proof, non-conductive, impact resistant, UV resistant, flame retardant and shall be made from fiber glass reinforced / polypropylene plastic / polyester / polycarbonate suitable for outdoor applications with a minimum of IP65 protection rating . The SCB shall be provided with a continuous polyurethane seamless gasket for providing water tightness and preventing ingress of dust. The gasket shall be held in position in groove provided in the enclosure and shall be pressed all around uniformly by suitably shaped projection of the door. All SCBs shall have an embossed aluminum name plates describing string numbers, capacities, voltages and designated identification number.

DC/Solar Cable

Bidder shall provide DC Cable for interconnection between Solar PV Modules and Inverters. Sections herein present the technical requirements for the DC Cables.

Code and Standards

- Halogen free- EN 50267-2-1, EN 50267-2-2, EN 60684-2
- Flame retardant EN/IEC 60332-1-2 EN/IEC -60332-3-24
- Low smoke emission EN/IEC 61034-2
- Resistance against acid and alkaline solution EN 60811-2-1
- Weathering/UV resistance HD 605/A1
- Ozone resistance EN 50396 72h/40 °C, method B
- Volume concentration 200x10-6
- Additional properties not part of the TÜV Rheinland test requirements:
- Low fire load DIN 51900
- No corrosive gases EN/IEC 60754-2

Technical Requirements

The cables shall be designed for a nominal DC voltage of 1.0 / 1.8kV with an operating temperature range of 2°C to 90°C. The conductors shall be multi-stranded electrolytic grade high conductivity annealed tinned copper and shall be uniform in quality, free from scale and other defects. The maximum conductor temperature shall not exceed 90°C during continuous operation at full rated current. The temperature after short circuit for 5 seconds shall not exceed 250°C with initial conductor temperature of 90°C.The Manufacturers shall indicate the overload capacities that the cable can carry and its duration, when operating initially at a conductor temperature of 90°C, with peak conductor temperature of 120°C. Cable sizing shall consider derating factors such as installation method, depth of installation, cable group factor, temperature effect etc. for optimized designs. Cables up to 6mm2 shall be tied along the solar PV module mounting structures. Only UV resistant cable ties shall be used in regular intervals.

Inverter and Control

Bidder shall propose the Central type inverters. However in case string inverters are required in order to match the DC capacity shall also be accepted. The Inverter offered shall fulfil the technical requirement furnished in this section.

Code and Standards

The inverters should conform to the following standards.

- IEC 61683: Photovoltaic systems – Power conditioners – Procedure for measuring efficiency.
- IEC 61727: Characteristics of the Utility Interface
- IEC 62116: Testing procedure of Islanding Prevention Methods for Utility-Interactive Photo voltaic Inverters
- EN 61000-6-1 to 4: Electromagnetic compatibility (EMC). Generic standards. Emission standards for residential, commercial and light-industrial environments.
- EN 55022: Information technology equipment. Radio disturbance characteristics. Limits and methods of measurement.
- EN 50178: Electronic equipment for use in power installations

Technical Requirements

The inverters shall comply the Indian grid code requirements . Inverter shall be provided with the following minimum requirement:

- DC Injection into the grid: This shall be avoided by using a step-up transformer at the output of the inverter. DC injection shall be limited to 1% of the rated current of the inverter as per IEC 61727.
- The total harmonic distortion limits on AC side should be less than 3%.
- Operational frequency: 50 Hz and Frequency variation +/-5%.
- Operational voltage variation: +/-10%.

The inverter control system should have the Software based Maximum Power Point Tracking (MPPT) techniques to optimize the solar energy fed into the grid. If the control system detects that the insolation level is above a predetermined value and the grid supply is within the preset limits in voltage and frequency, the inverter modules synchronize and connect to the grid supply and proceed to export the available solar energy.

The control unit will automatically disconnect from the grid if the grid voltage or frequency is beyond the operating range. The control system shall have the following control and automated functions.

- Inverter start up, shut off and disconnection sequence
- Over / under voltage & frequency protection
- Anti islanding protection
- Power tracking to match inverter to the arrays
- Adjustment of delay periods to customize system shutdown sequence
- Graphical user interface for real time communications, monitoring and control
- Optional remote monitoring via internet modem
- Faults notification via modem
- Data acquisition and logging
- DC monitoring

Inverters shall be capable of operating at varying power factor preferably in between 0.95 lag to 0.95 lead and shall be able to inject or absorb reactive power. Irrespective of installations, inverters shall operate at ambient temperature of 50°C without deration. The inverter shall be provided with the following protection:

- Over current
- Ground Fault Detector
- Over temperature
- Over voltage
- Reverse current
- Surge protection for main, auxiliary and control circuits

The inverters proposed by the Bidder/ Manufacturer should have a minimum efficiency of 98%, however preference may be given to inverters having higher efficiency than desired. Inverters shall be a facility of direct external communication and control. Inverters with outdoor duty installation shall have a minimum degree of protection of IP65. For indoor installation, IP-54 with adequate ventilation provisions shall be provided. The Inverters shall have at least a warranty period of 5 years from the date of commissioning. It is essential that the product should give a consistent performance for 25 years life cycle of the project. The option of extended manufacturer's comprehensive warranties with onsite support beyond the guarantee period of 5 years up to 25 years.

Inverter Transformer and Auxiliary Transformer

Bidder shall supply, install and commission the required no. of Inverter Transformers to step up the inverter output AC voltage to 66KV. The Bidder shall also provide the required no. of Auxiliary Transformer for Auxiliary Power Distribution in the Plant. Sections herein present the technical and construction requirements for the Inverter and Auxiliary Transformers.

Code and Standards

The design, manufacture and performance of the Transformer offered shall in general comply with the latest issues including amendments of the following standards, rules and acts:
IS:2026/IS 11171/ IEC: 60076/ IEC: 60726/IS 6600 and other relevant IS/IEC standards

Technical and Construction Requirements

The Inverter Transformers shall be used to step up the inverter output AC voltage to 66KV. The Inverter Transformer shall be of three winding configuration. However Bidder can also propose four winding / five winding Transformers also. The Auxiliary Transformer shall be of two winding. The rating and number of Auxiliary Transformer shall be decided during detailed engineering. The Auxiliary Transformers shall be either Resin Encapsulated Dry type or Oil Type. The dry type transformers shall be housed in a metal protective housing, having a degree of protection of IP-23. The transformer core shall be constructed from high grade non-ageing cold rolled grain oriented silicon steel laminations. The winding insulation shall be of class F. One number platinum resistance type-temperature detector shall be provided in each limb of the transformer. In addition to the above, Thermistors shall be embedded in each limb of the transformer. Necessary instrumentation to generate alarm and trip contacts from these Thermistors shall also be provided. The conductors shall be of electrolytic grade copper, free from scales and burrs.

Both Transformers shall be suitable for cable termination on HV side and flange connection for bus duct to switchgear on LV side. However Terminal arrangement of Inverter Transformer shall be decided during detailed engineering. The point where the LV Bushing comes out of the housing of dry type transformers should be properly sealed. The transformers shall be capable of being loaded in accordance with IEC. There shall be no limitation imposed by bushings, tap changer etc. The transformers shall be capable of being operated continuously without danger on any tapping at the rated kava with voltage and frequency variations in line with the applicable grid code. The Transformers shall be suitable for continuous operation at rated KVA at an over fluxing factor of up to 1.1. The transformers shall be capable of withstanding without damage 1.4 times the rated voltage at its terminals for 5 seconds.

The transformers shall accept, without injurious heating combined voltage and frequency fluctuations which produce the over fluxing conditions of 120% for 1 minute. Bidder shall also indicate 150% over voltage withstand time. The noise level when energized at normal voltage and frequency and measured at standard conditions shall not exceed the values specified in NEMA TR-1. The voltage rating of Unit Auxiliary Transformer will be 66/0.415 kV or 405/415 V at 50 Hz frequency. All the Auxiliary Transformers will be provided with off circuit tap changer (OCTC) having range of ±5% of nominal voltage @ 2.5% taps. The capacity of these transformers will be finalized during detailed engineering stage based on the detailed calculation and actual loads.

HV Switchgear/66KV RMU

The Power from all modular blocks (Bidder to propose radial/ RMU scheme) shall be combined at the 66KV Switchgear to be located at the Main Control Room Building of solar PV plant. Bidder shall supply and install the required nos. of 66KV Switchgear Panels/ 66KV RMU at Modula Blocks and at Main Control Room . The section herein describes the technical specifications for 66KV switchgear.

Code and Standards

The design, manufacture and performance of the HV Switchgear offered shall in general comply with the latest issues including amendments of the following standards, rules and acts

- IEC 62271, High voltage switchgear and control gear
- IEC 60376, Specification of technical grade sulphur hexafluoride (SF6) for use in electrical equipment
- IS 427, Metal Enclosed switchgear and control gear

Technical Requirements

The technical requirements of HV Switchgear shall be as follows:

Table 62. The technical requirements of HV Switchgear

Dimensions	:	Details
Type	:	Metal Clad , horizontal draw out
System	:	3 phase, 3 wire AC
Rated Voltage	:	66KV AC
Control Voltage	:	220 V DC (2 wire)
Rated Frequency in AC	:	50 Hz.
AC Voltage	:	+/-10%
Frequency Variation	:	+/-5%
DC Voltage Variation	:	+10% to -15%
Fault level	:	25 kA for 1 sec
Insulation Level	:	a) Power Frequency Voltage- 95 kV (rms) b) Impulse Voltage- 170 kV peak
System of Earthing	:	AC - Effectively Grounded/ DC – Ungrounded (Isolated)
Duty	:	Continuous at rated load

Design and General Requirements

The switchgears shall have a single front, single tier, fully compartmentalized, metal clad construction complying with IEC-298, comprising of a row of free standing floor mounted panels. It shall have the facility of extension on both sides. Adopter panels and dummy panels required to achieve the various Bus Bar arrangements, Cable / Bus Duct terminations and layouts shall be included in Bidder's scope of work.
The design shall be totally dust–tight, damp-proof and vermin proof offering degree of protection not less than IP-42 for indoor applications and IP-54 for outdoor applications. All the circuit breaker shall be rated for a nominal voltage of 36kV and shall be designed with minimum short circuit rating of 25 kA (indicative). Breakers should be of draw out type with vacuum / SF6 as arc quenching medium.

The switchgear panel shall be equipped with metering and protection relays. All relays shall be numeric type with multifunctional meter having an accuracy class of 0.2. Instrument transformers shall be suitable for measuring and protection. Earth bus shall have two earthing connection facility at its both ends of earthing conductor. Each breaker vertical shall be equipped with local/remote selector switch, emergency stop, TNC switch, indicating lamps showing breaker ON, OFF, TRIP, spring charge, trip circuit healthy, breaker in TEST/SERVICE position, gas pressure low. Additionally annunciation window with hooter shall also be provided.

Earthing and Lightning Protection

The complete plant area including Control Room, Main Control Room, Modular Blcoks (Inverter Stations)and all PV area, shall be appropriately earthed with adequate number of earth stations and adequately protected against Lightning. The Bidder shall design, supply, install and commission the entire Earthing and Lightning Protection System. Sections herein present the design and technical requirements of Earthing and Lightning Protection System.

Code and Standards

The earthing and lightning protection system shall in general comply with the latest issues including amendments of the following standards, rules and acts

- IEEE-80: Guide for safety in Alternating current sub-station grounding
- IS 3043: Code of practice for Safety Earthing
- IEEE 665 :
- IEC 62305 (all parts), Protection against lightning
- IEC 60099: Surge arresters

Design and General Requirements

Earthing System:

The earthing system shall have complete earthing network comprising of wires, copper tapes, electrodes and earth bonding of all relevant necessary non-current carrying metal parts of equipment's/ apparatus shall be connected as required. All mounting structures, String combiner boxes shall be connected to earth grid with appropriate size of earth conductor. Sufficient earth stations shall be planned to maintain earth resistance ensuring hazard free operation of PV plant. Each equipment shall be earthed through an additional protective conductor with equi-potential bonding conductor.

Metallic frame of all electrical equipment shall be earthed by two separate and distinct connections to earthing system, each of 100% capacity, Crane rails, tracks, metal pipes and conduits shall also be effectively earthed at two points. Steel RCC columns, metallic stairs, and rails etc. of the building housing electrical equipment shall be connected to the nearby earthing grid conductor by one earthing ensured by bonding the different sections of hand rails and metallic stairs. Each MV transformer shall have a minimum of four dedicated earthing stations. PLC equipment shall be earthed separately as per the recommendations of the manufacturers.

Earth pit shall be constructed as per IEEE. Electrodes shall be embedded below permanent moisture level. Minimum spacing between electrodes shall be 600mm. Earth pits shall be treated chemically if average resistance of soil is more than 20 ohm meter.

Lightning Protection System

Complete Solar PV Plant including all inverter stations and the main control room shall be protected from lightning. The protection system will be based on Early Streamer Emission Lightning Conductor Air Terminals. The air terminals shall provide an umbrella protection against direct lightning strike covering a radial distance of maximum 100m. The air terminal will be capable of handling multiple strikes of lightning current and should be maintenance free after installation. Lightning conductor shall be connected through test link with earth electrode/earthing system. Hazardous areas handling inflammable/explosive materials and associated storage areas shall be protected by a system of aerial earths.

LV Switchgear

Bidder shall supply, install and commission the requisite number of LV Switchgear to combine the AC power from Inverter as well as for Auxiliary Power Distribution. Sections herein present the technical specifications and requirements for the LV Switchgear.

Code and Standards

- IEC 61439, Low-voltage switchgear and controlgear assemblies -Part 1: General rules
- IEC 60439, Low-voltage switchgear and controlgear assemblies
- IEC 60947, Low-voltage switchgear and controlgear - Part 1: General rules
- IS: 13947 Part General Requirements for Switchgear and Control gear for voltages not exceeding 1000 V.
- IS: 3072 Code of practice for installation and maintenance of Switchgear

Technical requirements

The technical requirements of LV Switchgear are presented in table below;

Table 63. Technical requirements of LV Switchgear

Dimensions	:	Details
System	:	3 phase, 4 wire AC/ 2 wire DC
Rated Voltage	:	400 V AC/415 V AC
Rated Frequency in AC	:	50 Hz
AC Voltage	:	+/-10%.
Frequency Variation	:	+/-5%
DC Voltage Variation	:	+10% to -15%
Service	:	Indoor
IP Class	:	IP4X
Short Circuit Interrupting/ peak withstand current	:	50/125 kA (rms/peak)
Fault level	:	15 kA for 1 sec
System of Earthing	:	AC - Effectively Grounded/ DC – Ungrounded (Isolated)
Duty	:	Continuous at rated load

Design and General Requirements

The switch boards shall be totally enclosed, cubicle type suitable for floor mounted free standing / wall mounted indoor installations. The design shall be totally dust–tight, damp-proof and vermin proof offering degree of protection not less than IP-55. Circuit Breakers shall be air break, three pole, spring charged, horizontal draw out type, suitable for electrical operation. The bus bars shall be of high conductivity electrolytic copper, air insulated and housed in a separate compartment segregated from all other compartments. Bus bars should have uniform cross sections with suitable capacity for carrying rated current continuously and short circuit current for specific time duration without overheating. All the bus bars shall be provided with color coded heat shrinkable sleeves.

The temperature rise of the horizontal and vertical bus bars and main bus link including all power draw out contacts when carrying 90% of the rated current shall in no case exceed 55 deg. C with silver plated joints and 40 deg. C with all other types of joints over Design Electrical Equipment of 50 deg C. Adequate Instrument transformers, potential free contacts, connectors, auxiliary contactors with wiring etc. are to be provided for control & monitoring. Control terminal box with adequate spare provision for future use shall also be provided. All measuring instruments (Meters) shall be of digital electronic with Light Emitting Diodes (LED) display compatible with SCADA.

HV, LV Power and Control Cable

Bidder to design, supply and lay the HV, LV Power and Control Cable. The section herein describes the general specifications for low voltage grade cables up to 1100 volts AC.

Code and Standards

- IEEE-383 Standard for type test of Class IE Electric Cables.
- IEC -332 Tests on Electric cables under fire conditions Part-3 : Tests on bunched wires or cables (category -B)
- IS:7098 (Part -II) Cross linked polyethylene insulated PVC sheathed cable for working voltage from 3.3 KV upto & including 66 KV
- IS :1554 - I PVC insulated (heavy duty) electric cables for working voltages upto and including 1100V
- IS : 3961 Recommended current ratings for cables

General and Design Requirements

Cables sizes shall be selected considering the power loss, current carrying capacity, voltage drop, maximum short circuit duty and the period of short circuit to meet the anticipated currents. HV cables shall be66KV (UE) / 66KV (E) grade suitable for use in medium resistance earthed system, with stranded & compacted aluminium conductors, extruded semi-conducting compound screen, extruded XLPE insulated, extruded semi-conducting compound with a layer of non-magnetic metallic tape for insulation screen, extruded FRLS PVC (Type ST – 2) inner sheath, single round galvanized steel wire armoured, extruded FRLS PVC (Type ST – 2) outer sheathed, single / multicore conforming to IS 7098 (Part II), IEC-502 for constructional details and tests.

LTCables shall be 1.1kV grade, single / multicore, extruded XLPE insulated with extruded PVC inner sheath (ST-2). The conductor shall be electrolytic grade aluminum or high conductivity annealed copper and shall be smooth, uniform in quality and free from scale and any defects. The maximum conductor temperature shall not exceed 90 degree C during continuous operation at full rated current. The temperature after short circuit for 1.0 second shall not exceed 250 degree C with initial conductor temperature of 90°C. Power cables will have a minimum cross section of 2.5mm² for Copper conductor and 4 mm² for Aluminum conductors.

DC and UPS System

Bidder to provide the DC system and UPS system with the following configuration;

- 2X 100% float cum boost charger with two independent battery banks (with 3 hours back up).
- one set of Uninterrupted Power Supply (UPS) & ACDB System to cater all the UPS power requirement

The section herein presents the technical requirement of DC and UPS system.

General and Design Requirements

The rating of DC system shall be 220 V DC with 2 times AH requirement. However if any equipment require 48V DC supply, then separate 48 V DC system with same configuration as of 220 V DC system mentioned above shall also need to be provided. The batteries shall be of deep discharge lead acid, plant type conforming relevant IEC. Batteries shall be free from orientation constraints, eco-friendly, and ready to use. Appropriate ventilation arrangements to be provided in battery rooms. This shall essentially consist of sufficient air inlet and exhaust provisions.

The DC Distribution Board shall consist of incoming from battery bank and no. of outgoings for closing and tripping, alarm and indication for Control and Relay panel and switchyard equipment. A separate circuit for emergency loads to be provided in the event of AC supply failure. The Bidder shall provide.The UPS system of continuous duty shall supply regulated, filtered and uninterrupted 220V AC, 50 Hz, single-phase power, within specified tolerances. Each UPS System component shall be compatible for satisfactory and well-coordinated operation with other related components as well as with the input and output systems. The kVA rating of the UPS shall be guaranteed at 220VAC, 50 Hz, single phase output at Indoor design temperature and load factor of 0.8 lagging. The backup time for UPS shall be 3 hours.

Lighting System

All the main roads shall be lit with external lighting system strategizing site security and maintenance requirements; utmost care should be taken for avoiding any shading effect due to the poles. The light fittings shall be highly efficient having longer life. CFL / LED based lamps shall be used. Entire periphery of the solar PV plant shall have external lighting with LED / CFL based street lights that shall provide a minimum illumination of 5 lux. Solar Street Lights should preferably be used to reduce Aux. Consumption and cabling. Indoor inverter stations, main control rooms and administration / SCADA rooms shall be provided with adequate lighting fixtures comprising of high efficiency CFL / FTL lighting fittings. A minimum of 250 lux for the inverter stations and 300 lux for the admin / SCADA rooms shall be maintained.

66KV Switchyard/Double Pole Structure

A 66KV Switchyard/Double Pole Structure has been envisaged for evacuation of power. The switchyard shall be interconnected with the 66KV grid Substation by means of overhead conductor. The 66KV Switchyard will be designed based on the parameters presented in Table below.

Table 64. Technical requirements 66KV Switchyard

Dimensions	:	Details
System operating voltage		66KV
Maximum operating voltage of the system(rms)		36kV
Rated frequency		50Hz
No. of phase		3
Rated Insulation Level		
Full wave impulse withstand voltage (1.2/50 microsec.)		170kV
One minute power frequency dry withstand voltage (rms)		95kV
One minute power frequency wet withstand voltage (rms)		75kV
Minimum creepage distance		31mm/kV
Minimum Clearances		
Phase to phase		500 mm
Phase to earth		500 mm
Sectional clearances		2800 mm
Rated short circuit current for 1 sec. duration		25 KA

Circuit Breakers

66KV Vacuum Circuit breakers each comprising set of 3 pole live/dead tank units with spring operated mechanism, and meeting the requirements as specified in IS, IEC standards, and the regulations
The following minimum ratings:

- Rated Voltage : 66KV
- Short time rating : 25 kA for 1 sec

Disconnecting Switches

Center rotating post horizontal double break triple pole disconnecting switch with or without earth switch will be provided. Operation of the disconnecting switch will be interlocked with associated breaker and earth switch. The isolator shall have the following minimum ratings:

- Rated Voltage : 66KV
- Short time rating : 25 kA for 1 sec

Current Transformers

Live or dead tank type single phase multi-core multi ratio current transformers (CTs) with 1 amp secondary will be provided for indication, metering and protection requirements.
Accuracy of tariff metering cores shall be Class 0.2S. Separate CT cores will be provided for Main and Check Tariff Metering. The CT's shall have the following minimum ratings:

- Rated Voltage : 66KV
- Short time rating : 25 kA for 1 sec

Voltage Transformers

Voltage Transformers (VTs) with multiple secondary windings will be provided on lines, bus bars and step up transformers for metering and protection requirements. Separate cores with Class 0.2 accuracy will be provided for metering.

Lightning Surge Arresters

30 kV, 10 kA metal oxide (gapless) surge arresters of heavy duty station class (discharge class III) shall be provided. The arrester will include a digital impulse counter and leakage current detector.

Energy Metering

Dedicated CT and PT shall be provided in 66KV Switchyard for Tariff metering. Accuracy class of CT and PT shall be 0.2s and 0.2 respectively. Tariff metering panel to be located in the yard as per existing practice followed in India.

Mechanical Requirement

Fire Fighting and Detection System

The Solar PV plant shall be equipped with suitable fire protection and fighting systems for entire PV array area, inverter stations, main control room and switchyard as per the local fire authority requirements. Firefighting of transformers and other electrical equipment's as required shall be in accordance to relevant International Standards, NFPA 850, NFPA 70 and NFPA 15. Automatic fire detection cum alarm system shall be provided for the plant which shall be integrated with required cabling to a single fire alarm control panel. Fire detection alarm system shall include alarm initiating multi sensor type smoke detectors. The entire system shall work on auxiliary power supply. In case of power failure, the complete system shall function in normal condition on maintenance free back-up batteries for a minimum period of 24 hours duration. Manual call points and hooters shall be provided for all the modular block control rooms. These shall be further integrated with fire alarm control panel in main control room.

Air-Conditioning & Ventilation Systems

The design of the heating, ventilation and air conditioning (HVAC) will be based on ASHRAE. This will be a common unit share by three units and mainly for indoor facilities. The HVAC system shall be provided complete with all equipment and accessories necessary for safe, efficient, reliable and continuous operation.

- Inverter Station
- Main Control Room
- Switchgear Room
- All other locations as deemed fit by the Bidder

A minimum design margin of 10% is to be considered while designing the capacity of supply air fans, and exhaust air fans etc. A design margin of 10% is to be considered in the capacity of motors for the above fans.

Instrumentation and Control Systems

Philosophy

The power plant shall incorporate a communication system to monitor the output of each string and inverter so that system faults can be detected and rectified before they have an appreciable effect on production. The monitoring system will be a combination of web based internet portal solution and on site local area network for acquisition of data through onsite servers. Bidder shall provide the configuration of the proposed monitoring system along with Supervisory Station which refer to the server and software responsible for communicating with the field equipment, and then to the HMI software running on workstations in the control room, or elsewhere. Data loggers shall be used to collect data from the weather station, the inverters, meters, and the transformers to transfer data to a server which will carry out key functions:

- All the String combiner boxes, inverters, transformer inputs, RMUs inputs, LV/MV Switchgears inputs, and plant meters of 0.2s class shall be integrated with monitoring system.
- Monitoring system shall be designed with different dashboards for various users such as Plant O &M team, senior management.
- The recorded data shall be sequential right from string to metering. The data shall be compatible and transferable to MS Office excel.

In addition to conventional parameters (V, I, kW, kVA, kVAr etc.) below is the list of monitoring and recording parameters.

Table 65. Monitoring and recording parameters

Plant	Plant Performance Ratios	Meteorological
• String parameters. • String failure detection. • DC & AC currents and Power at various levels, Cumulative Energy, Grid Status, Error codes and all other parameters provided by the inverter. • Power generation at interconnection. • Daily power generation in kWh. • Monthly power generation in kWh. • Annual power generation power in kWh. • AC active power kW (both for import & export). • AC reactive (kVAr) and (kVA) (both for import & export). • Power factor (both for import & export). • Power generation from the date of commissioning. • Plant availability. • Grid availability. • Auxiliary consumption.	• Real time PR • Quarterly average PR. • Annual average PR. • Plant Performance Ratio, since commissioning. • Daily, Monthly, Annual PLF (Plant load factor)	• Global Irradiance on Horzontal • Global Irradiance on POA. • Module Temperature. • Ambient Air Temperature. • Wind Speed and Direction. • Relative Humidity • Precipitation •

Control and Instrumentation Requirement

The Control and Instrumentation requirement in a solar PV Plant generally consists of Monitoring system to monitor the string voltage, current, inverter data and Generation data. Supervisory Control and Data Acquisition system (SCADA) is preferred for solar PV Plant monitoring.

Supervisory Control and Data Acquisition System

The SCADA system operates as a standalone, autonomous system, monitoring sensors, displaying data, outputting controls, activating alarms and logging information to facilitate and optimize the plant processes and on-going operations. It shall be capable of pooling, transmitting and receiving data, both analog and digital, at high rates of speed, using secure digitizing protocols and error avoidance methods. The SCADA system shall be composed of an integrated operator human-machine interface (HMI), input/ (I/O), communication infrastructure and software. An industrial Ethernet LAN and fiber optic network shall be distributed throughout the field for communication to field devices.

The data acquisition shall be through a desk top computer of latest configuration. EPC Bidder shall provide external communications link/browser based monitoring option to the Owner to access all data acquisition and real time performance monitoring from its corporate office or from anywhere across the globe. Bidders shall provide all necessary hardware as required for entire setup. Provision of generating alarm/error code based on equipment Status, failure of equipment, nuisance tripping to be provided. Provision for presenting key plant characteristics and historic data in terms of graphs and reports, real time trends shall be provided.

Security and Communication System

The PV plant shall be under human and CCTV based vigilance. The Plant shall be provided with a one prefabricated security cabin and shall be strategically located across the periphery and access locations of the plant. The main security cabin and an entry / exit gates shall be monitored by CCTV (close circuit TV) system, the CCTV system shall provide an online display of video images and record onto a separate digital video recorder (DVR) that could be located in the main control room or at a central security office anywhere else within the building. The DVR shall be capable of holding the backup of all the cameras for at least two weeks. IP based Telephone communication system shall be provided with the EPABX system. Telephones shall be provided as per the system requirement at different location for smooth operation of the plant and integrated with the main telephone system. Telephones shall be located in the control room and offices, wall mounted telephones shall be located in the switchgear rooms, store rooms and other area of the plant wherever applicable.

Meteorological Stations

The Bidder shall provide a minimum of three set of weather station to provide adequate meteorological data to evaluate system performance. Stations shall essentially include sensors but not be limited to monitoring of Global Irradiation on the horizontal, Global Irradiation on POA, Module Temperature, Ambient Air Temperature, precipitation, wind speed and direction, relative humidity and Rain Gauge. Dedicated Pyranometers shall be used for measurement of global irradiation on horizontal & POA. Pyranometers of Secondary standard from the manufacturer of international repute such as Kipp and Zonen, Appley etc and approved by the Owner shall be used in Meteorological Stations.

All the Meterological station shall be used for evaluating plant performance during the plant operations. Apart from the above mentioned sensors, the meteorological station should be equipped with the following:

- Solar Panel
- Data logger

These Meteorological stations along with data loggers shall be located inside the plant and shall be capable of collecting the data points, sample frequency along with SCADA interface. These Station shall have capability of recording and storing environmental data without AC power for two (2) days.

Annexure 8: Technical specifications 220/66KV Pooling Substation

Salient Features of Each 220/66KV Pooling Substation

In 2000 MW Solar Park there shall be Eight (08) nos. 220/66KV Pooling Substation each of 250 MVA capacity shall be proposed for evacuation of Power.
The salient features and indicative layouts of each 220/66KV Pooling Substation is shown in the following drawings:

- Single Line Diagram of 220/66KV Pooling Substation (Drawing No. "Pooling Substation-SLD-01")
- Layout of 220/66KV Pooling Substation (Drawing No. "Pooling Substation Layout-02"))

The 220/66KV Pooling Substation has the following major components.

- Air Insulated outdoor 220 kV Substation with Two Main Bus Bar arrangement having the following bays.
  - One (01) nos. bays for 220 kV Dingle Circuit Line for evacuation of power.
  - Five(05) nos. bays for 220 / 66KV Transformer for evacuating power from 5 nos. 50 MW Solar PV Plants of Solar Park
  - One (1) Bay for Bus Coupler

- Two (02) nos. 220/66KV, 120/150 MVA power transformer with ONAN/ONAF Cooling and On Load Tap Changer. These transformers are excluded from the scope of supply of the Bidder. However, erection, testing and commissioning is in Bidder's scope.
- Air Insulated outdoor 66KV Substation with Single Bus Bar arrangement having the following bays.
  - Five (05) nos. outgoing line bays from Five (05) nos Solar PV Plant (each of 50 MW capacity) to 220 / 66KV Transformer for interconnection with 220 kV substation.
  - Two (2) nos. 200 kVA, 66KV/ 415 V Station Transformer will be connected with 66KV bus through Isolator and drop out fuse for supply of 400 V auxiliary power supply to the Substation auxiliaries and building.
  - Ten (10) nos. Incomer feeders from 66KV Wind farm at Agar.

The indicative Layout of 220/66KV Pooling Substation has been prepared based on 220 kV two main bus with high and strung bus bar arrangement. However, the bidder is free to optimise his design and may propose alternate layout of 220/66KV substation within the available land for approval of the Owner.

Main System Parameters

The following major technical parameters as mentioned in table below shall be used for design of equipment and system of 220/66KV Pooling Substation:

Table 66. System Parameters of 220kV & 66KV Systems

S. No.	Description of Parameters	220kV System	66KV System
1	**System Operating Voltage**	220kV	66KV
2	**Max. Operating voltage of the System (Vrms)**	245kV	36kV
3	**Rated Frequency**	50Hz	50Hz
4	**No. of Phase**	3	3
5	**Rated Insulation levels**		
a.	Full wave impulse withstand Voltage (1.2/50 microsec.)	1050 kVpeak	170 kVpeak
b.	One minute power frequency dry and wet withstand Voltage (Vrms)	460 kVrms	70 kVrms
6	**Minimum creep age distance (25mm/kV)**	6125 mm	900 mm
7	**Min. Clearances in air**		
a.	Phase to Phase	2100 mm	320 mm

b.	Phase to earth	2100 mm	320 mm
8	**Rated Short Circuit current**	40 kA for 1sec	25 kA for 3 sec
9	**System Neutral Grounding**	Solidly Grounded	Solidly Grounded

Electrical Auxiliary Power Supply

The electrical auxiliary and control power source shall be as follows:

a. AC auxiliary power source : 3 phase, 4 wire, 50Hz, 400V
1 phase, 50Hz, 230V

b. DC control power source : 220V

c. DC power source for communication : 48V

Codes and Standards

All equipment, materials, fabrication and tests under these specifications shall conform to the latest applicable standards and manuals contained in the following list or to standards, manuals and specifications approved by the Employer. Any details not specifically covered by these standards and specifications shall be subject to approval of the Employer.

- ✓ IS Indian Standards
- ✓ ANSI American National Standard Institute, Inc
- ✓ BS British Standard Institution
- ✓ EEI Edison Electric Institute
- ✓ IEC International Electro technical Commission
- ✓ NEMA National Electric Manufacturers Association
- ✓ IEEE Institute of Electrical and Electronics Engineers

All plants and equipment supplied under this Contract shall conform to or be of higher quality than the latest applicable standard.

If the Specifications contained in this Contract conflict in any way with any of the reference standards, the Specifications shall take precedence. If there are conflicts between different specified reference standards covering the same material or equipment, the standard, which will provide the highest quality and most suitable application, as determined by the Employer shall prevail. References to standards or to equipment of a particular manufacturer shall be regarded as follows by the words "or equivalent", except as otherwise noted.

The Contractor may propose alternative standards, or equipment, which shall be equal to those, specified unless the system requires specific equipment, as mentioned in the specification, to ensure compatibility. If the Contractor for any reason proposes alternatives to or deviations from the above standards, or desires to use equipment not covered by the above standards, the Contractor shall state the exact nature of the change, the reason for making the change, and shall submit, for their approval. The decision of the Owner in the matter of equality will be final.

Technical Parameters of Major Equipment

Technical Particulars for Power Transformer

S. No.	Description	*220/66KV*
1.	Rated capacity	*120/150 MVA*
2.	Quantity required	Four (04) no.
3.	Type	Outdoor, Oil-immersed
4.	Type of cooling	*ONAN/ONAF (120/150 MVA)*
5.	Temperature rise above 40 degree C ambient temperature	
	a) In oil by thermometer	50 degree C
	b) In winding by resistance	55 degree C
7.	Number of phases	3(three)
8.	Maximum voltage (line to line)	
	a) Primary	245 kV
	b) Secondary	36 kV
9.	Rated Voltage (line to line)	

	a) Primary	*220 kV*
	b) Secondary	*66 kV*
10.	Insulation level of winding	
	a) Basic impulse level as per IEC 76	
	- Primary	*1050 kV (crest)*
	- Secondary	*170 kV (crest)*
	b) Power frequency induced over voltage (1 minute)	
	- Primary	*460 kV(rms)*
	- Secondary	*70 kV(rms)*
11.	Connections	
	a) Primary	Star
	b) Secondary	Star
12.	Vector group reference	YNyn0
13.	Type of tap changer/make	*On-load*
14.	Range of taps	*+15 % to -10%*
15.	Number of taps	*20*
16.	Method of tap changer control	
	- Mechanical local	Yes
	- Electrical local	Yes
	- Electrical remote	Yes
	"MASTER-FOLLOWER-INDEPENDENT" and "AUTO - MANUAL" selection	Yes
17.	Percent impedance voltage at rated MVA and 75 degree C On normal tap	*≈12.5 % (at normal tap) at 100 MVA base* *Tolerance As per IS-2026*
18.	Over voltage operating capability & duration	110% rated voltage continuous. 125% rated voltage for 60 second. 140% rated voltage for 5 seconds.
19.	For overfluxing factor operating capability & duration	1.1 Continuous 1.25 60 sec. 1.4 5 sec.
20.	Noise Level	As per NEMA standard TR-1.
21.	Cooling equipment	Two 50 percent banks.. Adequate number of fans and one standby fan in each 50% bank
22.	Bushings	
	Rated voltage, kV rms	245 kV (HV) & 36 kV (LV)
	1.2/50 micro second impulse withstand voltage, kV, peak	1050 kVp (HV) & 250 kVp (LV)
	Dry and wet one minute power frequency withstand voltage kV rms	460 kV rms (HV) & 95 kV rms (LV)
	Minimum Creepage distance mm – total	6125 mm (HV) & 900 mm (LV)
	Rated Current A	1250 A (HV) & 2000 A(LV)
	Tan delta and capacitance	As per IS-2099
	Partial discharge level	As per IS-2099
23.	Terminal Connectors	
	High voltage	Twin Zebra ACSR conductor
	Low voltage	Twin Moose/Bersimis ACSR Conductor
	Neutral	Suitable to connect 2 nos., 10 mm thick, 500 x 80 mm copper flat (to be connected at 180°C)
24.	System grounding	
	a) Primary	Solidly grounded
	b) Secondary	Solidly grounded
25.	Neutral terminals & BCT	
	- Primary	Required
	- Secondary	Required
26.	Tank Mounted Lightning Arrester	
	HV	-

	LV	Required
27.	Bushing Current Transformers	
	a) Number of core & current ratio in HV	
	HV Neutral	*1*300/1A (Class:PS)* *1*300/1A(5P20, 20 VA)*
	b) Number of core & current ratio LV Phase	*1* 2000/1A (Class:PS) & 1*2000/1A (Class:0.2, 20VA) & 1*2000/1A (Class:5P20, 20VA)*
	Neutral	*1*2000/1A (Class:PS)* *1*2000/1A(5P20, 20 VA)*
28.	Losses (kW- Max) a. No load losses at rated voltage and frequency at principal tap	*50 kW(Max)*
	b. Load Losses at rated output(Max MVA), rated frequency and corrected for 75 deg C	*270 kW (Max)*
	c. Auxiliary losses at rated output (Max MVA), normal ratio, rated voltage, rated frequency and ambient temperature (kW)	*6 kW (Max)*
	d. Total Losses at normal ratio inclusive of auxiliary equipment losses (kW) corrected to 75 deg C	*330 kW (Max)*
29.	Site Attitude	1000m above MSL
30.	Rail gauge Shorter axis Longer axis	Two rails with 1676 mm gauge. Two rails with 1676 mm gauge.

Circuit Breaker

245kV SF6 Circuit Breaker

S. No.	Description	245kV Circuit Breaker
1.	Type	SF6, outdoor type
2.	Voltage rating: a) Nominal system voltage b) Rated maximum voltage	 220 kV 245 kV
3.	Insulation level a) Impulse withstand voltage b) Power-frequency withstand voltage (1 min.)	 1050 kV (crest) 460 kV (rms)
4.	Frequency	50 Hz
5.	Current rating a) Rated continuous current at 40 degree C ambient b) Short circuit breaking current	 1250 A 40 kA for 1 sec
6.	Creepage distance	6125 mm
7.	Auxiliary supply a) Control circuit b) Space heater and auxiliary equipment.	 220 V DC AC, 230/400V, 50 Hz
8.	Operation	Two (2) Nos. breaker single pole operation type for 220 kV transmission line bay for Line Bay-1 and Line Bay -2 feeders and remaining three pole operation type for others feeders)
9.	Reclosing duty cycle	O-0.3 sec-CO-3 min-CO
10.	Total maximum break time	60 ms
11.	First pole to clear factor	1.3
12	Additional Auxiliary Contacts	8 NO, 8 NC
13.	Maximum make time	120 ms
14.	Spring charging motor	220 V DC

16.	Temperature rise over the design ambient temperature	As per IEC: 62271-100
17.	Trip coil and closing coil voltage	220 V DC
18.	No of Terminals in common Control cabinet	All Contacts & control circuits to be wired out upto common control cabinet plus 24 terminals exclusively
19.	Noise level at base and upto 50 m (distance from base of breaker)	140 dB (Max.)
20.	Maximum allowable switching overvoltage under any switching condition	As per IEC
21.	Rated small inductive current switching capability with overvoltage less than 2.3 p.u.(A)	0.5 to 10

66KV Vacuum Circuit Breaker

S. No.	Description	66KV Circuit Breaker
1.	Type	66KV VCB, outdoor type
2.	Voltage rating: a) Nominal system voltage b) Rated maximum voltage	 66KV 36 kV
3.	Insulation level a) Impulse withstand voltage b) Power-frequency withstand voltage (1 min.)	 170 kV (crest) 95 kV (rms)
4.	Frequency	50 Hz
5.	Current rating a) Rated continuous current at 40 degree C ambient b) Short circuit breaking current	 2000 A for Transformer Bay & 800 A for Line bay 25 kA
6.	Creepage distance	900 mm
7.	Auxiliary supply a) Control circuit b) Space heater and auxiliary equipment.	 220 V DC AC, 230/400V, 50 Hz
8.	Rated Capacitor Breaking current	≥400A
9.	Rated Back to Back Capacitor Bank Breaking current	≥20kA
8.	Operation	Three pole operation type
9.	Reclosing duty cycle	O-0.3 sec-CO-3 min-CO
10.	Total maximum break time	60 ms
11.	First pole to clear factor	1.3
12	Additional Auxiliary Contacts	8 NO, 8 NC
13.	Maximum make time	120 ms
14.	Spring charging motor	220 V DC
17.	Trip coil and closing coil voltage	220 V DC
18.	No of Terminals in common Control cabinet	All Contacts & control circuits to be wired out upto common control cabinet plus 24 terminals exclusively
19.	Noise level at base and upto 50 m (distance from base of breaker)	140 dB (Max.)
20.	Maximum allowable switching overvoltage under any switching condition	As per IEC

Isolator with and without earth switch

S. No.	Description	Disconnecting switch 245 kV	Disconnecting switch 66KV
1.	Type	3-poles, Horizontal Double break & Horizontal Double Break tandem	3-poles Horizontal Double break
2.	Rated Voltage	245 kV	66KV

3.	Frequency	50 Hz	50 Hz
4.	Insulation levels		
	a) Basic impulse level (BIL)	1050 kV (crest)	170 kV (crest)
	b) Power frequency withstand voltage (For1 minute)	460 kV (rms)	70 kV (rms)
5.	Current ratings		
	a) Continuous current	1250 A	800 A & 2000 A
	b) Rated Short Time current	40 kA for 1sec	25 kA for 3 sec
6.	Operating mechanism of disconnecting switch	Motorized & gang operated (both local and remote operation) and manual	Motor & gang operated (both local and remote operation) and manual
7.	Auxiliary power supply		
	a) Space heater and cubicle	230V,1-phase, 50Hz	230V,1-phase, 50Hz
	b) Control circuit	220 V DC	220 V DC
	c) Operating motor	230/400 V, 50 Hz	230/400 V, 50 Hz
8.	Applicable standard	IEC	IEC
9.	Enclosure Protection	IP-55W	IP-55W

220 kV & 66KV INSTRUMENT TRANSFORMER

Capacitive Voltage Transformer for 245 kV and Voltage Transformer 66KV

S. No.	Description	245 kV CVT / VT	66KV VT
1.	**Type**	Outdoor, oil immersed for protection and metering.	Outdoor, epoxy resin encapsulated for protection and metering.
2.	**Rated primary voltage**	220kV	66KV
3.	**Max. system voltage**	245 kV	36 kV
4.	**Impulse withstand voltage**	1050 kV (crest)	170 kV (crest)
5.	**Power frequency withstand voltage (1min,rms)**	460kV(rms)	70 kV (rms)
6.	**Rated frequency**	50Hz	50Hz
7.	**Connection**	Line to ground	Line to ground
8.	**Number of secondary winding**	2	2
9.	**Voltage ratio**	220/√3/0.11/√3/0.11/√3 kV	33/√3 / 0.11/√3/0.11/√3 kV
10.	**Rated burden**	50 VA	50 VA
11.	**Accuracy class**	3P and 0.2 for metering	3P and 0.2 for metering
12.	**Rated voltage factor**	1.1 Continuous	1.1 Continuous
13.	**Creepage distance**	6125 mm	900 mm
14.	**Applicable standard**	IEC 60186 / IEC 60044-2	IEC 60044-2

245kV and 66KV Current Transformer

S. No.	Description	245kV CT	66KV CT
1.	Type	Outdoor, oil immersed for protection and metering.	Epoxy resin capsulated outdoor for protection and metering.
2.	Rated primary voltage	220 kV	66KV
3.	Maximum system voltage	245 kV	36 kV
4.	Impulse withstand voltage	1050 kV (crest)	250 kV (crest)
5.	Power frequency withstand voltage (1min,rms)	460 kV(rms)	95 kV (rms)
6.	Rated frequency	50 Hz	50Hz
7.	Number of core	5	2
8.	Short time thermal ratings	40 kA for 1 sec	25 kA for 3 sec

9.	Current ratio	*300/1A* *900-600/1A*	*2000/1A* *400-600-800/1A (MRCT)*
10.	Rated burden for each core	20 VA	20 VA
11.	Accuracy class	Class PS for protection and 0.2 & 0.2S for metering (as per SLD)	Class PS & 5P20 for protection and 0.2 for metering
12.	Creepage distance	6125 mm	900 mm
13.	Applicable standard	IEC 60044-1	IEC 60044-1

Lightning Arrestor

S. No.	Description	198 kV LA	30 kV LA
1.	Type	Gap less, Metal –oxide, Outdoor	Gap less, Metal –oxide, Outdoor
2.	Mounting	Pedestal mounted	Pedestal mounted & transformer tank mounted
3.	Rated frequency	50Hz	50Hz
4.	System voltage	220 kV	66KV
5.	Rated voltage	198 kV	30 kV
6.	Impulse withstand voltage (BIL)	1050 kV (crest)	170 kV (crest)
7.	Power frequency withstand voltage	460 kV (rms)	70 kV(rms)
8.	Nominal discharge current of 8/20 micro second wave shape	10 kA	10 kA
9.	Station Class	Class - III	Class - III
10.	Applicable Standard	IEC 60099-4	IEC 60099-4

Station Auxiliary Supply

S. No.	**Description**	**66/0.415 kV Transformer**
1.	Rated power	*200 kVA*
2.	Rated voltage -Primary -Secondary	 66KV 415 V
3.	Max. system voltage -Primary -Secondary	 36 kV 440 V
4.	Rated frequency	50 Hz
5.	Connection -Primary -Secondary	 Delta Wye, Solidly Grounded
6.	Cooling system	ONAN
7.	Voltage vector group	Dyn11
8.	Rated impedance voltage	~4.5 %
9.	BIL of winding and bushing for primary side	170 kV (crest)
10.	Withstand voltage 50 Hz, 1 min. -Primary -Secondary	 70 kV 3 kV
11.	Off-circuit tap changer voltage taps on HV side	+/- 5 % in steps of 2.5%
12.	Mounting	*Platform on ground*
13.	Bushing (suitable for) -HV -LV	 Exposed for connection with overhead conductor Enclosed for cable connection
14.	Insulation temperature class (IEC 76)	A
15.	Max. allowable noise level at 3 meter hemispherical radius	44 dB

16.	Applicable standard	IEC

Grounding Conductors

S. No.	Item	Size	Material
1.	Main Earthing Conductor to be buried in ground	40mm dia	Mild Steel rod
2.	Conductor above ground& earthing leads (for equipment)	75x12mm G.S. flat	Galvanised Steel
3.	Conductor above ground& earthing leads(for columns & aux. structures)	75x12mm G.S. flat	Galvanised Steel
4.	Earthing of indoor LT panels, Control panels and outdoor marshalling boxes, MOM boxes, Junction boxes& Lighting Panels etc.	50x6 mm G.S. flat	Galvanised Steel
5.	Rod Earth Electrode	40mm dia, 3000mm long	Mild Steel
6.	Pipe Earth Electrode (in treated earth pit) as per IS.	40mm dia, 3000mm long	Galvanised steel
7.	Earthing for motors	25x3mm GS flat	Galvanised steel
8.	Earthing conductor along outdoor cable trenches	50x6mm MS flat	Mild steel
9.	Earthing of Lighting Poles	20 mm dia 3000 mm long	Mild steel rod

Substation Automation System (SAS)

The SAS shall comprise the following main functional components / subsystems:

- Human-Machine Interface with process database
- Communication bus with associated hardware along with gateway for future IEDs for data exchange between different SAS components
- Bay Level Devices for Control, Monitoring and Protection i.e. Bay Control Units and Bay Protection Units, along with associated communication system.

Substation Level Functionality

- The SAS shall perform control functions on various switchyard equipment based on the status, analog and logical inputs acquired by SAS from various bay control units.
- It shall be possible to supervise and control all the switchyard bays in Bidder's scope from Control Level 2 i.e. Substation level workstations. However, in case of maintenance or any defect in the communication link between Control Level 2 and Control Level 1, it shall be possible to control completely, the individual bays from Control Level 1 i.e. from individual bay control units, without involving any wiring or without any change in hardware.
- Clear control priorities shall ensure that operation of particular bay equipment (Circuit Breaker or Isolator) cannot be initiated simultaneously from more than one of the control levels. The priority shall always be on the lowest enabled control level. The selected control level shall be indicated at all the levels so that the operator is aware of his control capabilities.
- The SAS shall have provision of Device Tagging for all the substation devices. This function is to block the control of any substation device in such a manner that it's command is prevented from Operator's Workstations.

Sequence of Events and Alarm Management

- The SAS shall be capable of reporting on both Operator Workstation and printers, the time sequenced record of events occurring in the substation. Separate logs shall be created for alarms and events and both the logs shall be time-tagged. Suitable filters, based on date and time, bay number, device number, function etc. shall be provided for both alarm as well as event logs for ease of viewing.
- SAS shall record all changes of alarms and state (Plant State) of switchyard equipment, including the alarms generated by Bay Control and Bay Protection units.
- All the alarms and events shall be time tagged with a time resolution of 1ms.
- The SAS shall cope with all the alarms and changes of state of 400kV switchyard equipment generated at BCU / Bay Protection Unit as well as Substation Levels.

- The SAS shall acquire the alarm signals from Bay Control Units and Bay Protection Units with preset priorities and on receipt of an alarm, shall generate an audible signal and report it either upon request or automatically to the respective printer.
- Owner shall approve the list of alarm states and plant states to be wired for Sequence of Events log and Alarm Management, during detailed engineering stage.

Human-Machine Interface

- The HMI as specified shall be based on the latest state of the art workstations and servers and technology suitable for industrial applications and switchyard environment. Two possible alternatives for the HMI can be offered by the bidder as indicated in Drg. Nos. 9518-230-POE-A-013, Rev. A. The quantity of peripherals, main and bulk memory etc. as shown in the referred drawing and indicated in scope of supplies is minimum the bidder has to provide. For alternatives I and II, the number of redundant Operator's Workstations (OWS) / Servers shall be as required to achieve the processing capability to meet all the functional requirements of this specification.
- The main memory shall be sized sufficient to meet the functional and parametric requirements as specified. The bulk memory shall be sized at 1.5 times the capacity required sufficient to meet the functional and parametric requirements. However, both the main and the bulk memory shall be subject to minimum hardware specification as per Annex-A to this chapter. The exact system configuration and sizing shall be approved by Owner during detailed engineering.
- All the OWS of the HMI shall be interchangeable i.e. all operator's functions shall be possible from any of the OWS at any point of time without the necessity of any action like downloading of additional files. Each OWS shall be able to access all the substation information related data under all operating conditions including a single processor / computer failure in the HMI.
- No single failure in HMI shall lead to non-availability of more than one OWS. In such an event, i.e. single failure leading to non-availability of any OWS, it shall be possible to monitor the entire switchyard from the other available OWS.
- The Workstations / servers employed for HMI implementation shall be based on industry standard hardware and software which will ensure easy connectivity with other systems and portability of Owner developed and third party software.
- Power Fail Auto Restart (PFAR) facility with automatic time update shall be provided, once the operator logs in.

The Bay Control Units:

- Switching of Switchyard Bay Equipment depending on conditions such as Interlocking, synchro-check, control mode, or external status condition. Adequate safety features like prevention of double operation, command supervision, block/deblock, over-riding the interlocking etc. shall be provided. All such security features shall be finalized and approved by Owner during detailed engineering.
- Status Supervision of switchyard equipment
- Interlocking Function to prevent unsafe operation of switchyard equipment such as circuit breakers, isolators, earth switches etc. All interlocking shall be achieved by user-friendly, menu-driven configuration software within the BCU. An over-riding / bypass function for bay-level interlocking statements shall be provided at appropriate security level for maintenance or during emergency conditions.
- Analog Measurements for bay voltage, current and frequency. These measurements shall not require the use of any intermediate transducers. The accuracy of measurement shall be 0.5 for voltage, current and frequency. The measured and computed values shall be displayed locally on BCU and on operator's workstation located in central control room.
- Event and Alarm Handling: BCUs shall acquire all the bay level alarms and events from field inputs with a resolution and time tagging of 1ms and shall transfer these to operator's workstation over substation LAN.
- Synchronization Check Feature: Synchronization Check feature shall determine the difference between the amplitudes, phase angles and frequencies of two voltage vectors. Checks shall be provided to detect a dead line or bus bar. The voltage difference and phase angle difference settings shall be adjustable.

    1. Energy Meters

2. The following energy meters conforming to the relevant clause indicated elsewhere shall be provided: For each 400KV line Main & check energy meter for export and import

Constructional Features

- The panels shall be free standing, floor mounting type and completely metal enclosed. Cable entries shall be from bottom.
- Shall have removable gland plates with glands made of brass and suitable for armoured cables
- All equipment mounted on front and rear side of the panels shall have individual nameplates with equipment designation engraved. Each panel shall also have circuit/feeder designation name plate.
- Each panel shall be provided with a 240V AC fluorescent lighting fixture controlled by door switch as well as a 5A, 240V AC switch-socket unit.
- Shall be provided with necessary arrangements for receiving, distributing, isolating and fusing of AC & DC supplies for various circuits for control, signaling, lighting, interlocking, etc. Selection of main and sub-circuit fuse rating shall ensure selective clearance of the sub-circuit faults.
- Voltage circuits for protection and metering shall be protected by fuses. Suitable fuse failure relays shall be provided to give an alarm for voltage circuits of protection/metering. Voltage selection scheme based on relays shall be provided for meters wherever possible.
- The DC supplies at the individual relay and protection panels shall be monitored by suitable relays and failure of DC supplies shall be annunciated.

Energy Meters

Energy meters shall have the following features:

- Static type conforming to IEC:687 and Shall carry out measurement of active energy (both import and export) and reactive energy (both import and export) by 3 phase, 4 wire principle suitable for balanced/ unbalanced 3 phase load.
- Accuracy of energy measurement of 0.2S for active energy and 0.5 for reactive energy.
- The active and reactive energy shall be directly computed in CT & VT primary ratings and stored in four different registers of memory of the meter as MWH(E), MWH(I), MVARH(E) and MVARH(I) along with a plus sign for export and minus sign for import. The VARH shall be computed and stored in four separate registers corresponding to various system voltage conditions, and these conditions shall be finalized during detailed engineering.
- Compute the energy sent out of the station busbars during each successive 15 minute block and store in the respective register.
- Display on demand the energy sent out during previous 15-minute block.
- Continuously integrate the energy readings of each register upto the previous 15-min. block. All these readings shall be displayed on demand.
- The reading shall be stored for a period of 40 days before being erased.
- Date/time shall be displayed on demand. The clock shall be synchronized by GPS time synchronization equipment being provided.
- Each meter shall have a unique identification code provided by Purchaser and shall be marked permanently on the front and also in the non-volatile memory.
- The voltage monitoring of all the three voltages shall be provided. The meter shall normally operate with power drawn from the VT supplies.
- The power supply to the meter shall be healthy even with a single-phase VT supply. An automatic backup, in the event of non availability of voltage in all the phases, shall be provided by a built in long life battery and shall not need replacement for at least 10 years with a continuous VT interruption of at least 2 years. Date and time of VT interruption and restoration shall be automatically stored in a non-volatile memory.
- Have an optical port on the front of the meter for data collection. Also the stored data shall be continuously transferred through necessary serial/parallel ports to a local IBM compatible PC to be supplied by the contractor. Necessary hardware and software shall be provided for downloading data on the local PC for display and printing.

- The necessary software shall be provided to accept the data on line and store in memory and on a floppy diskette and also to print the same. The data format for printing shall be finalized during detailed engineering.
- The tariff meters provided on the 400 kV feeders shall conform to the Indian Electricity Grid Code metering specification

Transducers (if provided)

Transducers shall have following features

- Conform to IEC: 688-1.
- The output of the transducers shall be 4-20mA/0-10mA/10-0-10mA dc as necessary for the instruments.
- Accuracy class shall be 0.5 or better except for frequency transducer, which shall have an accuracy of 0.2S.
- Summation transducer shall be suitable for taking multiple inputs from individual MW/MVAR transducers.
- Dual output. One output shall be used for the indicating instrument/recorder provided and other shall be wired upto terminal block of the panel for Purchaser's use in future.
- Energy transducers shall be suitable for 3 phase, 4 wire connection.

Annexure 9: Technical specifications 220 kV Transmission Line

This specification intends to cover performing of detailed survey including trimming of trees / clearing of any obstruction en-route for performing detailed survey including profiling and tower spotting, check survey, geotechnical investigation, defining types of towers, tower optimization and design of towers and foundations for normal & special towers, proto testing, fabrication & galvanizing of towers and supply of all line material (Galvanized Stranded Steel Earth wire, Conductor accessories and Earth Wire accessories & Insulator string hardware) excluding Power Conductor and Porcelain disc insulator units and construction of foundations, erection of towers and stringing of the conductors & ground wire on normal & special towers including clearing of ROW and testing & commissioning of the complete transmission line. The scope of work as envisaged is 8 nos. 220KV Single Circuit Transmission Line from each 220 kV Pooling Substation to 400/220 kV Grid Substation of POWERGRID with Drake ACSR Power Conductor –

General and Technical Requirements

System Particulars: General and Technical Requirements of the transmission line

Description	Data
Line Voltage(kV)	220
Highest System Voltage (kV)	245
No of Circuit	1 for each 250 MW unit)
Frequency (Hz)	50
Neutral	Effectively earthed
Normal Span(m)	350
Wind Span(m)	385
Weight Span (Man/min m)	525/-100
Basic Insulation level BIL kV (RMS) (peak)	1050
Power frequency withstand voltage wet (kV)rms	460
Corona extinction voltage Dry condition (kV)rms	156
Radio interference voltage at one MHz for phase to earth voltage of 266kVrms dry	100
Short circuit level (kA)	40
Maximum temperature deg C	
Conductor	75
Earthwire	53
Clearances	
Another power line (mm)	4580
Telecommunication line (mm)	3050
Railway line(mm)	
Above track	15300
Above crane	3200
Major roads (mm)	As per IE Rules-1956
Ground Clearance (mm)	7000

Conductor creep compensation shall be provided by increasing stringing tension by reducing stringing temperature by 26°C for Drake ACSR conductor during stringing operation.

Tower design

Towers shall be self supporting type of vertical configuration and are designated as suspension towers, tension towers, transposition towers and special towers. The requirement of transposition and special towers shall be assessed after finalization of the detailed survey, profiles etc. The 220KV Single circuit suspension towers shall be provided with single suspension string with twin bundle conductor and jumper pilot string and double suspension string with Quad conductor bundle and the 220KV Double circuit tension towers with double tension strings with twin bundle conductor and quad tension string with Quad bundle conductor of EMS rating as given in relevant clause.

The 220kV tower's configuration and clearance adopted shall meet the following environmental criteria:

Description	Data
Average Grade (above MSL)	4.0 Mtr.
Maximum Ambient Air Temperature (Deg C)	45
Minimum (Deg C)	-10
Design Ambient (Deg C)	40
Wind Zone (Basic Wind Speed)	Zone 5 (50 Meter/Sec)
Isoceraunic level	47
Seismic Zone	Zone III

Technical Details of Conductor (ACSR Zebra)

Particulars	ACSR Zebra
Code and Standards	IS:398 (Pt-5)-1996
Code name of Conductor	ACSR "ZEBRA"
No. of Conductor per phase	One
Stranding / wire diameter	54/3.18mm AL + 7/3.18mm Steel
Total sectional area	484.5 sq. mm
Overall diameter	28.62 mm
Approx. weight	1621 Kg/km
Calculated DC resistance at 20°C	0.06915 ohm/km
Minimum Ultimate Tensile Stress	130.32 KN
Modulus of elasticity	7034 Kg/sq. mm
Co-efficient of Linear expansion	19.30 X 10-6 /deg. C
Max. allowable temperature	75°C

Earth Wire Particulars (GS 7/3.15 Earthwire)

Particulars	Earthwire
Material of Earthwire	Galvanized Steel
No. of Earthwire	One
Stranding / wire diameter	7/3.15 mm
Total sectional area	54.55 sq. mm
Overall diameter	9.45 mm
Approx. weight	428 Kg/km
Calculated DC resistance at 20°C	3.375 ohms/km
Minimum Ultimate Tensile Stress	5710 KN
Modulus of elasticity	19361 Kg/sq. mm
Co-efficient of Linear expansion	11.5 X 10-6 /deg. C
Max. allowable temperature	53°C

Annexure 10: Minimum Functional specifications of 400 kV Substation

The 400kV outdoor switchyard shall employ one and half breaker scheme. All equipment shall be suitable for hot line washing. The Bidder shall supply substation equipment like circuit breakers, isolators, instrument transformers and surge arrestors of type and class which have been designed and manufactured as per IS/IEC or equivalent standards. The scope shall also Include PLCC (power line carrier communication) in this package. The responsibility of coordination with Electrical Inspection Agencies and obtaining all necessary clearances shall be of the Contractor. The section here resents the general and technical requirements of Switchyard equipment and accessories. The type and class of switchyard equipment are given below:

Table 67. Type and class of switchyard equipments

Switchyard equipment:	Type	Ratings
Circuit breakers	SF6	400 kV, 50kA for 1 sec
Isolators	HCB	400 kV
Current transformers	5/6 core	400 kV
Voltage transformers	3 core	4400/8800pF
Surge Arrestor	Gapless	8kJ/kV energy capability

Bidder shall supply control and relay panels including all relays, meters, switches, etc. from the manufacturer who has designed, manufactured, type tested and supplied same type of equipments for 400kV system earlier. For other items of supply the Bidder shall supply equipment/accessories from the manufacturer who has designed, manufactures, type tested and supplied similar items and these should have been in successful operation.

Code and Standards

- IEC 60071 – 1 or equivalent IS standard
- IE Rules (latest revision)
- CBIP Guidelines

General Requirements of 400kv Switchyard

400kV System parameters are provided in Table 68

Table 68. 400kV System parameters

Details	Dimensions
Rated voltage	400 kV
Rated frequency	50 Hz
Rated short time withstand current capacity	50 kA rms for one (1) second
Insulation levels for 400kV Circuit breakers and Disconnecting Switches	
i) Rated one minute power Frequency withstand voltage	a) 520 kV rms between live terminals and earth. b) 610 kV rms across isolating distance.
ii) Rated lightning impulse withstand voltage	± 1425 kVp between live terminals and earth.
Max. Radio interference voltage at 266kVrms	1000 micro volts for frequency between 0.5 Mhz and 2.0 Mhz for all equipment.
Phase to phase spacing	7000 mm
Rated ambient temperature	50 degree Centigrade
System neutral earthing	Effectively earthed
Seismic acceleration	0.3 g horizontal
Control Voltage	220V DC
Auxiliary contacts	The contacts shall have continuous rating of 10A and breaking capacity of 2A with circuit time constant of minimum 20

	millisecond at 220V DC.

- The towers and gantries shall be suitable for a normal conductor tension of minimum 2T/conductor in case of twin moose and 1.5T/conductor in case of quad moose conductor
- The Earthing and Lighting protection of Switchyard alongwith calculation shall be provided by the Bidder
- The switchyard control room shall house the control, relay and protection panels for bays under the scope. Alternatively, distributed architecture with control, relay and protection panels located in air-conditioned bay kiosks can also be offered. The battery systems and LT switchgears shall be located in the switchyard control room.
- Two Sets of 220V DC battery along with battery charger is envisaged for 400kV switchyard. The schemes are to be so designed that each battery shall be able to supply the total DC load of the switchyard.
- The illumination level for AIS shall be 20 lux in general . No lighting fixture shall be mounted on gantries, they shall be mounted on lighting masts only
- The Bidder shall provide surge arrestors and other devices as required to protect all the equipments from fundamental frequency, harmonics, ferro-resonance, switching surges, and lightning impulses over voltages under steady state, dynamic & transient conditions.
- Considering the environment prevailing at site, the creepage distance for all exposed porcelain insulators, bushings, etc. shall be minimum 31 mm/KV for heavily polluted environment.

Clearances

The minimum clearances for 400kV and 66 kV shall be as given below:

Clearance	400 kV	66 kV
Phase to earth clearance	3500 mm	630 mm
Phase to phase clearance	4000 mm	630 mm
Section clearance	6500 mm	3500 mm

The Bidder shall supply the structures suitable to meet the above clearances

Control and Protection

Codes and Standards

- IS:3231,IS:8686,IEC:60255,IEC:801&
- IS:9000,IEC:61000,IEEE/ANSI:037.901(1989),ENV50140CLASSIII,
- ENV50204,IEC:60068

General Requirements for Protections

Relays/Energy meters shall be flush mounted on the front with connections at the rear shall be draw-out or plug-in type/modular case with proper testing facilities. Provision shall be made for easy isolation of trip circuits for testing and maintenance. Substation Automation System (SAS) integrating the control and protection requirements of the 400kV switchyard and complying with IEC61850 shall be provided. SAS shall have facilities to share power station data with RLDC. All hardware/software required for this shall be provided.

Protections and Metering For 400kV System

Total critical fault clearing time from fault initiation in any part of the 400KV system under all conditions shall not be more than 80 ms for faults within zone-I reach (i.e. up to 70% of line length) and 100 ms for end zone faults including carrier transmission time of 20ms.

The SIR values to be considered for operating time of relays shall be between 4 and 15. Rated break time for 400KV breaker as offered shall be considered for the purpose of operating time.

400KV Line Protections

The transmission line parameters shall be taken as follows, unless otherwise stated by Purchaser during detailed design stage:

- Quad Moose ACSR conductor with 450mm sub-conductor spacing as phase conductor.
- Bus Switching Scheme: One-and-half-breaker configuration
- Transmission system is effectively earthed.
- The minimum fault current could be as low as 20% of the rated current. The characteristics shall be such as to provide satisfactory operation under such extremely varying conditions.

Each line of 400 kV and above shall be provided with the following protections;

Main-I – Numerical Distance protection scheme suitable for carrier aided protection scheme Main-II - Numerical Distance protection scheme suitable for carrier aided protection scheme having a hardware platform different from that of Main-I protection.

Both Main-I and Main – II Numerical Distance protection schemes shall preferably be provided with following built-in features Open jumper protection Auto reclosing with check synchronizing & dead line charging features. The reach of the relay for zones 1,2 & 3 should be able to cover line lengths associated with the project Relay shall have two independent continuously variable time setting range of 0-5 seconds for zone-2 and zone-3

Bus-bar Protection Scheme

A fast acting bus bar protection scheme suitable for 400 KV system shall be offered. The scheme shall have the following features:-

- It shall be based on circulating current principle and shall be highly stable for external faults, normal load flows, growing fault level, CT saturation and permissible CT errors.
- It shall provide independent zones of protection for each bus.
- It shall provide zone indication.
- It shall provide continuous supervision of CT secondary against any possible open circuits. In case of detection of open circuiting of CT secondaries, after a time delay the affected zone of protection shall be rendered in-operative and an alarm shall be initiated.
- It shall include dc supply supervision.
- It shall include adequate number of high speed tripping relays.
- It shall include necessary CT switching relay and have provision for CT switching incomplete alarm.
- It shall include IN/OUT switching facility with protective cover for each zone.
- The time of operation of scheme from inception of fault to tripping shall not exceed one cycle.

Necessary arrangements shall be provided in the busbar protection panel to be offered for mounting/wiring various relays for all future extension of the busbar system.

400KV Circuit Breaker Protection

Each 400kV circuit breaker shall be provided with following protections/functions:

- Duplicated Local breaker back-up protection(50Z)
- Trip circuit supervision for each trip coil.
- DC supply monitoring
- Pole discrepancy protection
- 400KV disconnecting switch interlocking
- Monitoring of various alarm/trip/lockout conditions of 400KV breakers to be provided.
- High speed trip relays as per scheme requirement

Local Breaker Back-up Protection (50 LBB)

Relay shall have the following features;

- Triple pole type having three single phase units

- Operate for stuck breaker conditions
- Operating/resetting time each of less than 15 ms.
- The relay DC circuit shall be initiated by trip relay contacts and after set time delay shall energize the trip bus in bus bar protection scheme on which the stuck breaker is connected for tripping of all breakers connected to the particular bus.
- setting range of 5-80% of rated current
- continuous thermal withstand of two times rated current irrespective of the setting
- separate timer with a continuously adjustable setting range of 0.1-1 sec.
- necessary elements to make an individual phase comprehensive scheme
- shall not operate during single phase auto-reclosing period

In case the LBB protection is provided as a built-in future of numerical distance protection scheme, it shall meet the requirements specified above in this clause.

Trip circuit supervision relay

- Shall be provided for each lockout trip relay and 400KV circuit breaker trip coils.
- Shall monitor the healthiness of each phase trip coil and associated circuit of breaker during 'on' and 'off' conditions.
- Shall have adequate contacts for providing connection to alarm.
- Shall have time delay on drop-off of not less than 200 ms. and provided with operation indications for each phase.

Trip Circuit Supervision as a built in feature of numerical relay / BCU is acceptable.

High Speed Trip Relay

The relay shall have the following features:

- With operating time of less than 10ms.
- With reset time of less than 20ms.
- Provided with operation indicator for each element/coil.
- Have adequate contacts to meet the requirements of trip, interlock, LBB, auto-reclose, DR, fault locator, etc.
- Hand reset or self reset, depending on the application.

Substation Automation System (SAS)

The SAS shall comprise the following main functional components / subsystems:

- Human-Machine Interface with process database
- Communication bus with associated hardware along with gateway for future IEDs for data exchange between different SAS components
- Bay Level Devices for Control, Monitoring and Protection i.e. Bay Control Units and Bay Protection Units, along with associated communication system.

Substation Level Functionality

- The SAS shall perform control functions on various switchyard equipment based on the status, analog and logical inputs acquired by SAS from various bay control units.
- It shall be possible to supervise and control all the switchyard bays in Bidder's scope from Control Level 2 i.e. Substation level workstations. However, in case of maintenance or any defect in the communication link between Control Level 2 and Control Level 1, it shall be possible to control completely, the individual bays from Control Level 1 i.e. from individual bay control units, without involving any wiring or without any change in hardware.
- Clear control priorities shall ensure that operation of particular bay equipment (Circuit Breaker or Isolator) cannot be initiated simultaneously from more than one of the control levels. The priority shall always be on the lowest enabled control level. The selected control level shall be indicated at all the levels so that the operator is aware of his control capabilities.

- The SAS shall have provision of Device Tagging for all the substation devices. This function is to block the control of any substation device in such a manner that it's command is prevented from Operator's Workstations.

Sequence of Events and Alarm Management

- The SAS shall be capable of reporting on both Operator Workstation and printers, the time sequenced record of events occurring in the substation. Separate logs shall be created for alarms and events and both the logs shall be time-tagged. Suitable filters, based on date and time, bay number, device number, function etc. shall be provided for both alarm as well as event logs for ease of viewing.
- SAS shall record all changes of alarms and state (Plant State) of switchyard equipment, including the alarms generated by Bay Control and Bay Protection units.
- All the alarms and events shall be time tagged with a time resolution of 1ms.
- The SAS shall cope with all the alarms and changes of state of 400kV switchyard equipment generated at BCU / Bay Protection Unit as well as Substation Levels.
- The SAS shall acquire the alarm signals from Bay Control Units and Bay Protection Units with preset priorities and on receipt of an alarm, shall generate an audible signal and report it either upon request or automatically to the respective printer.
- Owner shall approve the list of alarm states and plant states to be wired for Sequence of Events log and Alarm Management, during detailed engineering stage.

Human-Machine Interface

- The HMI as specified shall be based on the latest state of the art workstations and servers and technology suitable for industrial applications and switchyard environment. Two possible alternatives for the HMI can be offered by the bidder as indicated in Drg. Nos. 9518-230-POE-A-013, Rev. A. The quantity of peripherals, main and bulk memory etc. as shown in the referred drawing and indicated in scope of supplies is minimum the bidder has to provide. For alternatives I and II, the number of redundant Operator's Workstations (OWS) / Servers shall be as required to achieve the processing capability to meet all the functional requirements of this specification.
- The main memory shall be sized sufficient to meet the functional and parametric requirements as specified. The bulk memory shall be sized at 1.5 times the capacity required sufficient to meet the functional and parametric requirements. However, both the main and the bulk memory shall be subject to minimum hardware specification as per Annex-A to this chapter. The exact system configuration and sizing shall be approved by Owner during detailed engineering.
- All the OWS of the HMI shall be interchangeable i.e. all operator's functions shall be possible from any of the OWS at any point of time without the necessity of any action like downloading of additional files. Each OWS shall be able to access all the substation information related data under all operating conditions including a single processor / computer failure in the HMI.
- No single failure in HMI shall lead to non-availability of more than one OWS. In such an event, i.e. single failure leading to non-availability of any OWS, it shall be possible to monitor the entire switchyard from the other available OWS.
- The Workstations / servers employed for HMI implementation shall be based on industry standard hardware and software which will ensure easy connectivity with other systems and portability of Owner developed and third party software.
- Power Fail Auto Restart (PFAR) facility with automatic time update shall be provided, once the operator logs in.

The Bay Control Units:

- Switching of Switchyard Bay Equipment depending on conditions such as Interlocking, synchro-check, control mode, or external status condition. Adequate safety features like prevention of double operation, command supervision, block/deblock, over-riding the interlocking etc. shall be provided. All such security features shall be finalized and approved by Owner during detailed engineering.
- Status Supervision of switchyard equipment
- Interlocking Function to prevent unsafe operation of switchyard equipment such as circuit breakers, isolators, earth switches etc. All interlocking shall be achieved by user-friendly, menu-driven

configuration software within the BCU. An over-riding / bypass function for bay-level interlocking statements shall be provided at appropriate security level for maintenance or during emergency conditions.

- Analog Measurements for bay voltage, current and frequency. These measurements shall not require the use of any intermediate transducers. The accuracy of measurement shall be 0.5 for voltage, current and frequency. The measured and computed values shall be displayed locally on BCU and on operator's workstation located in central control room.
- Event and Alarm Handling: BCUs shall acquire all the bay level alarms and events from field inputs with a resolution and time tagging of 1ms and shall transfer these to operator's workstation over substation LAN.
- Synchronization Check Feature: Synchronization Check feature shall determine the difference between the amplitudes, phase angles and frequencies of two voltage vectors. Checks shall be provided to detect a dead line or bus bar. The voltage difference and phase angle difference settings shall be adjustable.

3. Energy Meters
4. The following energy meters conforming to the relevant clause indicated elsewhere shall be provided: For each 400KV line Main & check energy meter for export and import

Constructional Features

- The panels shall be free standing, floor mounting type and completely metal enclosed. Cable entries shall be from bottom.
- Shall have removable gland plates with glands made of brass and suitable for armoured cables
- All equipment mounted on front and rear side of the panels shall have individual nameplates with equipment designation engraved. Each panel shall also have circuit/feeder designation name plate.
- Each panel shall be provided with a 240V AC fluorescent lighting fixture controlled by door switch as well as a 5A, 240V AC switch-socket unit.
- Shall be provided with necessary arrangements for receiving, distributing, isolating and fusing of AC & DC supplies for various circuits for control, signaling, lighting, interlocking, etc. Selection of main and sub-circuit fuse rating shall ensure selective clearance of the sub-circuit faults.
- Voltage circuits for protection and metering shall be protected by fuses. Suitable fuse failure relays shall be provided to give an alarm for voltage circuits of protection/metering. Voltage selection scheme based on relays shall be provided for meters wherever possible.
- The DC supplies at the individual relay and protection panels shall be monitored by suitable relays and failure of DC supplies shall be annunciated.

Energy Meters

Energy meters shall have the following features:

- Static type conforming to IEC:687 and Shall carry out measurement of active energy (both import and export) and reactive energy (both import and export) by 3 phase, 4 wire principle suitable for balanced/ unbalanced 3 phase load.
- Accuracy of energy measurement of 0.2S for active energy and 0.5 for reactive energy.
- The active and reactive energy shall be directly computed in CT & VT primary ratings and stored in four different registers of memory of the meter as MWH(E), MWH(I), MVARH(E) and MVARH(I) along with a plus sign for export and minus sign for import. The VARH shall be computed and stored in four separate registers corresponding to various system voltage conditions, and these conditions shall be finalized during detailed engineering.
- Compute the energy sent out of the station busbars during each successive 15 minute block and store in the respective register.
- Display on demand the energy sent out during previous 15-minute block.
- Continuously integrate the energy readings of each register upto the previous 15-min. block. All these readings shall be displayed on demand.
- The reading shall be stored for a period of 40 days before being erased.
- Date/time shall be displayed on demand. The clock shall be synchronized by GPS time synchronization equipment being provided.
- Each meter shall have a unique identification code provided by Purchaser and shall be marked permanently on the front and also in the non-volatile memory.

- The voltage monitoring of all the three voltages shall be provided. The meter shall normally operate with power drawn from the VT supplies.
- The power supply to the meter shall be healthy even with a single-phase VT supply. An automatic backup, in the event of non availability of voltage in all the phases, shall be provided by a built in long life battery and shall not need replacement for at least 10 years with a continuous VT interruption of at least 2 years. Date and time of VT interruption and restoration shall be automatically stored in a non-volatile memory.
- Have an optical port on the front of the meter for data collection. Also the stored data shall be continuously transferred through necessary serial/parallel ports to a local IBM compatible PC to be supplied by the contractor. Necessary hardware and software shall be provided for downloading data on the local PC for display and printing.
- The necessary software shall be provided to accept the data on line and store in memory and on a floppy diskette and also to print the same. The data format for printing shall be finalized during detailed engineering.
- The tariff meters provided on the 400 kV feeders shall conform to the Indian Electricity Grid Code metering specification

Transducers (if provided)

Transducers shall have following features

- Conform to IEC: 688-1.
- The output of the transducers shall be 4-20mA/0-10mA/10-0-10mA dc as necessary for the instruments.
- Accuracy class shall be 0.5 or better except for frequency transducer, which shall have an accuracy of 0.2S.
- Summation transducer shall be suitable for taking multiple inputs from individual MW/MVAR transducers.
- Dual output. One output shall be used for the indicating instrument/recorder provided and other shall be wired upto terminal block of the panel for Purchaser's use in future.
- Energy transducers shall be suitable for 3 phase, 4 wire connection

Earthing & Lightning Protection System

The earthing system for switchyard shall be designed for a life expectancy of at least forty (40) years, for a system fault current of 50 kA for 1.0. sec. The minimum rate of corrosion of steel for selection of earthing conductor shall be 0.12mm per year.

Code and Standards

- Grounding and lightning protection for the switchyard and other areas or
- Buildings covered in the specification shall be provided in accordance with IS 3043, IS 2309, IEEE 80 and IEEE 665

General and Technical Requirements

Earthing

- The main conductor buried in earth shall be 40mm dia rod for main and auxiliary mat. The earthing conductors over the ground shall be of 75x12 mm GS flat. The earthing leads for columns and auxiliary structures, cable trenches shall be of 75x12 mm GS flat. The earthing of the lighting fixtures shall be carried out by 16 SWG wire.
- All earthing conductors above the ground level shall be galvanised steel only.
- Earthing conductors buried in ground shall be laid minimum 600 mm below grade level unless otherwise indicated in the drawing. Back filling material to be placed over buried conductors shall be free from stones and harmful mixtures. Back filling shall be placed in layers of 150 mm.
- Earthing conductors embedded in the concrete floor of the building shall have approximately 50 mm concrete cover.
- Aluminium earth coverage of 300 mm shall be provided between earth conductor and the bottom of trench/foundation/underground pipes at crossings. Earthing conductors crossings the road can be

installed in pipes. Wherever earthing conductor crosses or runs at less than 300 mm distance along metallic structures such as gas, water, steam pipe lines, steel reinforcement in concrete, it shall be bonded to the same.

- Earthing conductors along their run on columns, walls, etc. shall be supported by suitable welding / cleating at interval of 1000mm and 750mm respectively.
- Earth pit shall be constructed as per IS:3043. Electrodes shall be embedded below permanent moisture level. Minimum spacing between electrodes shall be 600mm. Earth pits shall be treated with salt and charcoal if average resistance of soil is more than 20 ohm meter.
- On completion of installation continuity of earth conductors and efficiency of all bonds and joints shall be checked. Earth resistance at earth terminations shall be measured and recorded. All equipment required for testing shall be furnished by contractor.

Lightning

- Lightning conductor on roof shall not be directly cleated on surface of roof. Supporting blocks of PCC/insulating compound shall be used for conductor fixing at an interval of 1500 mm.
- All metallic structures within a vicinity of two meters of the conductors shall be bonded to conductors of lightning protection system.
- Lightning conductors shall not pass through or run inside GI Conduits. Testing link shall be made of galvanized steel of size 25x 6mm.
- Pulser system for lightning shall not be accepted. Hazardous areas handling inflammable/explosive materials and associated storage areas shall be protected by a system of aerial earths.
- Lightning conductor shall be of 25x6mm GS strip when used above ground level and shall be connected through test link with earth electrode/earthing system
- Lightning system shall comprise of air terminations, down conductors, test links, earth electrode etc. as per approved drawings.
- Down conductors shall be as short and straight as practicable and shall follow a direct path to earth electrode.
- Each down conductor shall be provided with a test link at 1000 mm above ground level for testing but it shall be in accessible to interference. No connections other than the one direct to an earth electrode shall be made below a test point.
- All joints in the down conductors shall be welded type. Down conductors shall be cleated on outer side of building wall.

Parameters of Earthwire for lightning protection :

Particulars	Data
Number of strands	7 of steel
Strand diameter	3.66 mm
Overall diameter	10.98
Weight	583 kg/ km approx.
Ultimate tensile strength	68.4 kN minimum
Total cross-sectional area	73.65 sq.mm
Calculated d.c. resistance	2.5 ohms/km at 200C
Direction of lay of outer layer	Right hand
Protective coating for storage	Boiled linseed oil to avoid wet Stains (white rust)

ACSR Conductor

Particulars	Data
Code & standard	IS 398
Name	MOOSE ACSR
Overall diameter	31.77 mm
Weight	2004 kg/km
Ultimate tensile strength	161. 2 kN minimum
Strands & wire diameter of	- Aluminium 54/3.53 mm - Steel 7/3.53 mm

Annexure 11: Indicative Plant Layout (For 50MW Solar PV Plant)

Annexure 12: Indicative Single Line Diagram (For 50MW Solar PV Plant)

Annexure 13: Indicative Single Line Diagram of 220KV Pooling Substation

Annexure 14: Bill of Quantity and Cost of 220/66KV Sub Station

BOQ & COST FOR 220/66KV SUB - STATION					
S.No	**Description**	**Unit**	**Rate**	**Nos./Lump Sum**	**Estimated Cost**
1	Common General Works				
1-A	**Land development & Civil engineering works**				
a)	Soil Investigation (lump Sum)	Lump Sum	2.46	1	2.46
b)	Initial Civil Engineering Works like Levelling, Retaining walls, Approach Road, Peripheral Wall etc. (lumpsum)	Lump Sum	50	1	50
c)	Road work	Metre	0.022375	1,900.00	42.5125
d)	Storm water drain, Road culverts drain crossing, cable trench crossing	Metre	0.01473	1,120.00	16.4976
e)	Switch yard fencing	Metre	0.000885	1,052.00	0.93102
f)	DG room & Fire fighting Room (FFPH)	No	52.8912	1	52.8912
g)	Control room with cable vaults	No	65.21	1	65.21
h)	Cable ducts	Lump Sum	55	0.9	49.5
i)	Providing water supply including drinking water & water for fire fighting system and sewage system	Lump Sum	4.1	1	4.1
j)	Parking sheds,Rain water Harvesting systems & land scaping etc.,	Lump Sum	25	1	25
	Sub-Total -1-A	INR Lakhs			309.1
1-B	**Electrical works**				
a)	A.C.Supply				
i	LT Switch Gear consisting of 415 V main switch board, ACDB, MLDB, Emergency LDB, A/C DB, 220 V DCDB, 50V DCDB, 1 trasformer each of rating 500KVA, 66KV/440V,72.5KV Isolator, CT, PT, CB/Fuse 66 KV, 66KV and 11KV Isolator, fuse, SA	Set	45.33	1	45.33
ii	Foundations for 2 of 500KVA 66/0.415 kV and, BM Kiosk etc.	LumpSum	0.19	1	0.19
b)	Station D.C Batteries 220 V, 500 AH	Set	6.45	2	12.9
c)	Station D.C Batteries 50 V, 500 AH	Set	2.41	2	4.82
d)	Battery Charger System 220 V, 70A / 50 A Float cum Boost	Set	2.62	2	5.24

e)	Battery Charger System 50 V, 70 A / 50 A Float cum Boost	Set	1.76	2	3.52
f)	Sub-Station Automation including Hardware, software, Remote Control Station, DMT scheme along with associated equipment and kiosks	Set	200	1.38	276
g)	Power Cables	Km	1.25	24.5	30.625
h)	Control Cables	Km	1.04	45	46.8
J	Earth mat - 40mm dia MS rods	Km	6.03	21	126.63
k)	Diesel Generator set along with AMF panel 250 kVA	Set	20.23	1	20.23
l)	A/C and ventilation - High Valve Type split AC unit of 2TR capacity	No.	0.36	12	4.32
m)	Fire fighting system	1	75	1	75
o)	Illumination System - Indoor and Outdoor	Lump Sum	55	1	55
p)	Mandatory spares	Lump Sum	95	1	95
	Sub Total -1-B	INR Lakhs			801.55
1-C	Erection charges				
a)	Auxiliary Transformers,LT Switchgear, AC & DC Panels.72.5 kV ,66KV, & 11 kV equipments Etc	Set	2.46	1	2.46
b)	Station D.C Batteries 220 V, 500 AH	Set	0.31	2	0.61
c)	Station D.C Batteries 50 V, 500 AH	Set	0.13	2	0.26
d)	Battery Charger System 220 V, 70A / 50 A Float cum Boost	Set	0.25	2	0.49
e)	Battery Charger System 50 V, 70 A / 50 A Float cum Boost	Set	0.18	2	0.37
f)	Sub-Station Automation including Hardware, software, Remote Control Station, DMT Scheme along with associated equipment and kiosks	Set	8.6	1	8.6
g)	Power cables	Set	4.91	1	4.91
h)	Control cables	Set	7.37	1	7.37
i)	Earth mat formation	Set	18.43	1	18.43
j)	Diesel Generator set with AMF panel 250 kVA	Set	0.74	1	0.74
k)	Air Conditioning and Ventilation	Set	1.11	1	1.11
l)	Fire Fighting System	Set	9.83	1	9.83
n)	Illumination System - Indoor & outdoor	Set	12.29	1	12.29
	Sub Total -1-C	INR Lakhs			67.45
	Total -1	INR Lakhs			1,178.10
2	Power Transformer				

a)	Transformer 150 MVA, 3Phase, 220/66KV class	No.	900	2	1800
d)	Erection Charges	Nos	7.37	4	29.48
e)	Foundations	Nos	14.17	4	56.68
f)	Fire wall between the Transformers	Nos	0.94	4	3.76
	Total -2	INR Lakhs			1,889.00
3	220 kV Bays & Equipment				
3-A	245 kV equipment				
a)	Circuit Breaker 245 kV				
i	1600 A, 40 kA	No.	18.67	6	112.02
b)	Current Transformer 245 kV				
i	1600 A, 40 kA , 5 core, with 120% extended current	No.	4.01	21	84.21
c)	CVT 245 kV				
i	8800 pf, S- Ph, with 3 secondaries	No.	3.34	-	
ii	4400 pf, S- Ph with 3 secondaries	No.	3.6	18	64.8
d)	Isolator 245 kV	No.			
i	1600A, 40 kA, DB Type with two E/S	No.	4.93	6	29.58
ii	1600A, 40 kA, DB Type with one E/S	No.	4.17	8	33.36
iii	1600A, 40 kA, DB, Tandem Type without E/S	No.	3.74	5	18.7
e)	220 kV Wave Trap	No	8	1	8
e)	216 kV Surge Arrestors	No.	0.8	5	4
	Sub Total - 3-A	INR Lakhs			354.67
3-B	220 kV Simplex type Panels				
a)	Circuit breaker relay panel With Auto reclosure	No.	8.02	1	8.02
b)	Circuit breaker relay panel Without Auto reclosure	No.	6.45	5	32.25
c)	Line protection panel	No.	18.18	1	18.18
d)	Single Bus Bar protection panel	No.	63.46	1	63.46
	Sub Total - 3-B	INR Lakhs			121.91
3-C	220 kV Towers, Beams & Support structures				
a)	Tower Type 2C1 - Number * Unit Weight	MT	0.69	47.5	32.775
b)	Tower Type 2C2 - Number * Unit Weight	MT	0.69	52	35.88
d)	Beam Type 2B1 - Number * Unit Weight	MT	0.69	25	17.25
e)	Beam Type 2B2 - Number * Unit Weight	MT	0.69	26	17.94
g)	Equipment Support Structure - Number * Unit Weight	MT	0.69	20	13.8
	Sub Total - 3-C	INR Lakhs			117.6
3-D	220 KVTubular type (Pipe) Equipment support / mounting Structures				

a)	CVT - Number * Unit Weight	MT	0.92	13.5	12.4
b)	BPI - Number * Unit Weight	MT	0.92	31.5	28.94
c)	Isolators - Number * Unit Weight	MT	0.92	33	30.32
d)	SA - Number * Unit Weight	MT	0.92	10.5	9.65
	Sub Total - 2-D	INR Lakhs			81.32
3-E	Bus Bar & Hard ware materials for 220 kV				
b)	Twin Disc Iinsulator string with Suspension Hardware for Zebra(220KV Main Bus)	Set			
c)	Twin Disc Iinsulator string with Tension Hardware for Twin Zebra (220KV Transfer Bus and Jack Bus)	Set			
d)	Twin Disc Iinsulator string with Suspension Hardware for Zebra (220KV Transfer and Jack Bus)	Set			
e)	220KV Bus post I nsulators	No.			
f)	4" EH-IPS Alluminium Tube(OD- 114.2, ID-97.18)	Metre			
g)	Zebra	Metre			
h)	Tee Clamps	No.			
k)	Spacer Clamps	No.			
m)	PG Clamps	No.			
n)	Ground wire with Accessories	Lump Sum			
	Sub Total - 3-E	INR Lakhs			208.16
3-F	Foundations for 220 kV Towers & Equipment mounting structures				
a)	Towers				
i	Towers Type 2C1	No.	2.36		-
ii	Towers Type 2C2	No.	2.36		-
iii	Towers Type 2C3	No.	2.36		-
b)	Equipment support structures				
i	Circuit breakers	No.	0.47		-
ii	Isolators	No.	0.38		-
iii	C.Ts	No.	0.09		-
iv	CVT	No.	0.09		-
v	SA	No.	0.38		-
vi	WT	No.	0.47		-
vii	BPI	No.	0.38		-
	Sub Total - 3-F	INR Lakhs			159.58
3-G	Erection Testing & commissioning Charges 220 kV				
	OUTDOOR EQUIPMENTS				
a)	245 KV Circuit breakers	No.	0.25		-
b)	245 KV Isolators	No.	0.18		-
c)	245 KV Current Transformers	No.	0.06		-
d)	245 KV CVT	No.	0.06		-

e)	216 KV Surge Arrestors	No.	0.04		-
f)	220 kV Towers , Beams	Set	7.37		-
g)	221 kV Tubular type Pipe Structures	Set	3.69		-
h)	220 kV Bus Bars formation etc.	Set	19.66		-
j)	Control & Protection panels				
i	Circuit breaker relay panel	No.	0.31		-
ii	Line protection panel	No.	0.81		-
iii	Single Bus Bar protection panel	No.	2.46		-
	Sub Total - 3-G	INR Lakhs			57.35
	Total - 3	INR Lakhs			1,100.59
4	66 kV Bays & Equipments				
	Line Bays	INR Lakhs	50	10	500
	Total - 4	INR Lakhs			500.00
	Total Cost in Rs Lakhs (1+2+3+4)				**4,667.69**

Annexure 15: Bill of Quantity and Cost of 400/220 kV Sub Station

BOQ & COST FOR 400/220 KV SUB - STATION					
S. No	**Description**	**Unit**	**Rate**	**Estimated Cost**	**Estimated Cost**
1	Common General Works				
1-A	**Land development & Civil engineering works**				
a)	Soil Investigation (lump Sum)	Lump Sum	2.46	1	2.46
b)	Initial Civil Engineering Works like Levelling, Retaining walls, Appoch Road, Peripheral Wall etc (lumpsum)	Lump Sum	66.11	1	66.11
c)	Ant weed treatment & Site Surfing Cost per Meter	Sq mt	0.000617	230,160.00	141.91
e)	Road work	Metre	0.022375	2,900.00	64.89
d)	Storm water drain, Road culverts drain crossing, cable trench crossing	Metre	0.01473	2,120.00	31.23
e)	Switch yard fencing	Metre	0.000885	2,052.00	1.82
f)	DG room & Fire fighting Room (FFPH)	No	52.8912	1	52.89
g)	Control room with cable vaults	No	94.44858	1	94.45
h)	Cable ducts	Lump Sum	85.00372	0.9	76.5
i)	Providing water supply including drinking water & water for fire fighting system and sewage system	Lump Sum	6.14	1	6.14
j)	Parking sheds,Rain water Harvesting systems & land scaping etc.,	Lump Sum	28.33	1	28.33
	Sub-Total -1-A	INR Lakhs			538.4
1-B	**Electrical works**				
a)	A.C.Supply				
i	LT Switch Gear consisting of 415 V main switch board, ACDB, MLDB, Emergency LDB, A/C DB, 220 V DCDB, 50V DCDB, 2 transformer each of rating 630KVA, 66KV/440V,72.5KV Isolator, CT, PT, CB/Fuse 66KV and 66KV Isolator, fuse, SA	Set	73.33	1	73.33
ii	Foundations for 1of 630KVA 66/0.415 kV and one of 800kVA 66/0.415kv LT transformer, BM Kiosk etc.	LumpSum	0.19	1	0.19
b)	Station D.C Batteries 220 V, 500 AH	Set	6.45	2	12.9
c)	Station D.C Batteries 50 V, 500 AH	Set	2.41	2	4.83
d)	Battery Charger System 220 V, 70A / 50 A Float cum Boost	Set	2.62	2	5.24
e)	Battery Charger System 50 V, 70 A / 50 A Float cum Boost	Set	1.76	2	3.51
f)	Sub-Station Automation including	Set	250	1.38	345

	Hardware, software, Remote Control Station, DMT scheme along with associated equipment and kiosks				
g)	Power Cables	Km	1.25	44.5	55.79
h)	Control Cables	Km	1.04	90	94.03
J	Earth mat - 40mm dia MS rods	Km	6.03	27.7	167
k)	Diesel Generator set along with AMF panel 250 kVA	Set	20.23	1	20.23
l)	A/C and ventilation - High Valve Type split AC unit of 2TR capacity	No.	0.36	12	4.32
m)	Fire fighting system	1	75	1	75
o)	Illumination System - Indoor and Outdoor	Lump Sum	55	1	55
p)	Mandatory spares	Lump Sum	175	1	175
	Sub Total -1-B	INR Lakhs			1,091.38
1-C	Erection charges				
a)	Auxiliary Transformers,LT Switchgear, AC & DC Panels.72.5 kV ,66KV, & 11 kV equipments Etc	Set	2.46	1	2.46
b)	Station D.C Batteries 220 V, 500 AH	Set	0.31	2	0.61
c)	Station D.C Batteries 50 V, 500 AH	Set	0.13	2	0.26
d)	Battery Charger System 220 V, 70A / 50 A Float cum Boost	Set	0.25	2	0.49
e)	Battery Charger System 50 V, 70 A / 50 A Float cum Boost	Set	0.18	2	0.37
f)	Sub-Station Automation including Hardware, software, Remote Control Station, DMT Scheme along with associated equipment and kiosks	Set	8.6	1	8.6
g)	Power cables	Set	4.91	1	4.91
h)	Control cables	Set	7.37	1	7.37
i)	Earth mat formation	Set	18.43	1	18.43
j)	Diesel Generator set with AMF panel 250 kVA	Set	0.74	1	0.74
k)	Air Conditioning and Ventilation	Set	1.11	1	1.11
l)	Fire Fighting System	Set	9.83	1	9.83
n)	Illumination System - Indoor & outdoor	Set	12.29	1	12.29
	Sub Total -1-C	INR Lakhs			67.45
	Total -1	INR Lakhs			1,697.23
2	Transformer				
a)	500 MVA 400/ 220 kV	No.	3,800.00	4	15,200.00
					0.00
					0.00
					0.00
					0.00
					0.00
d)	Erection Charges	Nos	7.37	6	44.22
e)	Foundations	Nos	14.17	6	85.02
f)	Fire wall between the Transformers	Nos	0.94	2	1.88
	Total -2	INR Lakhs			15,331.00
3	Shunt & Bus Reactors Reactors				
3-A	Bus Reactors				
a)	Bus Reactor, 420KV, 63 / 50 MVAR	No.	391.06		-

b)	Bus Reactor, 420KV, 80 MVAR	No.	432.08		-
c)	Bus Reactor, 420KV, 125 MVAR	No.	442.82	1	442.82
d)	NGR,145KV	No.	27.58	1	27.58
e)	Surge Arrestors 120kV for NGR	No.	1.53	2	1.53
d)	Erection Charges	No.	4.91	1	4.91
e)	Foundation for 400 kV Bus Reactors	No.	9.44	1	9.44
	Sub-Total -3-A	INR Lakhs			486.3
	Total -3	INR Lakhs			486.3
4	400 kV Bays & Equipments				
4-A	400 KV Equipments				
a)	420 KV,2000A, 40KA CB with CR & with support structure	No.	49.75	12	597
					0
c)	420 kV CT 2000A, 40KA, 5-Core with 120% extended current	No.	8.09	55	444.95
d)	CVT				0
i	420 kV CVT 4400 PF	No.	5.85	15	87.75
ii	420 kV CVT 8800 PF	No.	7.41	20	148.2
e)	Isolators	No.			0
i	420 KV,2000 A,40 kA Isolator, DB Type with one E/S (3phase)	No.	10.21	30	306.3
ii	420 KV,2000A,40 kA Isolator one Phase with one E/S	No.		-	
iii	420 KV,2000 A,40 kA Isolator, DB Type with two E/S (3phase)	No.	11.69	4	46.76
f)	Surge Arrestor 390 kV	No.	2.02	21	42.42
g)	PLCC equipments on 400 kV side (Both for 400 & 220 kV)	1	76	1	76
	Sub Total - 4-A	INR Lakhs			1,750.00
4-B	400 kV Simplex type Panels				
a)	Circuit breaker relay panel With Auto reclosure	No.	8.32	4	33.28
b)	Circuit breaker relay panel Without Auto reclosure	No.	6.61	8	52.88
c)	Line protection panel	No's	19.64	4	78.56
d)	Reactor protection panel	Nos	12.29	1	12.29
e)	Transformer Protection panel for both HV and MV sides	No.	16.19	8	129.52
f)	Double Bus Bar protection panel	No.	107.15	1	107.15
	Sub Total - 4-B	INR Lakhs			413.68
4-C	400 kV Towers, Beams & support structures - Lattice Type			Alt-II	
a)	Tower Type 4C1 - Number * Unit Weight	MT	0.69	25	17.23
b)	Tower Type 4C2 - Number * Unit Weight	MT	0.69	38	26.19
c)	Tower Type 4C3 - Number* Unit Weight	MT	0.69	72	49.62
d)	Beam Type 4B1 - Number * Unit Weight	MT	0.69	16	11.03
e)	Beam Type 4B2 - Number * Unit Weight	MT	0.69	73.5	50.65
f)	Lightning cum Lighting mast on both 400 & 220 kV switch Yard (6Nos *4.5 MT + 6Nos *3MT)	MT	0.69	45	31.01
g)	Equipment Support Structure - Number * Unit Weight	MT	0.69	28.2	19.43
	Sub Total - 4-C	INR Lakhs			205.16
4-D	400 KV Tubular type (Pipe)				

	Equipment Support Structures				
a)	CVT - Number * Unit Weight	No/MT18*0.5 MT	0.92	18	16.54
b)	BPI - Number * Unit Weight	No/MT63*0.5 MT	0.92	21.6	19.85
c)	Isolators - Number * Unit Weight	No/MT24*2.0 MT	0.92	52.5	48.24
d)	SA - Number * Unit Weight	No/MT18*0.5 MT	0.92	10.5	9.65
	Sub Total - 4-D	INR Lakhs			94.28
4-E	Bus Bar & Hard ware materials for 400 kV				
a)	4" EH-IPS Alluminium Tube(OD-114.2, ID-97.18)	L/S	181	2	362
b)	Moose ACSR				
c)	Twin Disc Iinsulator string with Tension Hardware for Twin Moose on 400KV side				
d)	Single Disc Iinsulator string with suspension Hardware for Twin Moose on 400KV side				
e)	400KV Bus post insulators				
f)	Tee Clamps Twin Moose to EH-IPS Al Tube 4" - 400kV side				
g)	Tee Clamps Twin Moose to Twin Moose - 400kV side				
h)	PG Clamps				
i)	Spacer Clamps for Twin Moose				
j)	Ground wire and accessories				
	Sub Total - 4-E	INR Lakhs			362
4-F	Foundations for 400 kV Towers & Equipment Support structures			Alt-II	
a)	Towers				
i	Towers Type 4C1	No.	2.83	5	14.17
ii	Towers Type 4C2	No.	2.83	8	22.67
iii	Towers Type 4C3	No.	2.83	16	45.34
b)	Equipment support structures				
i	Circuit breaker	No.	1.18	12	14.16
ii	Isolator	No.	0.47	26	12.22
iii	CT	No.	0.09	30	2.7
iv	CVT	No.	0.09	20	1.8
v	SA	No.	0.05	21	1.05
vi	Line Trap	No.	0.47	8	3.76
vii	BPI	No.	0.05	70	3.5
	Sub Total - 4-F	INR Lakhs			121.37
4-G	Erection, Testing & commisioning Charges for 400 kV Outdoor Equipments				
a)	420 KV Circuit breaker	No.	0.37	12	4.44
b)	420KV Isolator	No.	0.25	34	8.5
c)	420 KV Current Transformer	No.	0.07	55	3.85
d)	420KV CVT	No.	0.07	35	2.45
e)	390KV surge Arrestor	No.	0.04	21	0.84
f)	Towers & Beams - Lattice Type	Set	7.74	1	7.74
g)	Support Structures - Pipe Type	Set	2.46	1	2.46
h)	Bus Bars formation etc	Set	18.43	1	18.43

k)	Control & Protection panels				0
i	400KV CB relay Panel	No.	0.37	12	4.44
ii	400KV Line Protection Panel	No.	1.11	4	4.44
iii	400/220KV Transformer Protection Panel	No.	0.67	8	5.36
iv	400KV Reactor Protection Panel	No.	0.12	1	0.12
v	Duplicate Bus Bar Protection Panel - 400KV	No.	1.96	1	1.96
l)	PLCC Equipments (Both for 400 kV & 220 kV)	Set	1.54	1	1.54
	Sub Total - 4-G	INR Lakhs			66.57
	Total - 4	INR Lakhs			3,013.06
5	220 kV Bays & Equipments				
5-A	245 kV equipment				
a)	Circuit Breaker 245 kV				
i	1600 A, 40 kA	No.	18.67	6	112.02
b)	Current Transformer 245 kV				
i	1600 A, 40 kA , 5 core, with 120% extended current	No.	4.01	21	84.21
c)	CVT 245 kV				
i	8800 pf, S- Ph, with 3 secondaries	No.	3.34	-	
ii	4400 pf, S- Ph with 3 secondaries	No.	3.6	18	64.8
d)	Isolator 245 kV	No.			
i	1600A, 40 kA, DB Type with two E/S	No.	4.93	6	29.58
ii	1600A, 40 kA, DB Type with one E/S	No.	4.17	8	33.36
iii	1600A, 40 kA, DB, Tandem Type without E/S	No.	3.74	5	18.7
e)	220 kV Wave Trap	No	8	1	8
e)	216 kV Surge Arrestors	No.	0.8	5	4
	Sub Total - 5-A	INR Lakhs			354.67
5-B	220 kV Simplex type Panels				
a)	Circuit breaker relay panel With Auto reclosure	No.	8.02	1	8.02
b)	Circuit breaker relay panel Without Auto reclosure	No.	6.45	5	32.25
c)	Line protection panel	No.	18.18	1	18.18
d)	Single Bus Bar protection panel	No.	63.46	1	63.46
	Sub Total - 5-B	INR Lakhs			121.91
5-C	220 kV Towers, Beams & Support structures				
a)	Tower Type 2C1 - Number * Unit Weight	MT	0.69	47.5	32.775
b)	Tower Type 2C2 - Number * Unit Weight	MT	0.69	52	35.88
d)	Beam Type 2B1 - Number * Unit Weight	MT	0.69	25	17.25
e)	Beam Type 2B2 - Number * Unit Weight	MT	0.69	26	17.94
g)	Equipment Support Structure - Number * Unit Weight	MT	0.69	20	13.8
	Sub Total - 5-C	INR Lakhs			117.6
5-D	220 KVTubular type (Pipe) Equipment support / mounting Structures				
a)	CVT - Number * Unit Weight	MT	0.92	13.5	12.4
b)	BPI - Number * Unit Weight	MT	0.92	31.5	28.94
c)	Isolators - Number * Unit Weight	MT	0.92	33	30.32
d)	SA - Number * Unit Weight	MT	0.92	10.5	9.65

	Sub Total - 5-D	INR Lakhs			81.32
5-E	Bus Bar & Hard ware materials for 220 kV				
b)	Twin Disc Iinsulator string with Suspension Hardware for Zebra(220KV Main Bus)	Set			
c)	Twin Disc Iinsulator string with Tension Hardware for Twin Zebra (220KV Transfer Bus and Jack Bus)	Set			
d)	Twin Disc Iinsulator string with Suspension Hardware for Zebra (220KV Transfer and Jack Bus)	Set			
e)	220KV Bus post I nsulators	No.			
f)	4" EH-IPS Allumininium Tube(OD-114.2, ID-97.18)	Metre			
g)	Zebra	Metre			
h)	Tee Clamps	No.			
k)	Spacer Clamps	No.			
m)	PG Clamps	No.			
n)	Ground wire with Accessories	Lump Sum			
	Sub Total - 5-E	INR Lakhs			208.16
5-F	Foundations for 220 kV Towers & Equipment mounting structures				
a)	Towers				
i	Towers Type 2C1	No.	2.36		-
ii	Towers Type 2C2	No.	2.36		-
iii	Towers Type 2C3	No.	2.36		-
b)	Equipment support structures				
i	Circuit breakers	No.	0.47		-
ii	Isolators	No.	0.38		-
iii	C.Ts	No.	0.09		-
iv	CVT	No.	0.09		-
v	SA	No.	0.38		-
vi	WT	No.	0.47		-
vii	BPI	No.	0.38		-
	Sub Total - 5-F	INR Lakhs			159.58
5-G	Erection Testing & commissioning Charges 220 kV				
OUTDOOR EQUIPMENTS					
a)	245 KV Circuit breakers	No.	0.25		-
b)	245 KV Isolators	No.	0.18		-
c)	245 KV Current Transformers	No.	0.06		-
d)	245 KV CVT	No.	0.06		-
e)	216 KV Surge Arrestors	No.	0.04		-
f)	220 kV Towers , Beams	Set	7.37		-
g)	221 kV Tubular type Pipe Structures	Set	3.69		-
h)	220 kV Bus Bars formation etc	Set	19.66		-
j)	Control & Protection panels				
i	Circuit breaker relay panel	No.	0.31		-
ii	Line protection panel	No.	0.81		-
iii	Single Bus Bar protection panel	No.	2.46		-
	Sub Total - 5-G	INR Lakhs			57.35
	Total - 5	INR Lakhs			1,100.59
6	**Hard cost ---- Grand total (1+2+3+4+5)**	**INR Lakhs**			**21,628.30**

Annexure 16: Cost of Solar PV Power Projects in FY 2015-16 in India

Multi-Crystalline Technology (50 MW Solar PV Plant)

The cost breakup of MW scale solar PV power projects based on multi-crystalline solar PV technology has been presented in Table 69. The estimation made by CERC for solar PV power projects for FY 2014-15 and FY 15-16 have also been presented in the Table.

Table 69. Benchmark cost of solar PV power projects in India estimated by CERC

Particulars	FY 2014-15		FY 2015-16	
	Capital Cost (INR Lakh/MW)	Percentage of Capital Cost	Capital Cost (INR Lakh/MW)	Percentage of Capital Cost
PV Modules	377.09	54.56%	332.35	54.86%
Land Cost	25.00	3.62%	25.00	4.13%
Civil and General Works	60.00	8.68%	50.00	8.25%
Mounting Structures	50.00	7.23%	50.00	8.25%
Power Conditioning Unit	50.00	7.23%	45.00	7.43%
Evacuation Cost up to Inter-connection Point (Cables and Transformers)	60.00	8.68%	55.00	9.08%
Preliminary and Pre-Operative Expenses including IDC and contingency	69.00	9.98%	48.50	8.01%
Total Capital Cost	**691.09**	**100%**	**605.85**	**100%**

Table 70. Cost breakup of MW scale Solar Plant based on Multi-crystalline Technology

Milestones	Cost per MW (INR in Crore)	Cost for 50 MW (INR in Crore)
Land Cost	0.23	11.33
EPC & Transmission Infra Cost	6.90	345.00
Preliminary Expenses	0.17	8.33
Finance Cost	0.07	3.33
IDC	0.06	2.83
Margin Money for WC	0.03	1.67
DSRA	0.16	8.17
Contingencies	0.09	4.50
Total Cost (Per MW)	**7.7**	**385**

Using Multi-crystalline solar PV technology the capital cost of 50 MW solar PV power project has been estimated as 385 Crores Cr in FY 2015-16. The project cost of recently commissioned solar PV power projects based on Multi-crystalline solar PV technology has been presented in Table 71.

Table 71. Cost of MW scale Solar Plant based on Multi-crystalline Technology

Project Capacity	Year	Location	Solar Policy	Total Project Cost	Cost per MW
25 MW	2014	Madhya Pradesh	MP	208.75	8.35
20 MW	2014	Maharashtra	Maharashtra	180.20	9.01
130 MW	2014	Madhya	MP	1179.88	9.07

		Pradesh			
20 MW	2015	Rajasthan	JNNSM-Phase-II	155.00	7.75
25 MW	2015	Odisha	Odisha	206.90	8.27

Thin Film Technology (50 MW Solar PV Plant)

The cost breakup of MW scale solar PV power projects based on Thin Film solar PV technology has been presented in Table 72 .

Table 72. Cost breakup of MW scale Solar Plant based on Thin Film Technology

S No.	Description	Cost (INR Cr/ MW)	Cost of 50 MW Plant
1	Land & Land Development	0.1	5.3
a	Local Costs	0.45	22.8
b	Onshore Services	0.36	18.2
c	Onshore Supplies	1.3	64.5
d	Offshore Supplies	4.2	21.1
2	Total Engineering, Procurement & Commissioning Cost (sum of a to d)	6.3	321.8
A	**Total Hard Cost (1+2)**	**6.4**	**327.1**
e	Project Development Expenses	0.14	7.3
f	Interest During Construction & Finance Cost	0.18	9.3
g	Contingency		0
B	**Total Soft Cost**	**0.33**	**16.6**
A+B	**Total Project Cost**	**6.77**	**343.8**

The project cost of recently commissioned solar PV power projects based on Thin Film solar PV technology has been presented in Table 73.

Table 73. Cost of MW scale Solar Plant based on Thin Film Technology

Project Capacity	Year	Location	Solar Policy	Total Project Cost	Cost per MW
25 MW	2013	Rajasthan	JNNSM Phase-I	225.03	9.03
34 MW	2014	Punjab	Punjab	251.60	7.40
10 MW	2015	Uttar Pradesh	UP	79.40	7.94
40 MW	2015	Rajasthan	JNNSM Phase-II	270.78	6.77

Annexure 17: Bill of Material of 50 MW Solar PV Power Project

The approximate quantum of work involved in the construction of the power plant has been estimated based on site condition, connectivity to the site, area covered by the power plant, security etc. The Bill of Quantity (BOQ) for the 50 MW solar PV Power Project based on multi-crystalline/thin film solar PV technology has been determined through the simulation exercise for energy yield estimation using PVSYST (Annexure 2: and Annexure 3: of the DPR), Overall Key SLD and indicative layout is provided in Annexure 11: .

A list of materials and estimated quantity has been prepared and is presented in Table 74.

Table 74. BOQ for 50 MW Solar PV Power Plant at Tumkur Karnataka

S. No	Name of the Equipment	Model/ Type	Rating	Total Quantity	Remarks
1.	PV Module	CS6X-300P (Multi Crystalline/ FS- 3100 Plus(Thin Film)	300Wp/100Wp	19 nos. in series 8772 nos. in parallel Total-166668 nos. for each 50 MWp unit (For Multi Crystalline 15 nos. in series 33333 nos. in parallel Total-499995 nos. for each 50 MWp unit (For Thin Film	
2.	PV Arrays	---	300 Wp per module	15 Modules of 300 Wp rating per string for Multi Crystalline / 19 Modules of 100Wp per striung for Thin Film	
3.	DC Junction Box/ String Monitoring Boxes	---			Nos will be finalized during detail Engineering stage
4.	DC Distribution Board	As per Manufacturer's Standard	220V DC	---	
5.	Battery	VRLA/Ni-Cd	---	1 nos.	
6.	Battery Charger	Float Cum Boost Charger	---	1 nos.	
7.	Inverter	Sunny Central 1000 CPXT Model of SMA	1000 kW	50 nos.	
8.	DC cable -Array	UV Type	---	---	

	JB Inverter				
9.	Air Circuit Breaker (for interconnection between inverter to Inverter Transformer)	As per Manufacturer's Standard	405 V, 2500 A	50 nos	
10.	VCB/ACB Circuit Breaker (for interconnection between Inverter Transformer to 66 kV Switchgear)	As per Manufacturer's Standard	66KV, 630 A	75 nos	
11.	SF6 Circuit Breaker (for interconnection 66KV Switchgear to Auxiliary Transformer)	As per Manufacturer's Standard	66KV, 630 A	1 no	
12.	Air Circuit Breaker (for interconnection between Auxiliary Transformer to LT Board)	As per Manufacturer's Standard	415 V, 400 A	1 no	
13.	Cable		---	---	Rating shall be finalized during detailed Engineering
	From Inverter to Inverter Transformer	1CX5RX630 SQ . MM, 1100V Grade, XLPE, Cu cable		Length shall be finalized during detail engineering stage	
	From Auxiliary Transformer to LT Board	3.5CX185 SQ . MM, 1100V Grade, XLPE, AL cable	---	Length shall be finalized during detail engineering stage	
14.	HV Coductor		---	-Length shall be finalized during detail engineering stage --	Rating shall be finalized during detailed Engineering
	for interconnection between 66 kV Switchgear to Power Transformer)	1CX630 Sq. MM, 66KV grade, AL., XLPE, cable		Length shall be finalized during detail engineering stage	
	From Inverter	ACSR Panther	---	Length shall be	

	Transformer to 66KVSwitchgear	Conductor		finalized during detail engineering stage	
	From 66KV Switchgear to Auxiliary Transformer	3CX240 SQ . MM, 66KV Grade, XLPE, AL cable	---	Length shall be finalized during detail engineering stage	
15.	Control Cable	1100V grade, Multicore	Minimum 2.5sqmm	---	
16.	Cable Trays & Accessories	Metallic	150mm/300mm/600 mm width and a length of 2.5mt.	Lot	
17.	MV Switchgear	As per Manufacturer's Standard	66KV, 25 kA for sec	10 (tentative)	
18.	Bus PT for 66KV	As per Manufacturer's Standard	66 kV, 31.5 kA for sec	2 nos.	
19.	415V LT Switchboard	As per Manufacturer's Standard	short time rating 50kA for 1 sec	6 nos.	
20.	Three Winding Inverter Transformer	Oil Type, Outdoor	66/0.405-0.405kV 2/1-1 MVA,	50 nos.	
21.	Auxiliary Transformer	Dry Type/Oil Type, Indoor/Outdoor	250 kVA, 66/0.415 kV	2 nos.	Capacity is tentative
22.	Transformer Protection Panel for inverter transformer	As per Manufacturer's Standard	---	15nos.	
23.	Transformer Protection Panel for auxiliary transformer	As per Manufacturer's Standard	---	2 no.	
24.	Line Protection Panel	As per Manufacturer's Standard	66KV	2 nos.	
25.	Lightning Arrester	Metal Oxide, gapless	66KV, 10kA	2sets.	
26.	Circuit Breaker	SF6 Type, Outdoor	66KV, 25 kA, 1250 A	2 sets.	
27.	Isolator with Single Earth Switch	Motor Operated , Air Break	66KV, 25kA	4 sets.	
28.	Current Transformer (for protection and Metering)	Outdoor Type	66KV	2 sets	5 core CT
29.	Current Transformer for Tariff metering	Outdoor Type	66KV, 0.2S calss	2 sets. (1 set spare)	
30.	Potential Transformer (for metering and Protection)	Outdoor Type	66KV	2 nos.	
31.	Bus Post Insulator	---	66KV	1 lot	

32.	Lighting Fixture with all Accessories	As per Manufacturer's Standard	---	1 lot	
33.	Indoor/Outdoor Lighting Panel	As per Manufacturer's Standard	---	1 lot	
34.	Lighting Pole	As per Manufacturer's Standard	---	1 lot	
35.	Lighting Wire	As per Manufacturer's Standard	---	1 lot	
36.	66KV XLPE cable with all necessary accessories	1CX630Sq Mm	66KV	Exact Length shall be finalized during details Engineering	
37.	66KV Gantry Structure	Outdoor	66KV	Lot	

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