50 KW ON-Grid Solar Plant at Techno India NJR

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Chapter 1 Glossary

Photovoltaic	The physical effect of direct Conversion of light (sunlight) to electrical energy
PV Cell	The smallest photovoltaic (PV) element that generates electricity from light.
PV Module	A collection of interconnected PV cells, encapsulated between protective materials such as glass and back sheet (Poly Vinyl Fluoride) or glass and glass, and mounted in an aluminium frame. This is a hermetically sealed unit.
String	Multiple PV modules connected in series electrically
Array	Several strings of modules with the same orientation and tilt angle, located together.
Inverter	An electronic device that converts direct current electricity into alternating current electricity suitable for feeding directly into the electrical grid or to normal AC loads.
Insolation	It is a measure of solar radiation energy received on a given surface area in a given time. It is commonly expressed as average irradiance in watts per square meter (W/m^2) or kilowatt-hours per square meter per day ($kWh/(m^2 \cdot day)$) (or hours/day)
Solar Irradiation	The total electromagnetic radiation emitted by the Sun
STC	"Standard Test Conditions" - Incident Solar Irradiance of 1000 Watts/m2, at a spectral density of AM1.5 and cell temperature of 25˚C
Mounting Structure	Device used to hold modules in place, at desired angle & direction
Power Evacuation	Power generated from Solar PV Power Plant is transmitted to a point (substation) where it is distributed for consumer use.

Sub-station	The place where the generated power from solar is synchronised with utility grid and metered.
Control Room	A conductor with one or more strands bound together, used for transmitting electrical energy.
Efficiency	The ratio of the output to the input of any system.
Junction boxes	Inputs of several strings are connected to this box and taken as single output
Current	A flow of electricity through a conductor measured in Amps.
Voltage	The rate at which energy is drawn from a source that produces a flow of electricity in a circuit; expressed in volts It is the difference of electrical potential between two points of an electrical or electronic circuit, expressed in volts. It is the measurement of the potential for an electric field to cause an electric current in an electrical conductor.
Lightning Arrestor	Device used to protect all the components from lightning strikes
Earthing	Described as a system of electrical connections to the general mass of earth
Transformer	An electrical device by which alternating current of one voltage is changed to another voltage
Grid	A system of high/low tension cables by which electrical power is distributed throughout a region

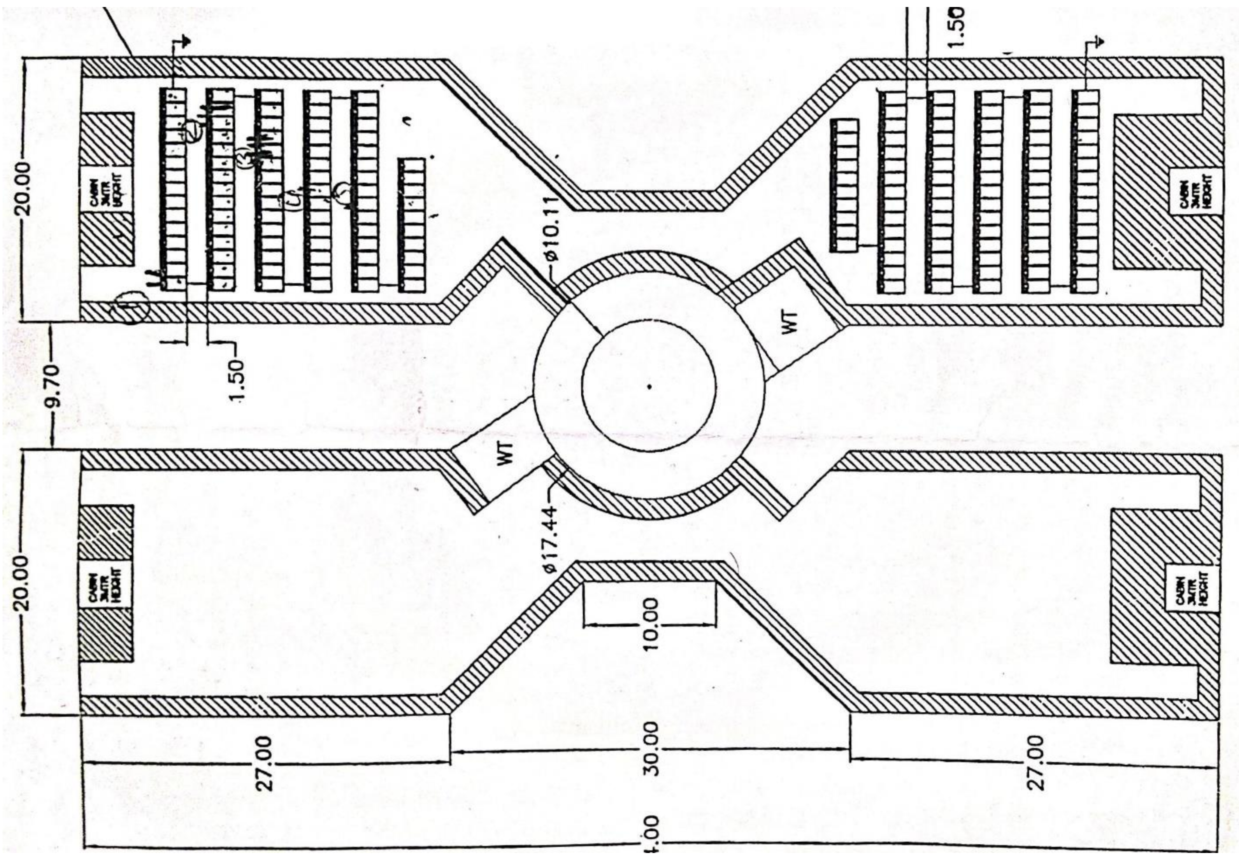
Chapter 2 Introduction

SECI has been entrusted by MNRE for implementation of a Large-scale Grid connected Rooftop pilot projects, with 30% subsidy support from National Clean Energy Fund (NCEF). This program is being successfully implemented across 16 big and small cities, and projects for around 19.00 MW have been sanctioned in 3 phases.

Installation of 50 KW Grid-Tied Solar Rooftop Plant at Techno India NJR Institute of Technology. Its occupies total rooftop space is 1080 square meter. A total load of college is approximate 120 KW and 50 KW of power sending back to grid or RSEB (Rajasthan State Electricity Board) from the Solar plant in form of renewable energy.

In grid-connected rooftop or small SPV system, the DC power generated from SPV panel is converted to AC power using power conditioning unit and is fed to the grid either of 33 kV/11 kV three phase lines or of 440/220 Volt three/single phase line depending on the capacity of the system installed at institution/commercial establishment or residential complex and the regulatory framework specified for respective States.

These systems generate power during the day time which is utilised fully by powering captive loads and feed excess power to the grid as long as the grid is available. In case, where solar power is not sufficient due to cloud cover etc., the captive loads are served by drawing power from the grid.

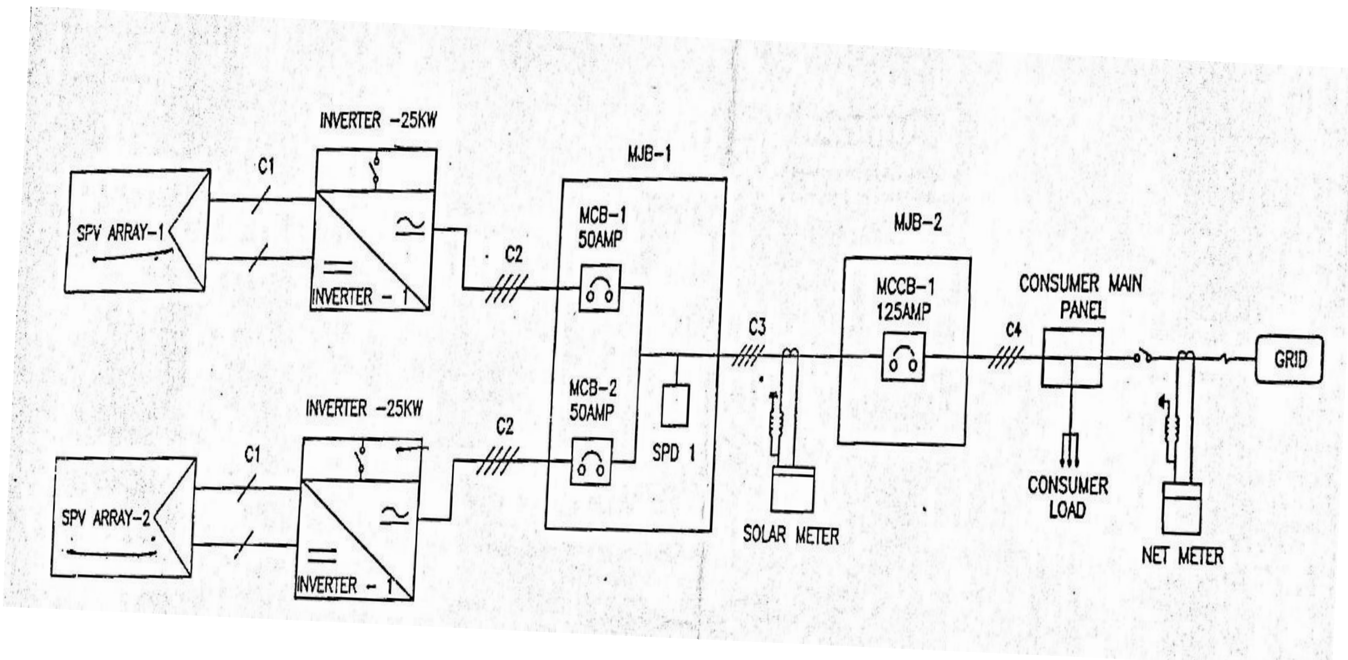


A total number of solar panel is 170 and two grid-tied type inverters each is 25 KW. Connections of all solar panel are in the manner of that 17 panels are connected in series, this is one string of 17 panels and we have 5 strings, which makes a total number of the panel is 85.

(17 panels in series) * (5 strings) = 85 panels

The output of all 5 strings goes to one 25 KW inverter. As it is the other output of remaining 5 strings goes to another 25 KW inverter.

The single line diagram of the plant shown below:



As shown in SLD (Single Line Diagram) There are two SPV (Solar Photovoltaic) arrays each containing 85 solar panels going to two set of inverters each of 25 KW rating after than output of each inverter which is in form of Alternating Current (AC) are combining in the MJB1 (main junction box) with protecting of 50 A rating of MCBs. C1, C2, C3 and C4 are types of cables used.

All ratings and specification of each equipment are shown below:

Sr. No.	Ratings/ Specifications
1.	SPY Array 1: 300Wp- 85 Nos. – 17X5 Strings 1Nos.
2.	SPY Array 2: 300Wp- 85 Nos. – 17X5 Strings 1Nos.
3.	Inverter 1: INVT, 25 KW X 1Nos.
4.	Inverter 1: INVT, 25 KW X 1Nos.
5.	MJB 1: MCB -1 (4P, 50 Amp-1Nos.)
6.	MCB -2 (4P, 50 Amp-1Nos.)
7.	SPD-1 (3 Phase AC, 320V)
8.	MJB 2: MCCB -1 (4P, 125 Amp-1Nos.)
9.	C1: 1CX2(R/B) 4sq.mm, CU. Solar Cable
10.	C2: 4CX10 sq.mm, CU. Cable
11.	C3: 3.5CX50 sq.mm, AL. Armoured Cable
12.	C4: 3.5CX50 sq.mm, AL. Armoured Cable

Chapter 3 Project Summary

1.	**Name of the Company**	Techno India NJR Institute of Technology
2.	**Proposed Project Location**	RIICO Industrial Area, Kaladwas
3.	**District Name**	Udaipur
4.	**State**	Rajasthan
5.	**Proposed Power Plant capacity**	50KWp
6.	**Technology**	Solar Photovoltaic
7.	**Location of place on Earth**	(i) Latitude: 24.5176° N (ii) Longitude: 73.7516° E
8.	**Average annual solar isolation**	6.16 kWh/m^2/day
9.	**Type of Module proposed**	Mono Crystalline
10.	**Type of Inverter proposed**	String
11.	**Total Inverter capacity**	25 KW

Chapter 4 Selection of PV Technology

Science of Silicon PV Cells

- Scientific base for solar PV electric power generation is solid-state physics of semiconductors
- Silicon is a popular candidate material for solar PV cells because:
  - It is a semiconductor material.
  - Technology is well developed to make silicon to be positive (+ve) or negative (-ve) charge-carriers – essential elements for an electric cell or battery
  - Silicon is abundant in supply and relatively inexpensive in production
- Micro- and nanotechnologies have enhanced the opto-electricity conversion efficiency of silicon solar PV cells

Polycrystalline Solar Panel

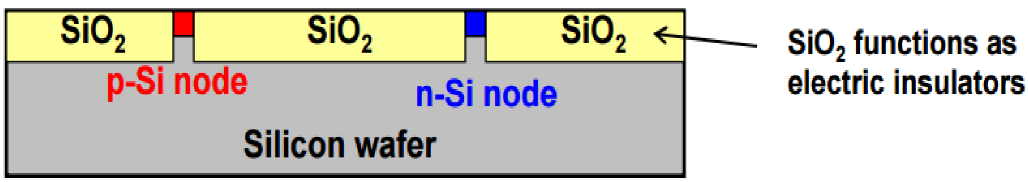
Working Principle of Silicon Solar PV Cells

Photovoltaic material of device converts:

Light (photon) Energy → Electric Energy

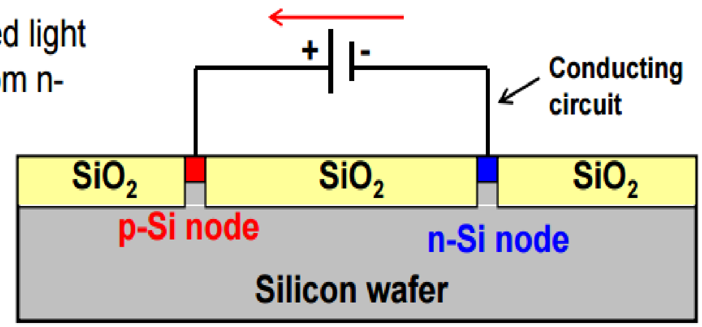
Silicon solar photovoltaic cells = a device made of semiconductor materials that produce electricity under light

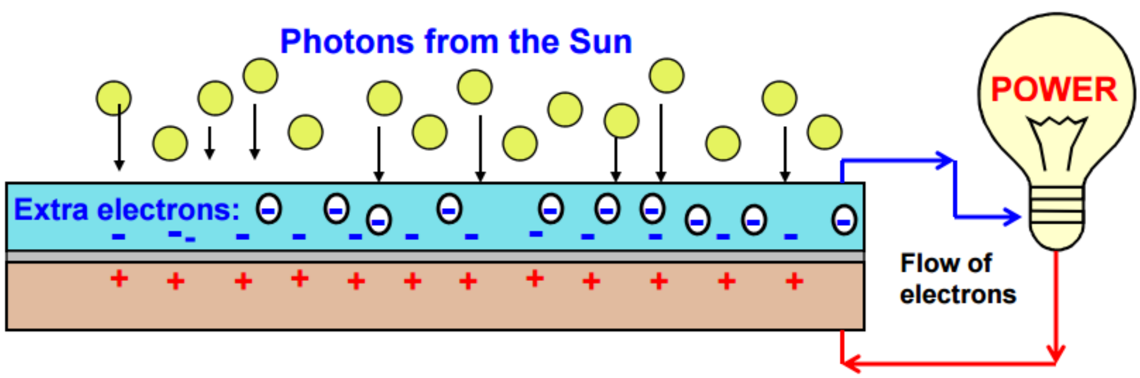
- A **p-n junction** is created in silicon by a **doping process**.



Flow of electrons → current, i

- The **photons** from the exposed light prompted electrons flowing from n-junction to the p-junction → **Electric current flow**.





Common Solar Cell Materials

Single Crystalline	Polycrystalline (Thin films)
Silicon (Si): Single crystalline Polycrystalline silicon Amorphous silicon (non-crystalline Si for higher light absorption) **Gallium arsenide** (GaAs)	**Cadmium telluride** (CdTe) **Copper indium diselenide** (CIS)

Approximate Achievable Conversion Efficiencies

Single Si	15 – 25%
Poly Si	10 – 15%
A-Si	5 - 10

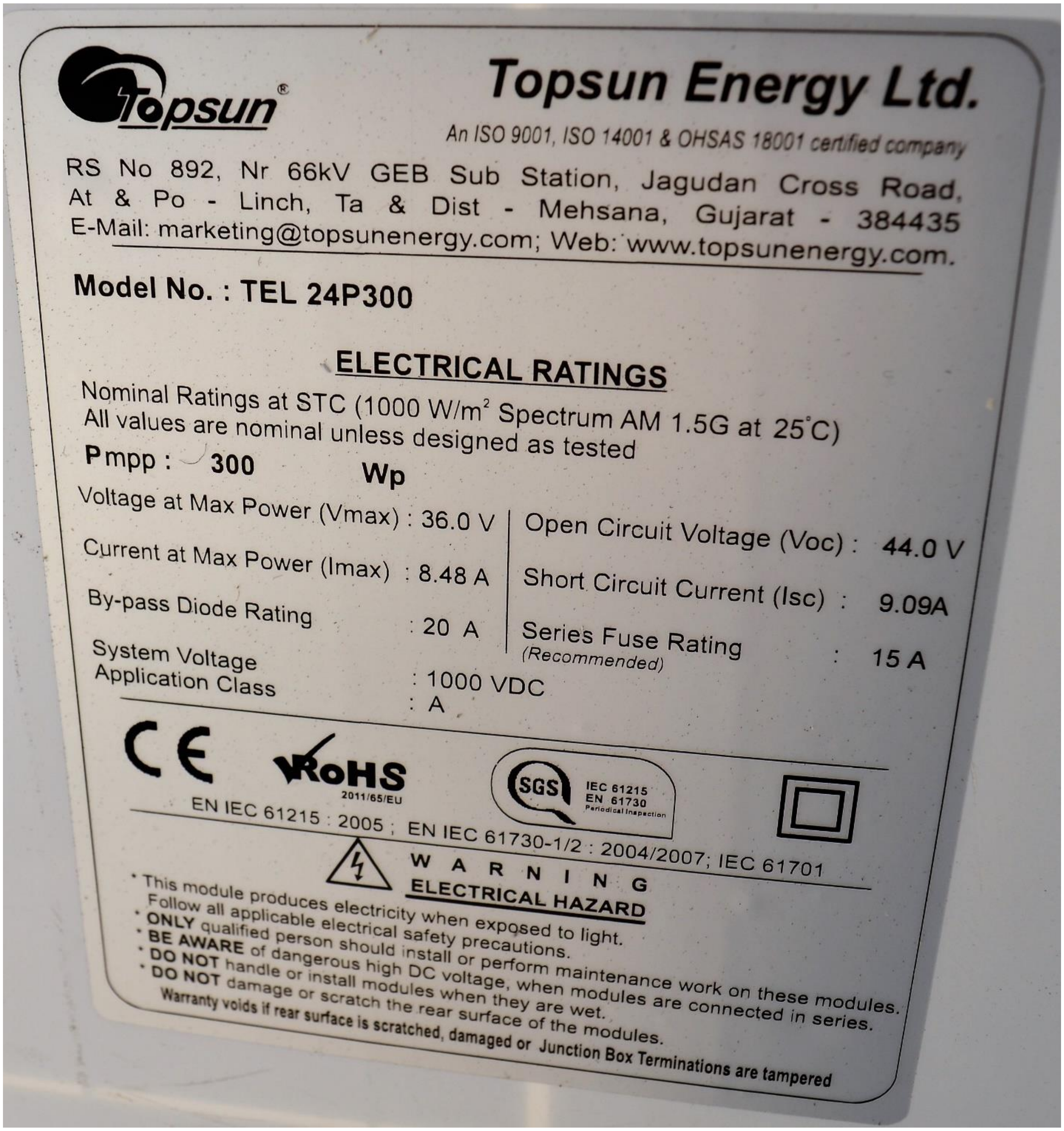
GaAs	25 – 30%
CdTe	7%
CIS	10

Chapter 5 Solar Panel Connections

As for showing in single line diagram, there is one string of 17 panels and we have such 5 strings, which makes a total number of the panel is 85. In one string 17 panels connected in series.

Series connection

Specification of the single solar panel:



According to solar panel electrical ratings:

The Voltage at Max Power (Vmax) is 36V, Current at Max Power (Imax) is 8.48A and Max peak power is 300W. So 17 panels of such ratings connected in series which add up voltages of all panels:

17 X 36 = 612 V and 8.48 A (because current is common in series)

Finally, this 612 V and 8.48A is the output of one string. Five strings output connected to one 25KW Grid-Tied Inverter.

Connections are showing in fig:

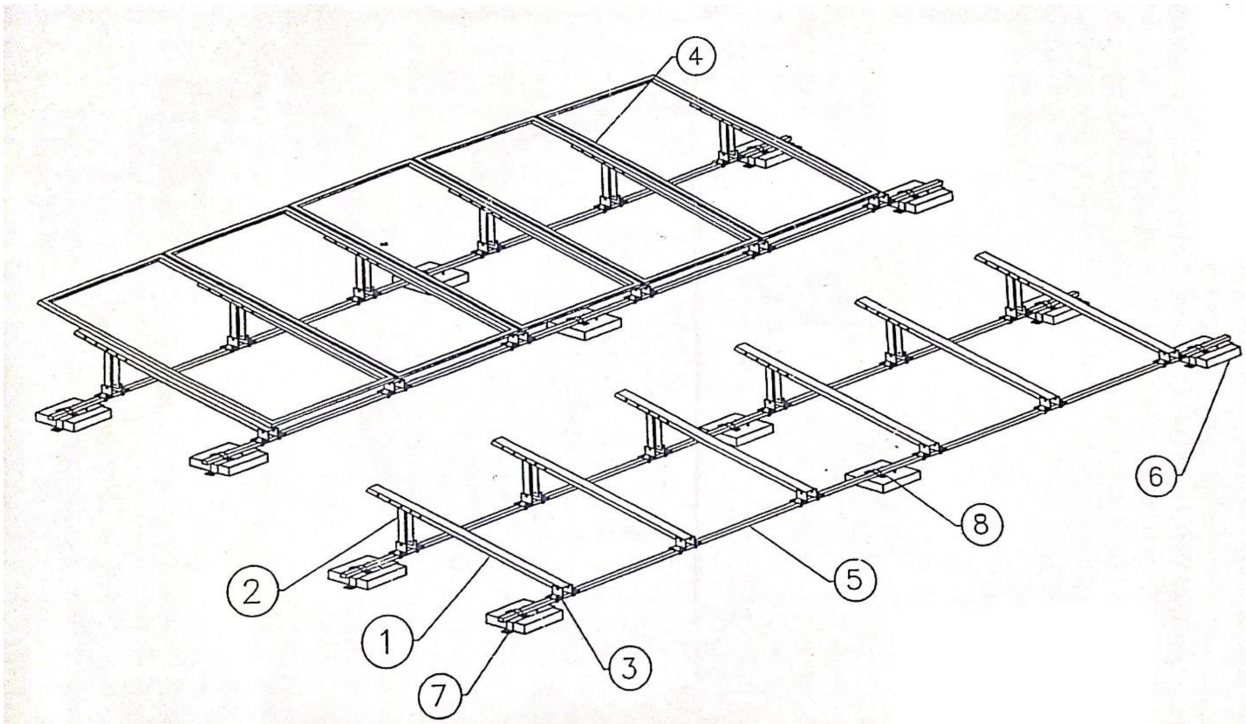
Chapter 6 Solar Panel Mounting Structure

Module mounting structures play a very important role in the efficient working of a solar power plant. While most of the components of balance of system (BOS) such as inverter DC cables junction boxes transformers, etc. are readily bought from the equipment suppliers the workmanship of an EPC contractor is reflected mainly through module mounting structures and wiring management

The Recent installation of a solar project in India has adopted various module mounting structure design which includes the structures made of galvanised iron as well as aluminium structures. Some of the projects have adopted a combination of steel structure and aluminium structure wherein vertical legs are made off hot dipped galvanised steel and rest of the members are made off extruded aluminium structure. Typically module mount structure comprises of following components:

1. Vertical rail (Rafter)
2. Vertical posts
3. Purlin (Horizontal rail)
4. Tilt bracket
5. Mounting clips
6. Cable tray

The mounting structure should consider local site conditions such as wind speed, rainfall & temp. While selecting module mounting structures. As the solar plant is expected to be designed for a 25 years lifetime, it is important for a project developer to ensure that the mounting structure remains until the lifetime of the project. Mounting structure life is high effected by corrosion and it is important that structure galvanization should be sufficient to protect it from corrosion. The typical structure galvanization thickness is kept of the order of 100-120 microns. In the case of purlin, the structure can be an old formed steel with a lesser galvanization thickness of the order of 80 microns.



1. Module Mounting 'C' Channel–50x72x50x2mm–1600mm Long
2. Vertical Support 'C' Channel–50x65x50x2mm–500mm Long
3. Support 'L' Clamp
4. Aluminum 'T' Clamp
5. Base Pipe
6. Rcc Base
7. Rcc Base Fitting Clamp
8. Base Pipe Fitting Clamp

All Dimensions Are In M.M
Material : M.S (Hot–dip galvanized)

Typically the vertical posts are of C-section, however recent design use sigma section as well in order to add strength and durability. Some of the structure design use tubular/square section which is good to provide connectivity with a rafter. The tubular section/ square section allow a U-bolt and saddle connection to hold rafter. The purlin is lighter members in the structure on which modules are mounted. Many structure design use Z section purlins so that the bottom flinch of the Z section can be used for carrying the DC cables along with it. The purlin is typically the rate of 2 mm thickness pre-galvanized sheet to protect the purlin from corrosion. It is advisable to use snake tray to carry DC cables rather than carrying the cable in the purlin the nuts & bolts use to connect structure member should be made of stainless steel in order to avoid corrosion. The modules are mounted on the structure with the help of module clips which is typically design for a panel thickness of about 50 mm. spring loaded hardware allows clips to be installed before the panel is installed. The module structure should be grounded properly and the structure leg should have a provision of grounding stake.

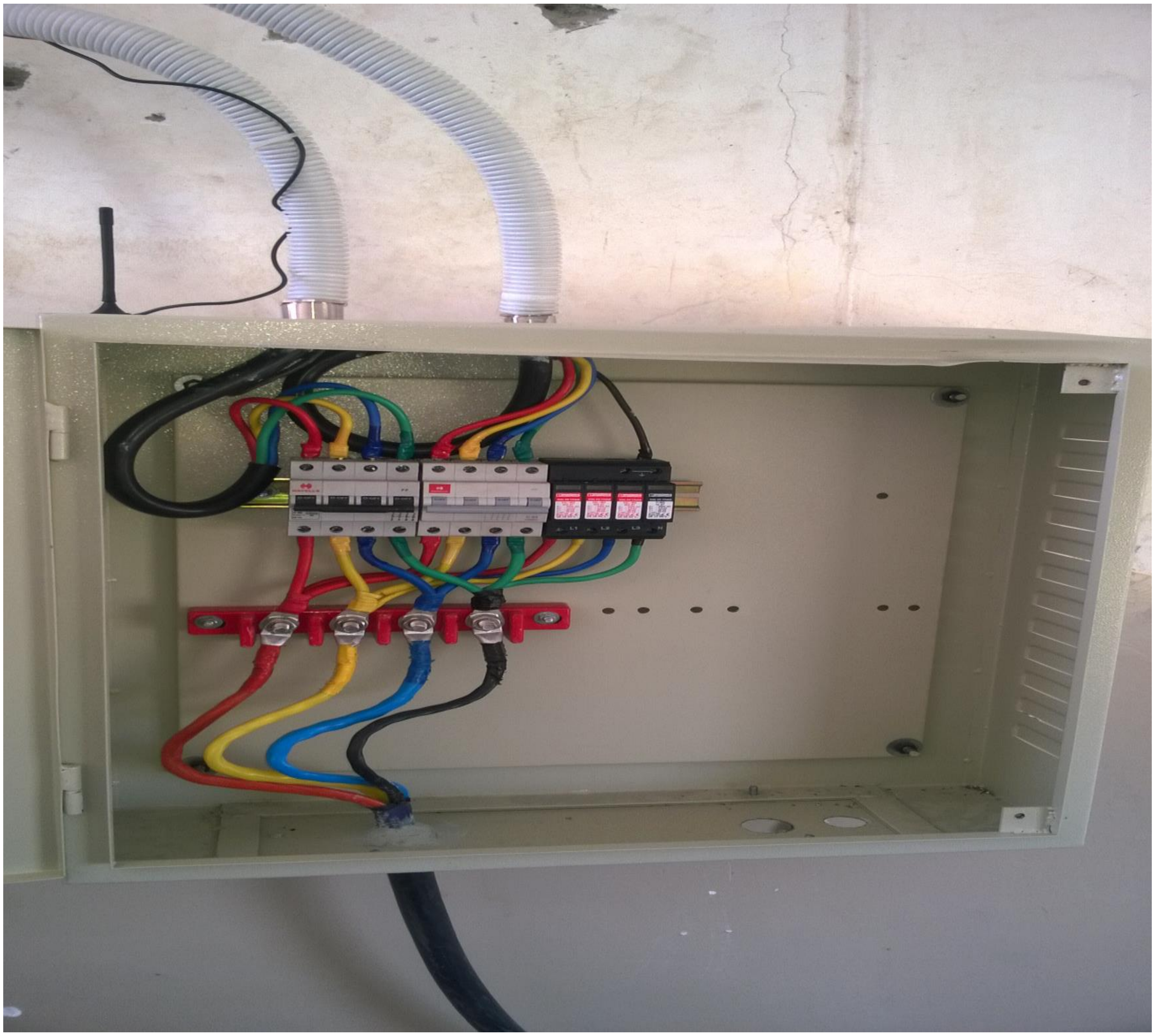
A good structure design can significantly reduce structure weight per MW. It should have an integrated wiring management system so that cables can run through perforated sections it’s important to carry out on-site pull-out test in order to decide the structure foundation death.

Many times the structures are design to accommodate single axis/double axis tracking system which makes the structure design complicated. Mounting of modules of the structure should be done by torque wrenches so that it does not put excessive pressure on modules. Finally, structure design should have adequate provisions to accommodate thermal expansion so that sagging in the structure does not occur.

Chapter 7 Grid-Tied Solar Inverter

A solar grid-tied inverter converts the DC output of PV modules into AC power suitable for transmission on the power grid, or use it for your own consumption, often deploying reactive power to meet new grid codes. It must always optimise the power output via MPPT (maximum power point tracking) and additionally monitor both the system and grid connection. In practice, each solar inverter installed in solar power plants needs to connect an array or string of PV modules to the power grid. e more efficient the inverter, the better the LCOE (leveled Cost of Electricity) generated by the system. An on-grid solar inverter is composed of a DCDC module, a DC-AC module and a control module. DC-DC module is built with a MOSFET, an inductor and a transformer, and functions to provide a stable DC output through rectifying and filtering the unstable DC power produced by PV modules; DC-AC module includes an IGBT array and an output filter circuit to convert the DC output of DCDC module into an AC output suited for transmission on power grid. The control module is the core of the whole system. It has a DSC, a voltage sensor, a current sensor, and a driver that drives MOSFET and IGBT module. DSC calculates the maximum power point of PV module array based on signals collected by sensors including PV modules' voltage and current, power grid's voltage and current, as well as phase. And accordingly, it sends out instructions to the driver which drives DC-DC and DC-AC modules. Furthermore, DSC is able to find out abnormal conditions such as transmission failure of the power grid and take measures such as cutting off the connection between inverters and grid to prevent "island effect "occurrences on the power grid. Additionally, the control module has an interface for external display showing PV modules' status and input/output voltage and current and integrates an RS232/RS485 communication interface to connect with control centres of solar power plants, so that real-time monitoring of solar panels and inverters can be implemented.

Each inverter is of 25KW rating and converting DC to AC and output of each adding in junction box shown in fig:



How does it work?

PV Grid Connected Inverters operate at a lower, safer voltage from the PV array while having the advantages of reliability, flexibility and improved energy yield. Using lower voltages on the PV side means there are lower voltages in your roof eliminating high voltage hazards and giving peace of mind to installers and service personnel. By using short multiple strings of panels, PV Grid Connected Inverters make sure that there are more paths for electricity to flow, which ensures minimal power loss due to varying environmental or panel conditions.

ON GRID/GRID TIE SOLUTIONS

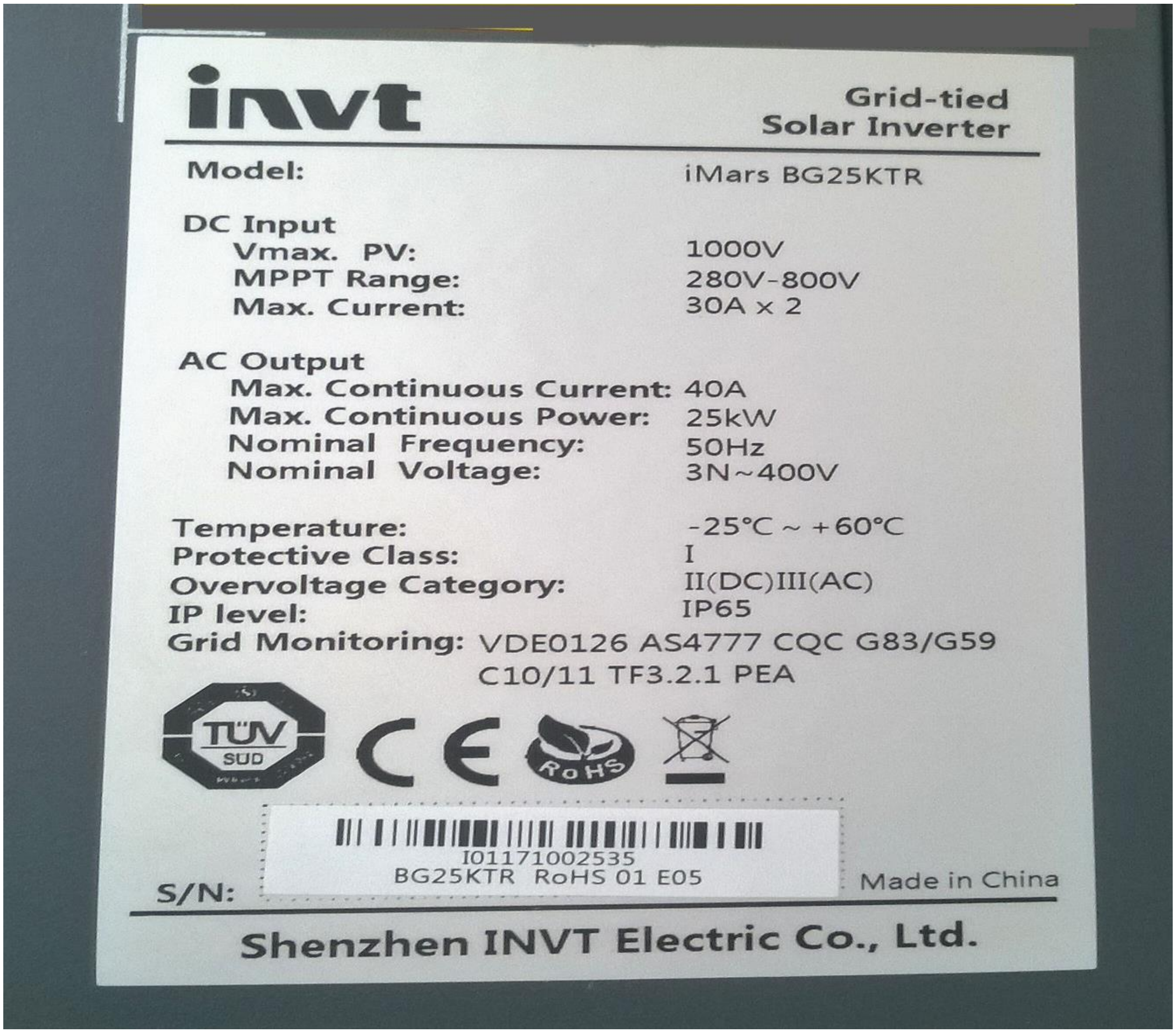
String Inverter - Single Phase

1800Wp, 2400Wp, 3300Wp
4600Wp, 5500Wp
12000Wp

Central Inverter - Three Phase

50KWp, 100KWp, 250KWp, 500KWp, 1000KWp

Specification of Inverter:



Chapter 8 SPV Monitoring System

As the name suggests, a monitoring system continuously reviews the critical aspects of a product and reports on the progress of each component. Think of it as an automated, software version of a supervisor. Solar power plants, especially large solar farms, today have sophisticated monitoring systems. These systems enable solar power plant operators to streamline operations and monitor the critical activities on a continuous basis.

Solar monitoring makes certain that your solar panels are working properly by tracking the power output of your system. With solar monitoring, you gain 24/7 peace of mind that your panels are working as efficiently as possible. Importantly, you'll also gain the ability to view how much money your solar system is actually saving you in energy costs. Solar monitoring gives you real-time visibility into the number of kilowatt hours of electricity your solar panels are producing at any given moment in time.

Monitoring solar panel output is a great tool to continually track how well your solar power system is working. It's an easy way to see the amount of energy you've produced and follow the proper power output of your solar panel system. Solar monitoring software allows you to easily view how many kilowatt hours of electricity your solar panels are producing at any given moment in time. In the unlikely event something was to go wrong with your system — a faulty wire or panel, for example — your solar monitoring system will pinpoint the specific issue so that you can resolve the problem quickly and efficiently. Solar monitoring also provides you quick and easy ways to track how much money your solar system is saving you in energy costs.

Solar monitoring can tell you if your panels are working properly and how good of a job they're doing. With solar monitoring, you're able to see how much your system is generating, when it's producing the energy and whether your system is over producing or underproducing. **Monitoring your solar panel output** helps you make the necessary adjustments to be certain your system is working properly. Not only are solar monitoring systems able to tell you how much energy your panels are currently producing, but they can also keep you informed about many your panels have produced over time, giving you a sense of how much energy and money you’ve saved.

Chapter 9 Earthing

Basically, there are 3 types of earthing in a solar plant - DC, AC and LA.

AC Earthing:

AC earthing is a standard one as you have in any commercial/Industrial Earthing. The list of earthing will be as follows.

1) Earthing for your ACDB Panel

2) Earthing for your Transformer and other switchgear panels/equipment's

DC Earthing:

The DC Earthing is done to basically ground the Metallic body of your panel and prevent people from getting electrocuted in case of an accident

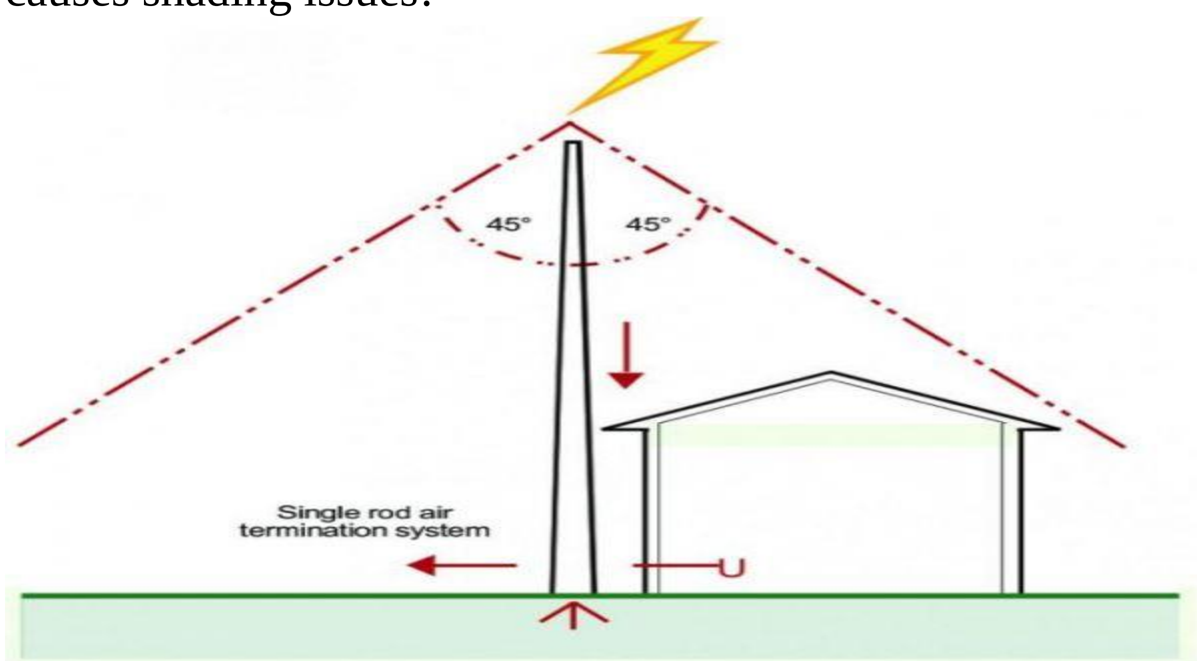
Even DC SPD's (Surge Protection Devices) can have a special separate earth for them

Lightning Arrestor:

Lightning Arrestor is a bit complicated.

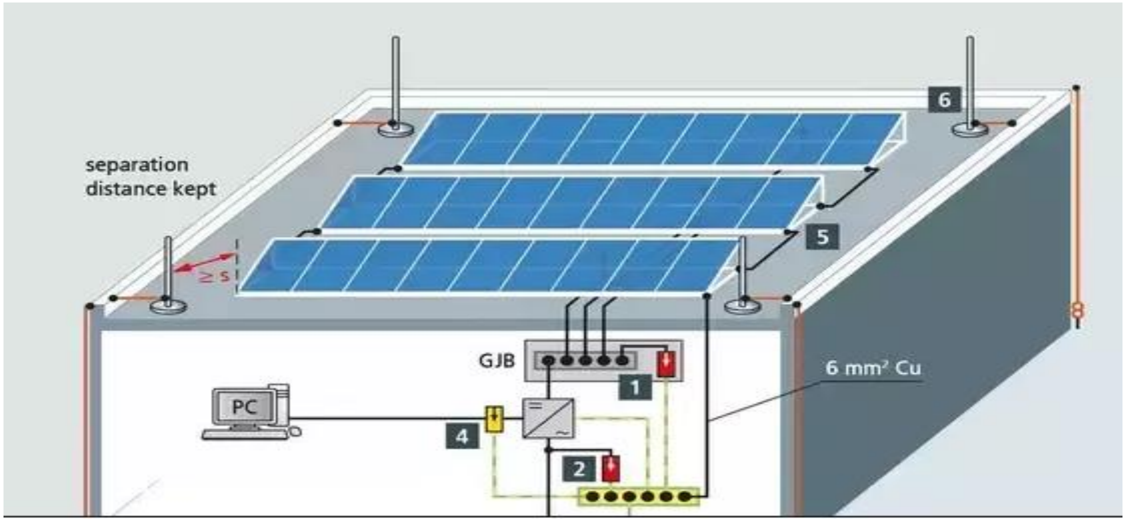
There are Multiple Methods to do this

1. **Conical Area Coverage:** In this you generally have long pole earthed solidly to ground. The Area covered by this is equal to the conical area formed (45 Degree). The Figure is Self-explanatory But generally, this method causes shading issues!



2. **Surrounding by Conductor:** In this method, you surround you entire modules by surrounding it by a G.I wire

connected to poles surrounding the entire modules. (Assume the house to be your modules)



Selection of Earthing Techniques: As far as material selection for earthing is concerned it is based upon commercials and site requirements.

Copper is always preferred over G.I. but it is costly as compared to G.I. you can do electrode earthing over conventional plate earthing but again it is a costlier alternative and depends upon site requirements.

Most importantly you have to get your earth resistance below the specified range generally 1 Ohm.

Chemical Earthing that you mentioned includes a special chemical powder that you put in the earth pit instead of conventional salt and Coal. The powder provides a better resistance as compared to salt and coal.

Chapter 10 Net Metering

Rajasthan would probably be the next Gujarat in India in terms of a role model for solar. The irradiation in Rajasthan is in the range of 5.5-6.0 (kWh/m2/day). That's among THE best in India (refer to this map). So, in general, the state is perfectly appropriate to go solar climatically. Further, looking at Rajasthan's solar policy which was revised in 2014 (refer), it is clear that the push for solar is not only through small rooftop plants but also through ground-mounted solar parks that should be developed soon. This article, however, will focus on rooftop solar in Rajasthan.

"Net metering" means methodology under which the electricity generated by the solar rooftop system owned by the consumer and delivered to the Distribution Licensee may be utilised to offset the electricity supplied by the Distribution Licensee to the consumer during the applicable billing period.

Following are the key highlights of the net-metering guidelines (refer) in Rajasthan:

- Released on 26.02.15
- Cumulative capacity allowed at the particular distribution transformer shall not exceed 30% of the transformer capacity
- The distribution licensee will update the capacity available at each distribution transformer, on a yearly basis on their website

- The maximum Rooftop PV solar power plant capacity that can be installed at any eligible consumer premises shall not be more than 80% of the sanctioned connected load.
- Any eligible customer needs to install a minimum of one-kilo watt peak on the rooftop and a maximum of 1 MW

The average commercial tariff for Rajasthan is ₹ 7.4. Excess injected electricity into the grid shall be paid by the distribution licensee at feed-in-tariff as follows in the next billing cycle as long as the export is above 50 units. If the export is below 50 units it shall be adjusted in the next billing cycle at the same tariff as their billing rate.

Table- 8: Summary of Solar PV and Solar Thermal Tariffs

S. No.	Particulars	Tariff (₹/kWh) if AD benefit is not availed	Tariff (₹/kWh) if AD benefit is availed
1	2	3	4
1	Solar Photo Voltaic (PV) Power Plants commissioned by 31.03.2017	6.74	6.10
2	Solar Thermal Power Plants commissioned by 31.03.2018	11.46	10.30
3	Roof Top Solar PV installations and other small solar PV power generation plants to be commissioned by 31.03.2017	6.74	6.10
4	Small Solar Thermal Power generation plants to be commissioned by 31.03.2018	11.46	10.30