Grid connect solar system

Work Safety and Health

Safety is a full time job and is the responsibility of everyone working with solar PV system

We expect all persons working on Solar systems to adopt the following towards safety

1. Develop a safety policy
2. Consult your organization for help
3. Provide information and training
4. Identify and assess hazard
5. Implement and follow control measures
6. Maintain and improve an HSSE standard

1. Good work Habit
2. A clean and orderly work area
3. Proper equipment and training to use
4. An awareness of potential hazard and how to avoid them
5. Periodic review of safety procedures
6. A training to all on basic first aid.

Solar PV – Basic Components

1. Modules/Panels – Solar electricity generator. 3 basic types in the market place: Mono crystalline, Multi crystalline and thin film

2. Array – Several modules connected together into a system

3. Grid Tie Inverter – converts DC to AC and feeds the utility grid with the A/C power (Referred as PCU for battery based system)

4. MPPT- Maximum power point tracker, maximizes the energy from the panels.

5. Batteries – stores DC power used for off grid systems /storage systems

6. Charge Controller – regulates the power going to the batteries – only for the battery based system

Solar PV – Type of systems

Each type of system has very specific capabilities and limitations. All PV systems consist of one or more modules which produce DC power . What we do with this power after it is produced is that what determines the type of system.

Stand Alone – Off grid

Modules, charge controller, batteries, and may or may not have an inverter which converts DC power to AC power

Grid Tie – Grid connected

Modules, and inverter connected to the utility grid, generated power is exported to the grid

Hybrid – Grid connected with batteries

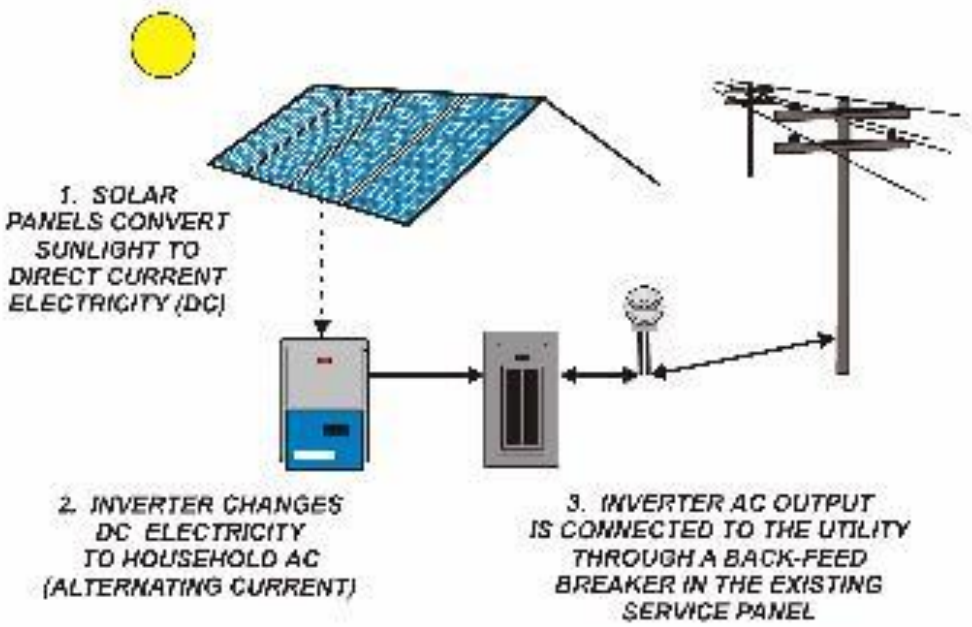
Modules, grid-tie inverter, and batteries for storage when the grid is unavailable

Systems can be installed on roof, ground or on any structure that is exposed to direct sunlight i.e shadow free through out the day.

Grid tie – Grid connected

1. PV System:
GRID-TIE (BATTERY FREE)

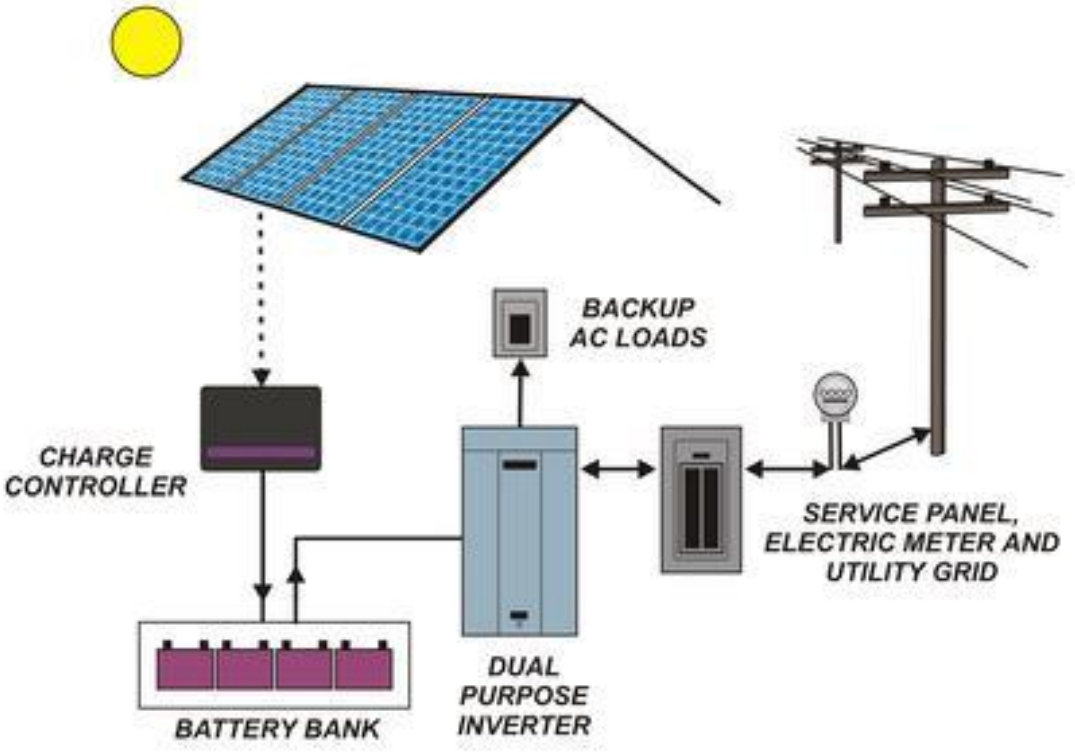
The simplest and most cost effective PV design for most sites is the "Grid-Tie" (sometimes referred to as inter tied or utility-interactive) system. This system does not provide backup power during a power outage (even if the sun is shining) but for sites with reliable grid power, this is usually the bestand economical system choice for industries and residences



GRID-TIE WITH BATTERY BACKUP

PV System:
GRID-TIE WITH BATTERY BACKUP

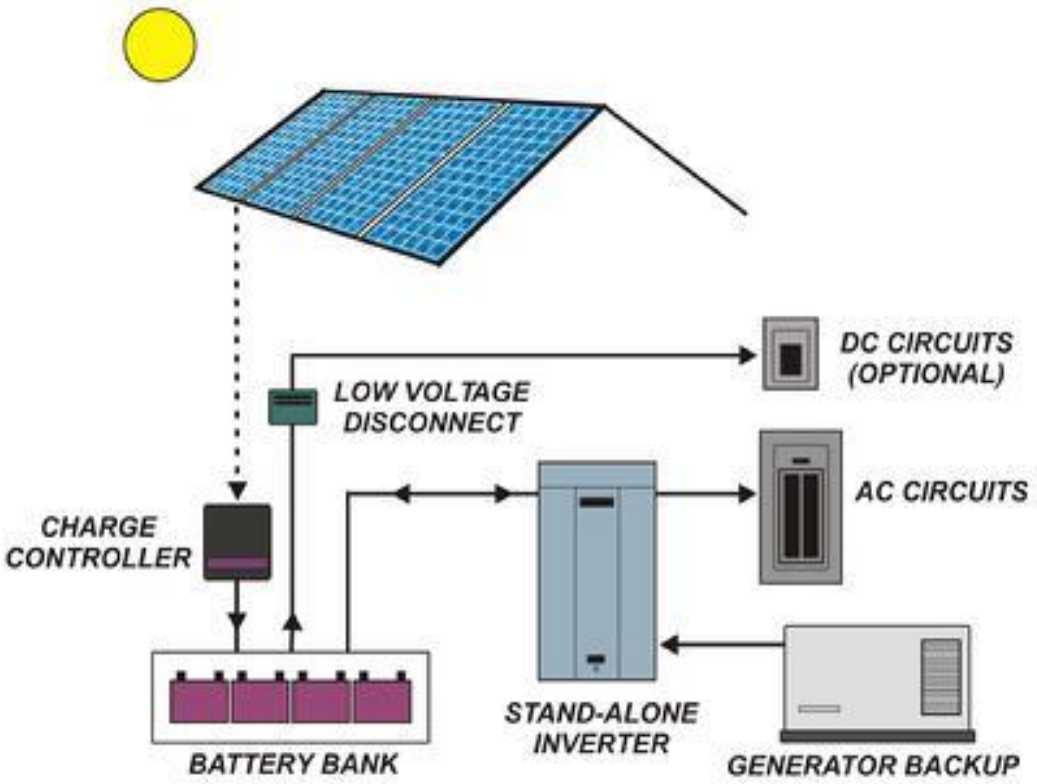
The Grid-Tie With Battery Backup system can also push excess electricity produced to the electric utility grid but has the added feature of batteries in order to power some selected backup loads when the grid is down. With this benefit comes increased cost and maintenance requirements.



STAND-ALONE

3. PV System: STAND-ALONE

The Off-Grid or Stand-Alone PV System incorporates large amounts of battery storage to provide power for a certain number of days (and nights) in a row when sun is not available. The array of solar panels must be large enough to power all energy needs at the site and recharge the batteries at the same time. Most Off-Grid systems benefit from the installation of more than one renewable energy generator and may include Wind .
A standby diesel generator is often employed for emergency backup power.



Solar Radiation or Irradiance or Insolation

The standard test conditions (known as STC) under which the solar modules output is rated is:

- Air mass =1.5
- Solar Radiation = 1000W/m2
- Cell temperature =25Deg C

Irradiance

The top of the atmosphere receives energy at 1.367KW/m2, this is known as solar constant. As the radiation passes thru the atmosphere it is attenuated to 1 kW/m2 at sea level. The amount of solar power available per unit area is known as *irradiance.*

Parameter	Symbol	Quantity and Unit
Irradiance	G	kW/m2 ; W/m2
Solar constant	Gsc	1.367 kW/m2. 1,367W/m2
Peak value at sea level	G_O	1.0 kW/m2, 1000W/m2
Nominal Value	-	0.8KW/m2; 800W/m2

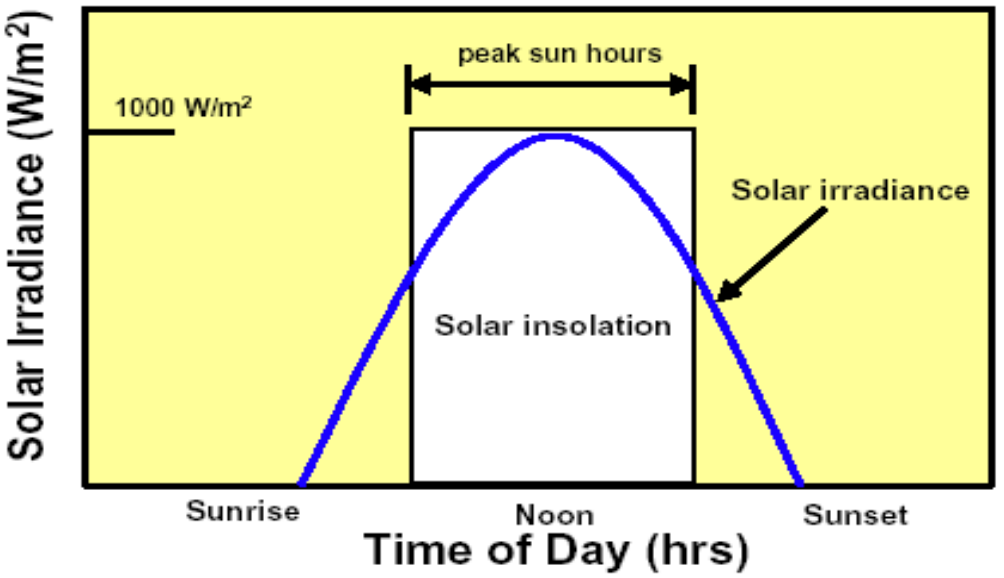
Why Nominal value: The accepted value as an approximation of what would be measured in the field as opposed to the peak value. (The practical value after all the possible losses)

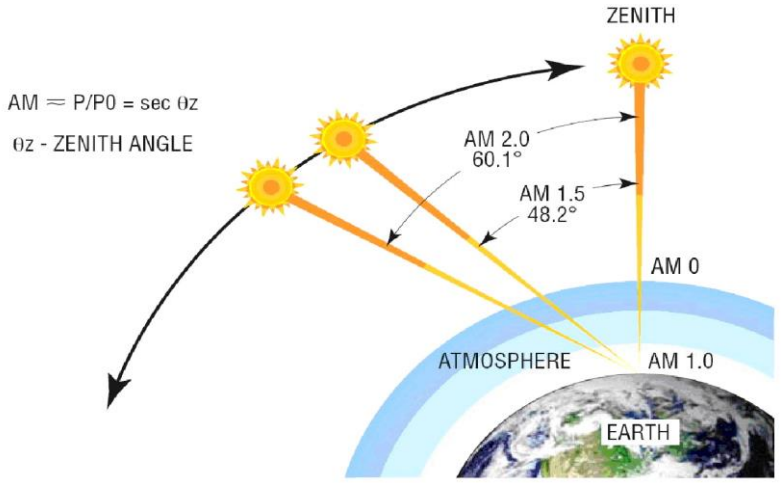
Irradiation and the Peak SUN Shine Hours

Irradiation is the total quantity of radiant solar energy per unit area received over a given period, e. g Daily, monthly or annually.

The amount of solar radiation striking any location on earth varies from sunrise to sunset due to clouds, the sun's position in the sky, and what's mixed into the atmosphere. (air mass)

Maximum solar radiation occurs at solar noon—the time when the sun is highest in the sky, compared to the rest of the day. Sunlight in the morning and evening does not deliver as much energy to the earth's surface as it does at midday because at low angles more atmosphere filters the sunlight





PSH Calculation

A peak sun-hour is roughly the amount of solar energy striking a 1-square-meter area perpendicular to the sun's location over a 1-hour period

So we can compare apples to apples, the amount of power is standardized at 1,000 watts (1 kilowatt) hitting that 1-square meter surface.

By adding up the various amounts of solar irradiation over the course of a day, and counting them as units equivalent to 1 solar-noon hour (1,000 watts per square meter for 1 hour), we get a useful comparison number—**the peak sun-hour.**

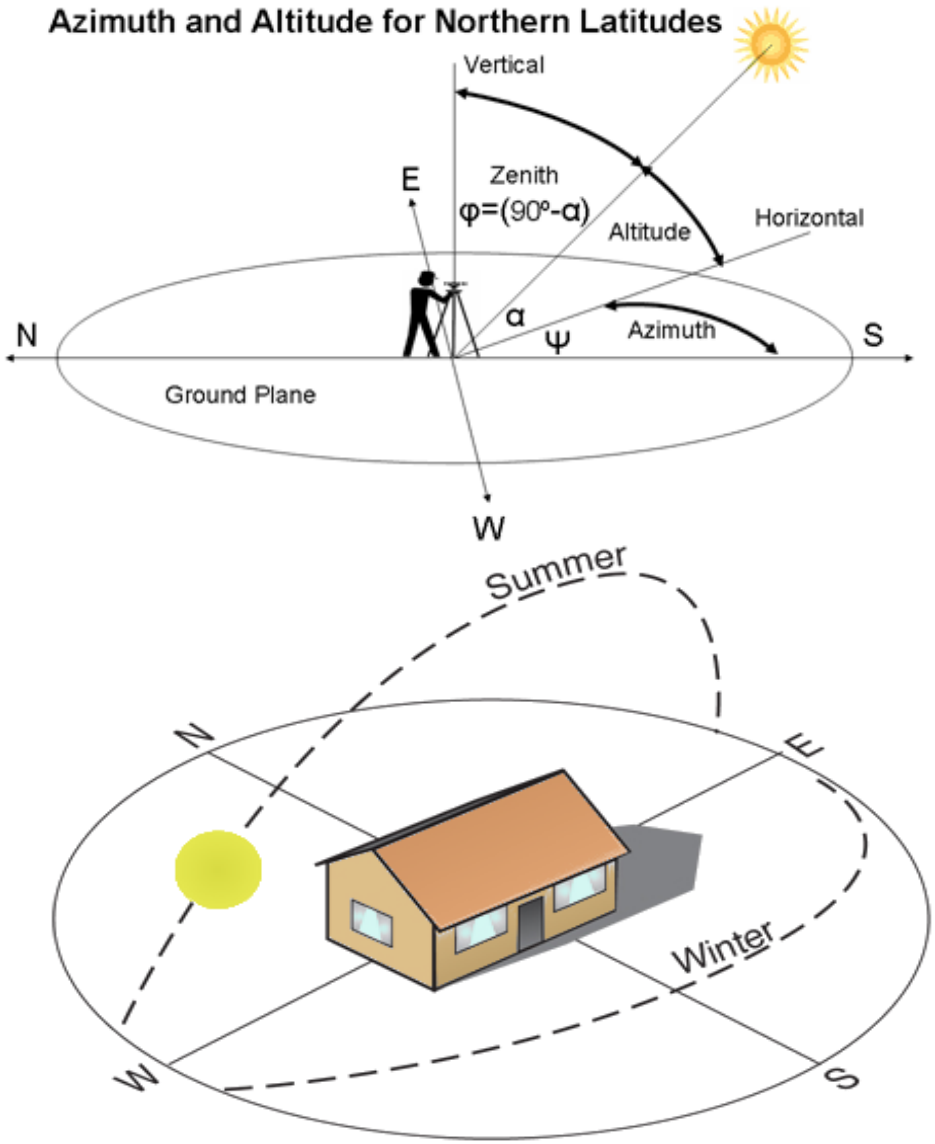
Hour	Watts/m^2	Watts Hours/m^2
05 AM - 06 AM	0	0
06 AM - 07 AM	25	25
07 AM - 08 AM	25	25
08 AM - 09 AM	50	50
09 AM - 10 AM	300	300
10 AM - 11 AM	1000	1000
11 AM - 12 AM	1200	1200
12 AM - 01AM	1000	1000
01 PM - 02 PM	300	300
02 PM - 03 PM	50	50
04 PM - 05 PM	25	25
05 PM - 06 PM	25	25
06 PM - 07 PM	0	0
Total Watt-hrs/m^2/Day		4000

Defining the position of the SUN

There are two angles to be specified when defining the Position of the Sun

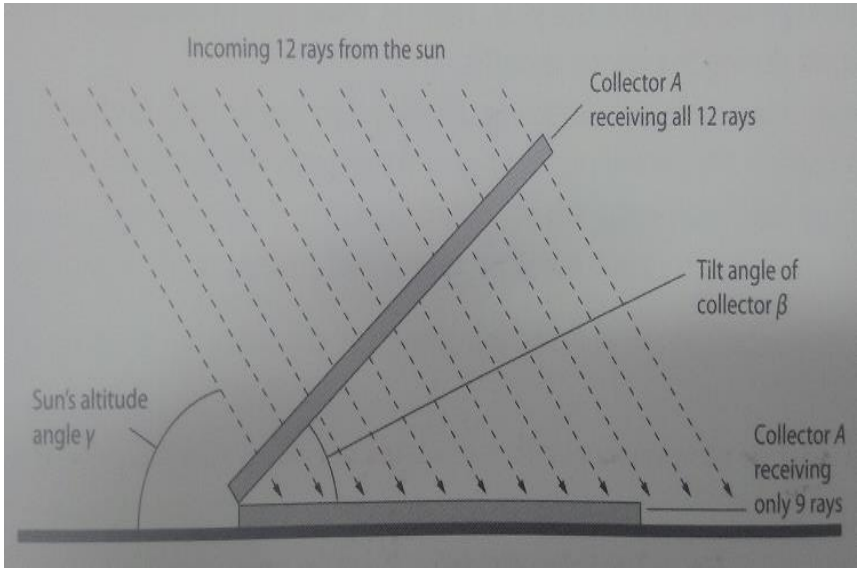
1. Altitude – Angle between the sun and the horizon
2. Azimuth – Angle between North and the suns position.
   Both the above will change constantly through out the year due to the seasonal movement of the sun.

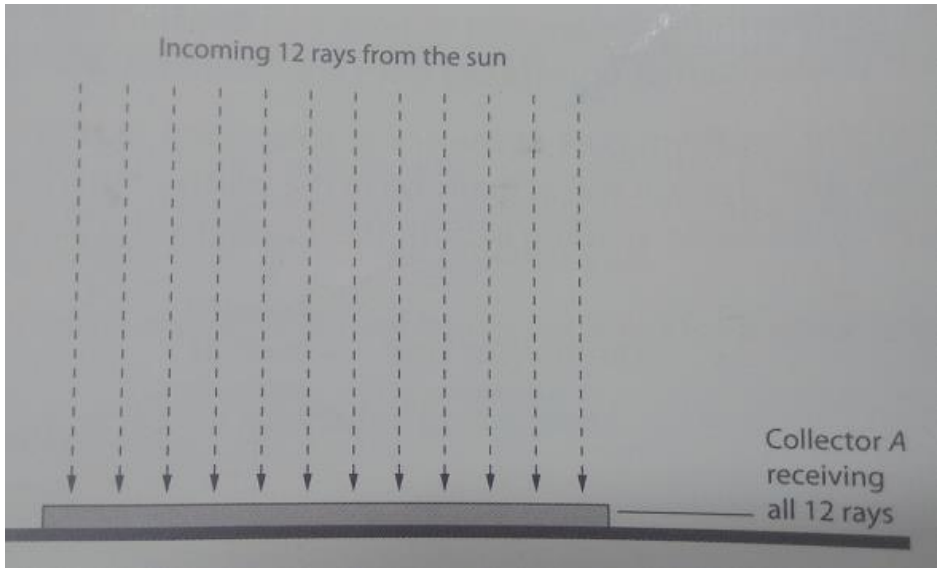
In India SUN is in the southern part of the sky, Hence our solar panel will face south direction as all the sun light reaches the panel from the south direction.



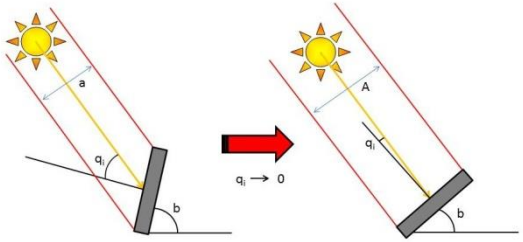
Geometric Effects

Latitude, time of the day and seasons all affect the amount of energy reaching the surface
Oriented horizontally on the earth surface. The correct angle will determine how much
Perpendicular the suns rays are to the collecting surface.





Incidence Angle Effect



Tilting the solar Module

Solar modules should be installed such that the maximum solar radiation is captured.
To achieve this we need to tilt the solar module to true magnetic south since we are in the northern hemisphere. ***The best output will be when the solar radiation is perpendicular to the panel surface.***
This calls for solar tracking to be installed ,this can be expensive, so it is not common practice in grid connect system especially small ones.
The most common approach is to install the solar panel at an angle such that solar radiation is perpendicular at the equinox, that is at an angle which **is equal to the latitude** of the site.
Idle tilt angle can be calculated at any time using the formula:

Module tilt= 180deg-90deg-Altitude of the sun

Example: altitude of sun in Delhi in winter 48.5degS, what is the tilt?
180-90-48.5 = 41.5deg South tilted.
So the optimal angle for tilting is *41.5deg south.*

*Note: This will change depend*ing on the sun movement during the year.

Purpose of an Inverter (or PCU – battery based)

A PCU is an equipment that converts electrical energy generated by an array into appropriate frequency and voltage value to be delivered to a load, stored in a battery or injected into the electrical grid. This includes both charge controller and inverter.

Note: In this case Loads define the frequency and voltage of the inverter output.

The Grid connect inverter is a device that delivers solar power to AC power grid, The PV array is configured to operate within the specified DC voltage to suit the operating range. The inverter will convert the DC power to an AC sine wave that matches the AC supply in voltage and frequency to which it is connected.

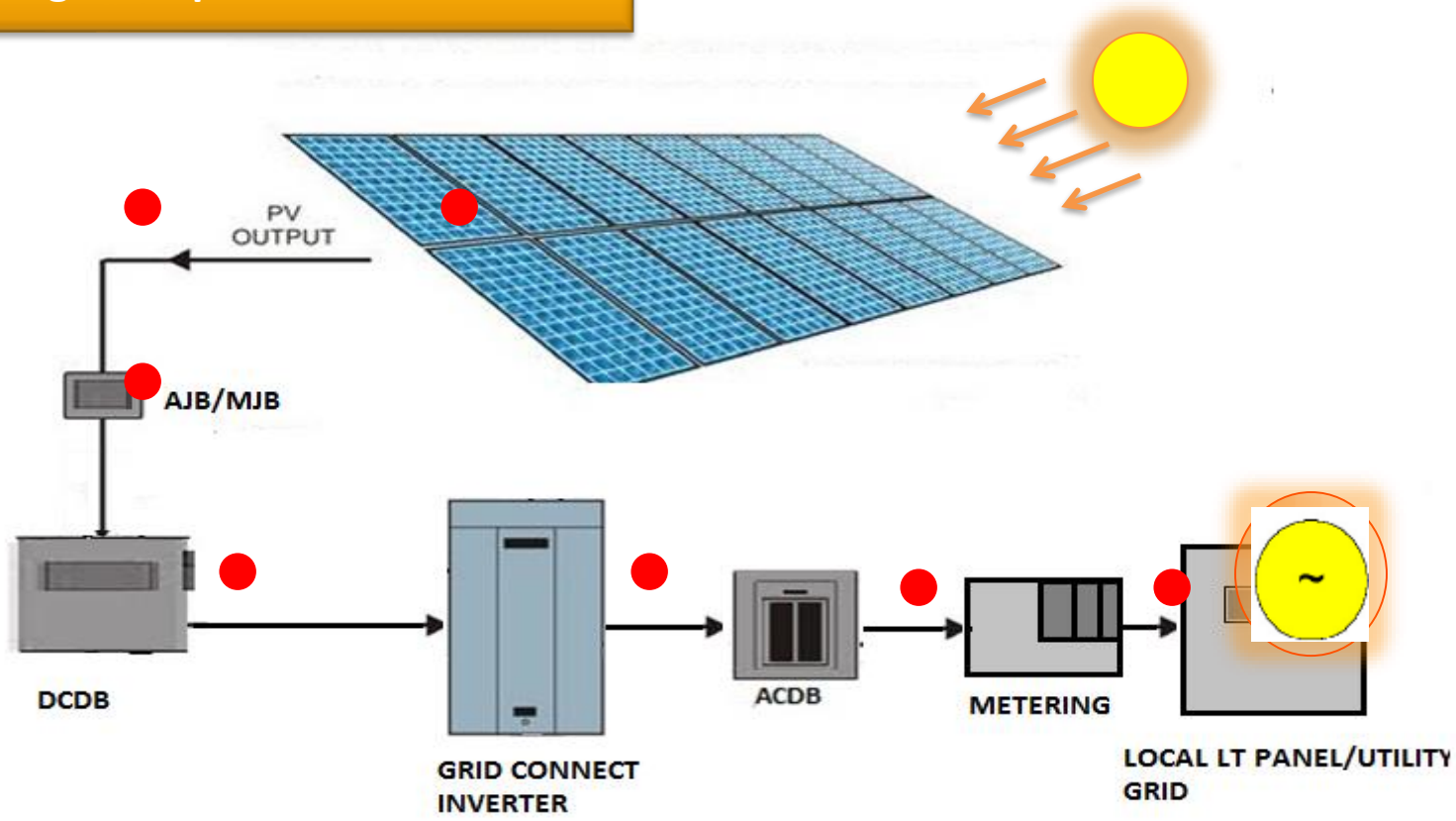
Note: In this case Grid define the frequency and voltage of the inverter output. But the loads are parallel to the grid and the GTI. The GTI output is slightly higher than the Grid voltage so that the GTI can push current into the Grid.

A grid connect inverter cannot independently produce a grid equivalent AC sine wave. The inverter must see a grid reference to be able to operate. The grid voltage and frequency must fall within the predetermined range to be able to output power to the grid. *(Please refer Slides on protection to know more about this)*

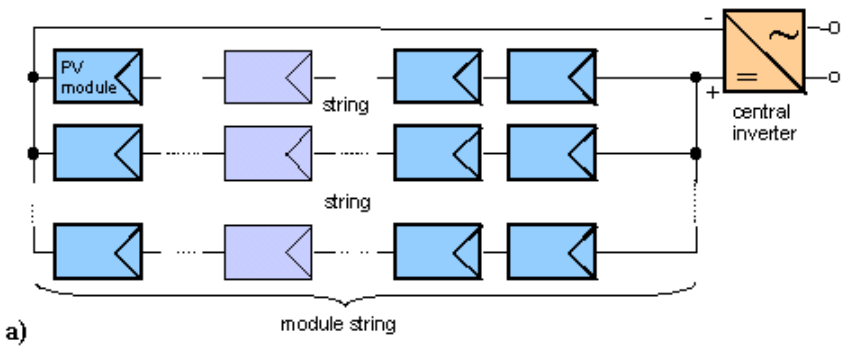
If the GRID is not present, the inverter will not function.

Solar PV System-Grid connect

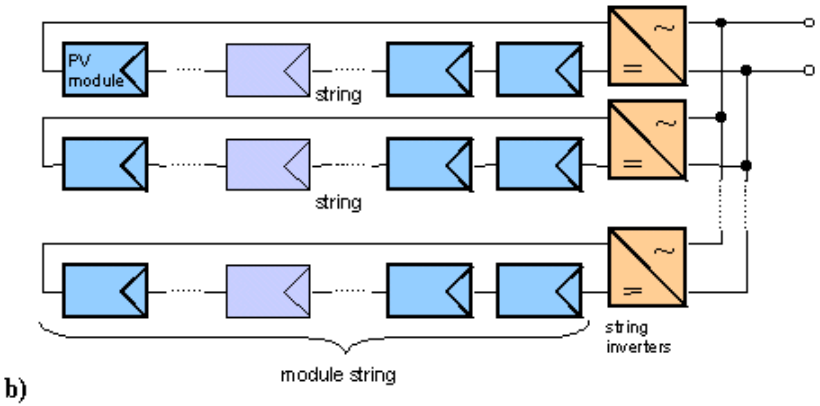
Working Principle – Grid Connected



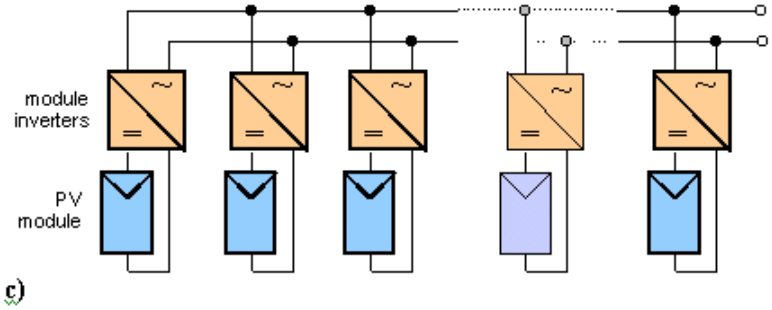
Types of Grid Tie Inverters



Central Inverter



String Inverter



Micro grid tie Inverter

Passive and active protections

When the grid waveform is too distorted or outside the voltage and frequency range of the inverter, the grid tie inverter will disconnect from the grid and will not produce power . This is called ***Passive anti islanding protection***

The following protection will be incorporated in the GTI.

1. Under voltage protection- Vmin
2. Over voltage protection- Vmax
3. Under Frequency protection - fmin
4. Over frequency protection –fmax

Following are the ranges :

Low voltage- 184- 230V (80% of the grid voltage)
High Voltage – 230V-253V (110% of grid voltage)
Low frequency – 47.5 -49.5 Hz
High frequency – 50.5 Hz – 52 Hz

Active protection

1. Real time frequency instability check
2. Frequency drift check
3. Power variation check

PV Panel mounting systems

There are two basic panel mounting systems :

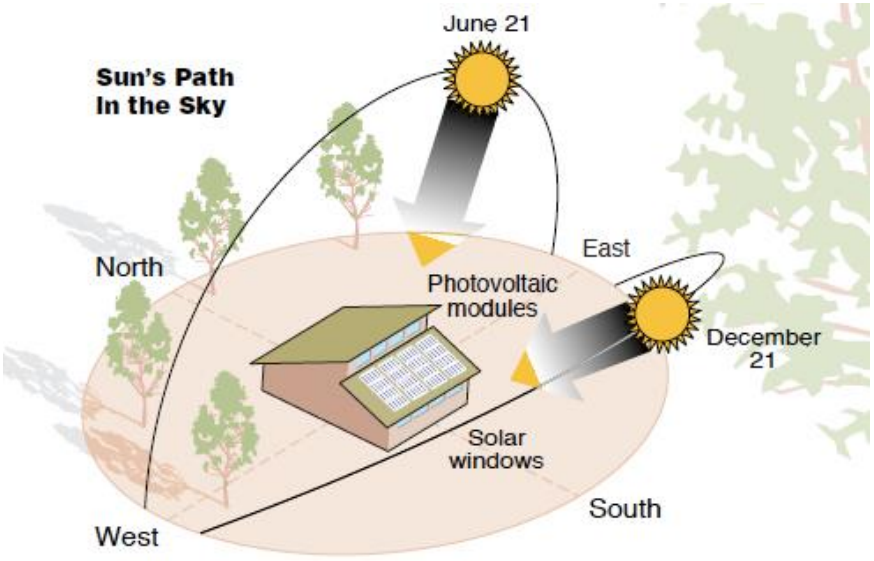
1. **Ground mounting**
2. **Roof mounting**

Ground mounting is used in large commercial and utility sized PV systems. These can be in Sizes of several KW or moderate size of less than 100KW.

Smaller commercial and domestic grid connect market, where the PV systems are required to be installed on existing roof space, roof mounting is used. The installed system capacity will be limited to roof space available.

PV Array Row Spacing

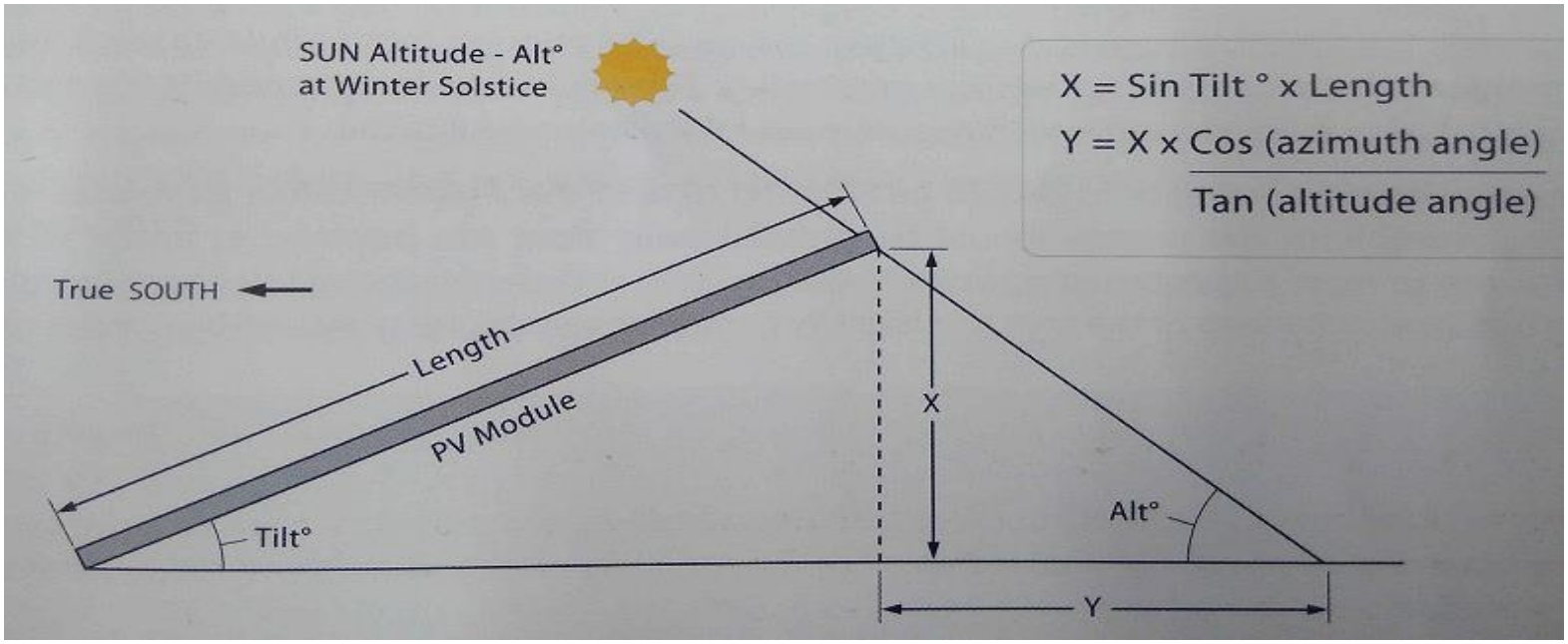
- Solar Module must be installed such that there is no shadow on them at any part of the day.
- Many a times, there could be multiple module mounting structures to be installed on one roof.
- Must consider one module mounting structure do not cast shadow on the row behind.
- It is necessary to find the minimum distance between PV array row to avoid winter day shading.



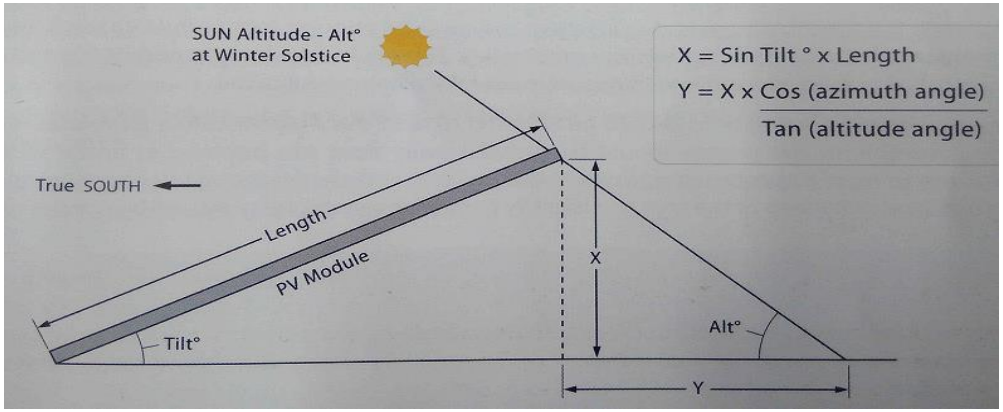
Maximum shadow will on Dec 21

PV Array Row Spacing Contd…

Example: Our panel length is 1600, tilt angle is 30deg
Calculate Height X
Sin tilt deg =X/1600
X= Sin30 deg X 1600mm
Sin 30 = 0.5
1600* 0.5 = 800mm



PV Array Row Spacing Contd…

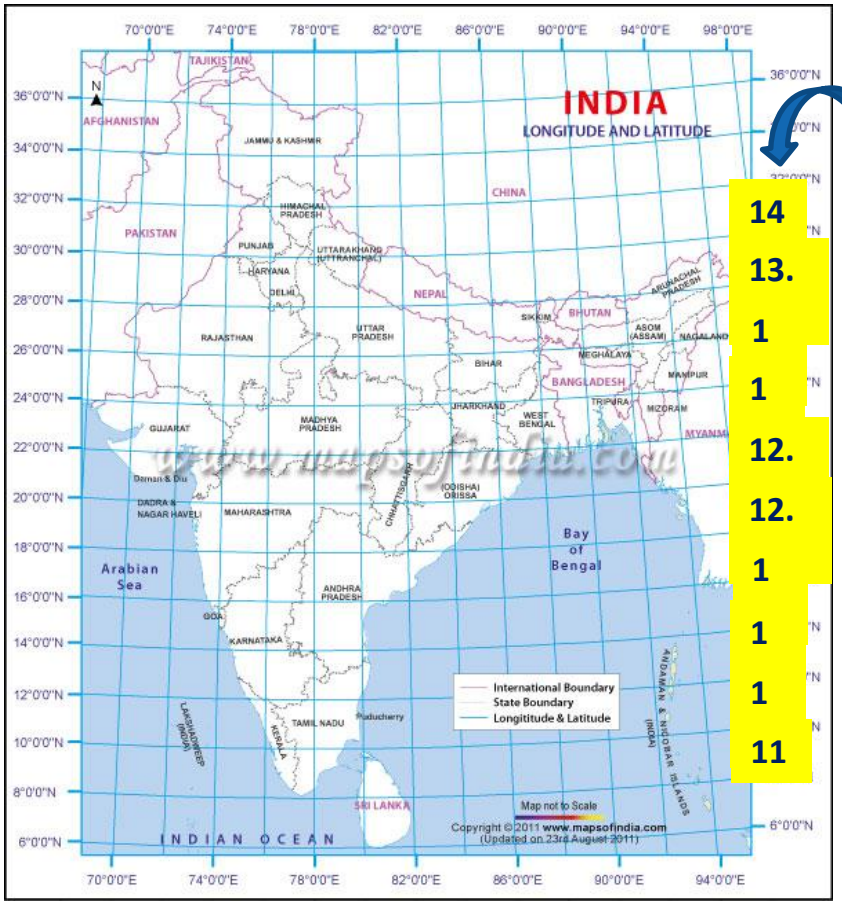


Row Spacing

$$Y = (X) \times \frac{\text{Cos (azimuth angle)}}{\text{Tan (altitude angle)}}$$

Location	Latitude Deg N (Tilt Angle)	Azimuth	Altitude	Cos Az /Tan Al
Delhi	29	143.5	28.1	1.505
Kolkata	22.5	151.95	38.68	1.1
Mumbai	18.9	206.5	43.01	0.959
Hyderabad	17.36	140.21	37.73	0.99
Chennai	13.08	139.49	42.13	0.84
Bangalore	12.9	137	40.46	0.85
Pune	18.52	180	42	0.90
Coimbatore	11.01	120	41.3	0.82

Area required flat roof



m^2 required per kWp
14
13.
1
1
12.
12.
1
1
1
11

Divide the area available by this number to get KWp

Example

If area available is 1500 m^2

Delhi: 110 KWp

Raipur: 115 KWp

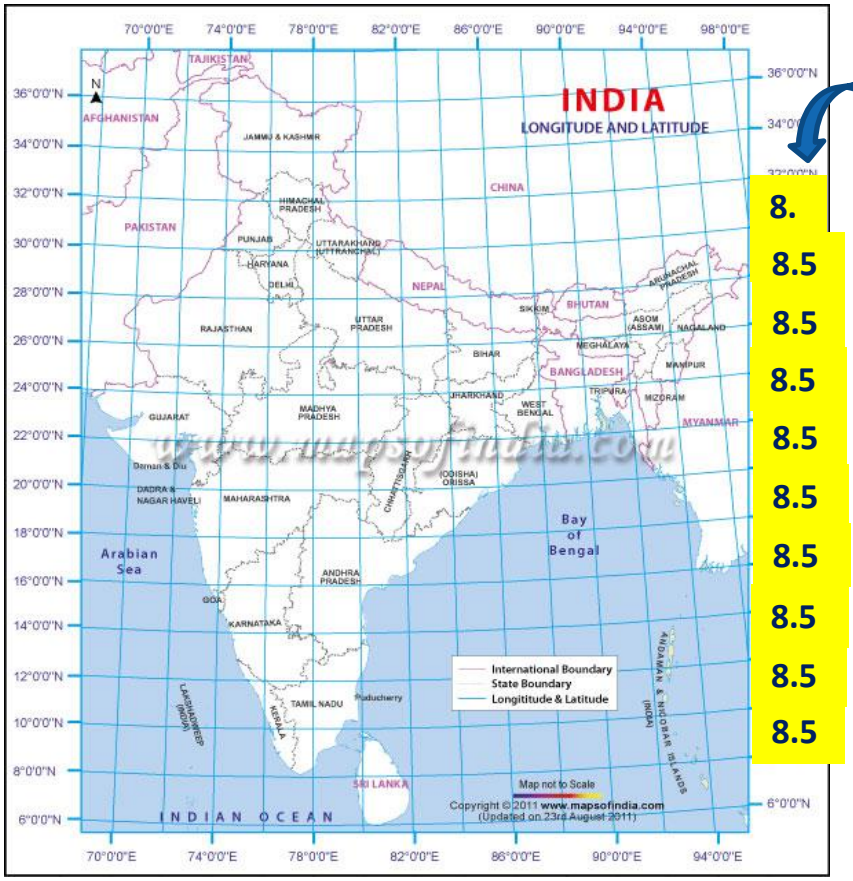
Hyderabad: 120 KWp

Chennai: 125 KWp

Trivendrum: 140 KWp

Key: Shadow will be larger if tilt angle is larger. Tilt is usually latitude degree of the place.

Area required for sheet roof



m^2 required per KWp
8.
8.5
8.5
8.5
8.5
8.5
8.5
8.5
8.5
8.5

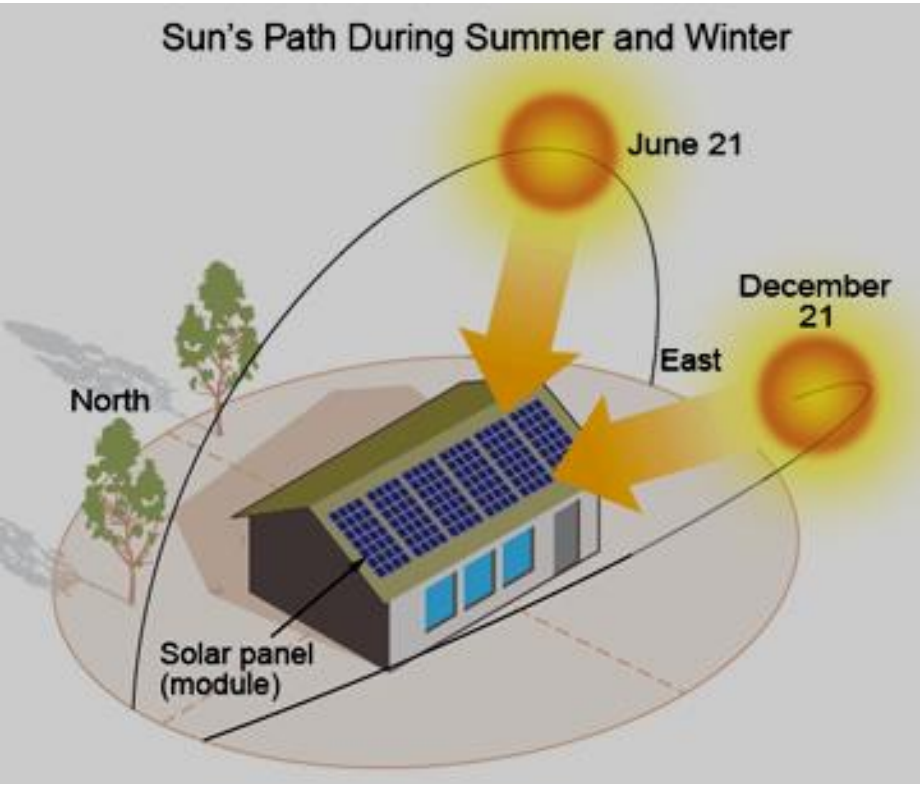
Divide the area available by this number to get kWp

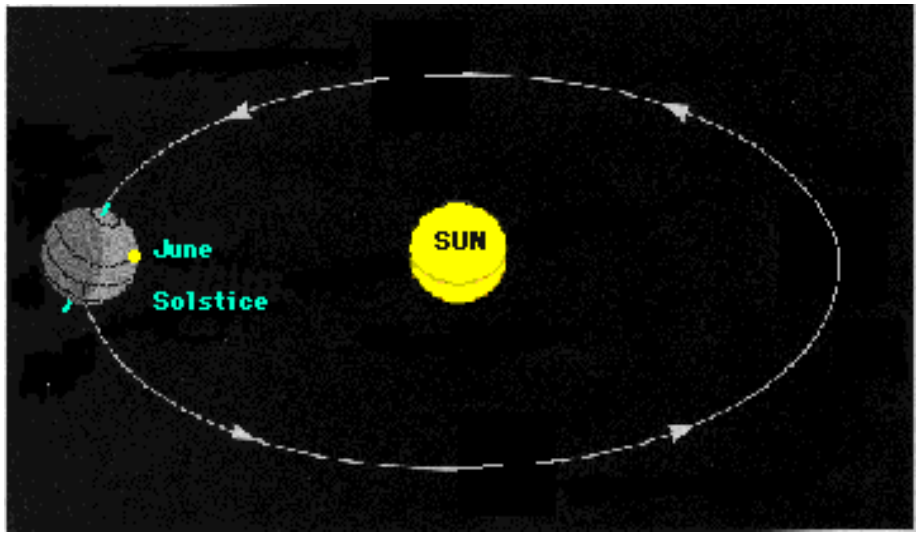
Interesting right?

1. On slanted roof no issue of shadowing
2. Panels are placed side by side or one above the other
3. Space required for walkway or maintenance only

Key: Panels are on single plane

WHY SOUTH DIRECTION??





The amount of incident energy per unit Area and day depends on a number of factors, e.g.:

- **latitude**
- **local climate**
- **season of the year**
- **inclination of the collecting Surface in the direction of the sun.**

Understanding latitude and your position in the earth

India is in the Northern Hemisphere and all the solar radiation will be from the south

So how do we ensure shadow free Installation?

There are two basic questions to answer,

1. Does your location get enough sun radiance?
2. Do nearby obstacles (trees, buildings, etc.,) at your location block too much sun radiance?

The 1st question depends on geographical location. Most of locations in India get enough sun to successfully use solar energy round the year

The 2nd question is critically important

Therefore site visit or site survey is essential.

Finding shadow free environment on roof top (limited space) may be a challenge.

Site Assessment to install a Solar System

There are two basic questions to answer to determine if solar can work well at the site of installation.

1. **Does your location get enough sun?**
2. **Do nearby obstacles (trees, buildings, etc.,) at your location block too much sun?**

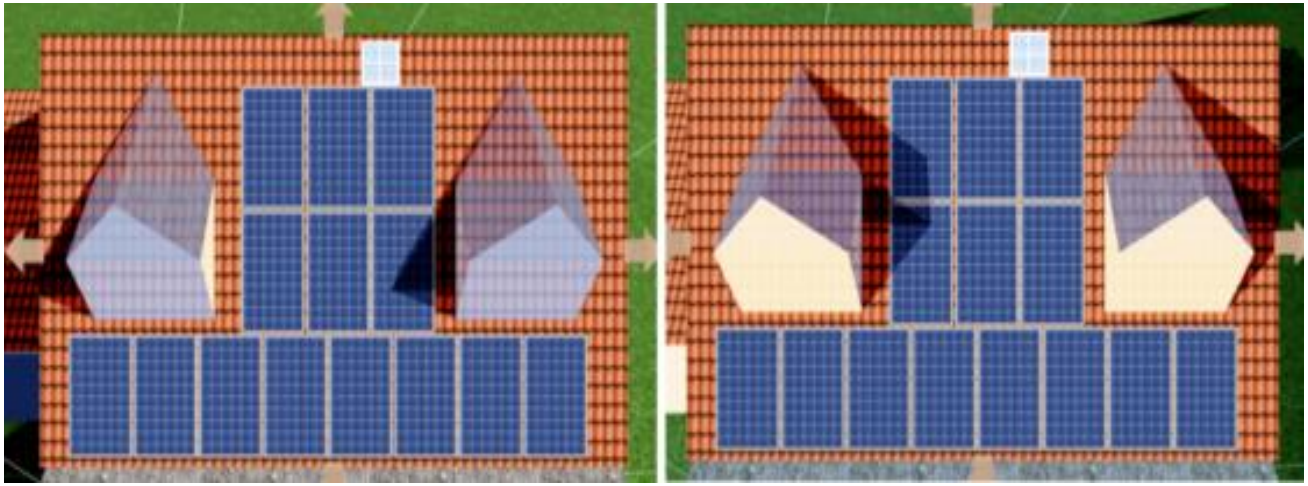
Shadow test: To collect maximum sunlight during the day, the solar PV panel should face as much south as possible. The rooftop must be checked for the shadows of trees or adjoining builds etc., particularly from south direction. A clear rooftop without any shadow from all around is an ideal case for solar PV installations. In case there is shadow on rooftop, a detailed analysis of time and direction of sunlight needs to be performed

Rooftop type: The load carrying capacity of the roof should be checked. The solar panels with structure typically weigh 15 kg per sq. meter. This weight varies with type structure.

Sizing of solar system: Size of solar system depends on the rooftop area available for panels. This can be calculated by dividing the available area by each panel area and multiplying it by panel's rated output. For estimate purpose, 70% of rooftop area can be used for panel installation.

Site Assessment to install a Solar System

- WHAT TIME DID YOU DO THE SURVEY?
- WHICH MONTH DID YOU DO THE SURVEY?
- ANY TREES NEARBY
- ANY CONSTRUCTIONS NEARBY
- WHICH IS SOUTH?



Solution

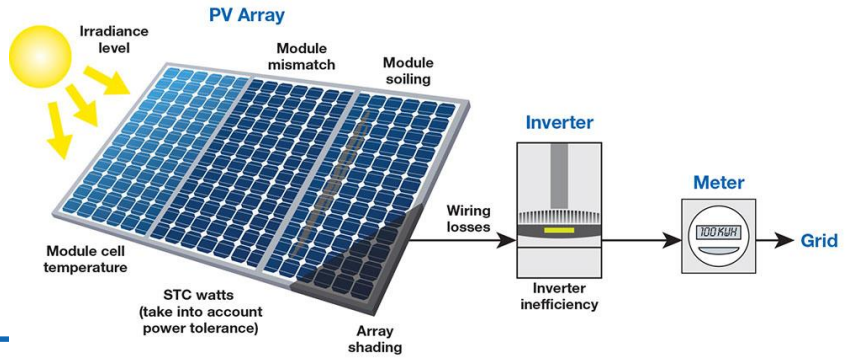
But in reality, this could be a challenge to avoid shadow effect, given the limited space on roof tops.

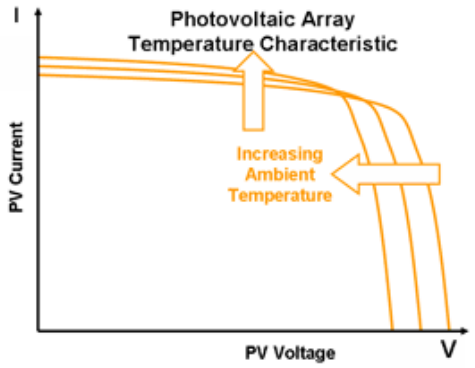
So the only choice we have here is to increase our structure height to avoid the effects of shadows and ensure maximum PV Panel output

Factors effecting performance

For a Solar system to operate at 100% Efficiency, it will have NIL losses. This is not the fact in the real world. There are several unavoidable looses or derating factors.

a. Temperature of the solar module, Higher the heat , lower the output.
b. Dirt or soiling on the surface of the solar module
c. Voltage drop across the array cables and grid cables.
d. Inverter efficiency.
e. Shading
f. Tilt angle of the solar array
g. Orientation of the solar array.
h. Grid downtime /out of operating range.
i. Irradiance losses





Summary of losses in PV system

Causes	Average Expected losses	Remarks
Temperature	8-13%	Depends on ambient and region
Dirt	3-7%	Depends on site and O&M cycle
Module tolerance	0-3%	
Shading	0-5%	Layout dependent
Orientation	0-3%	Layout dependent
Tilt Angle	0-5%	Structural dependent. Constant for roof top
Voltage drop	0-2%	
Inverter	2-4%	

Energy Yield = **Irradiation** X **Module rated Power** X **Losses (As efficiencies)**

We learned that the solar system cannot be 100% efficient. There for all the factors that will Reduce the overall efficiency of the PV system must be calculated for the given plant.

Power from Module 1000W

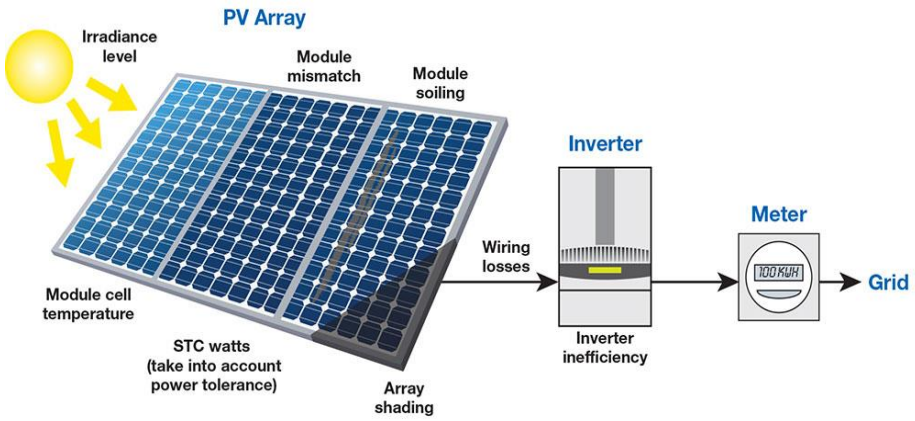
Module Tolerance (3%) 1000 X 97% 970W

Temperature loss (10%) 970W X 90% 873W

Dirt loss (5%) 873W X 95% 846.8W

Voltage drop(2%) 873W X 98% 855.5W

Inverter Losses (6%) 873W X 94% 804W



To arrive at the total efficiencies of the system, Also called the system operating efficiency, All the individual efficiencies are multiplied are multiplied together as above

Additional information

- ✓ Day time connected load must be >= KWp rating
- ✓ Poor grid quality affects the energy generation
- ✓ Cable lengths from array area to feeding point
- ✓ If DG switched on during grid failure, DG rating shall be >1.5 times the solar array capacity and shall be loaded at least 50% with full solar capacity

FAQs

1. **Can Grid tie or grid export PCU work with out Grid supply.**
   No, grid with correct voltage and frequency range is required for proper functioning of Grid Tie Inverter (GTI)
2. **Can I connect a diesel generator to create a grid for GTI to work.**
   We cannot pump power to a generator under normal conditions and doing so will spoil the generator. More over while the GTI pumps power to the generator its frequency and voltage will be unstable which makes the GTI to back off.
3. **How much money do I get if I supply power to the Grid.**
   The rate of buying power from solar power plant is fixed by the state electricity board and depends on state top state, please consult your local electricity supply company.
4. **What if there is shadow in the roof, how much will be the energy loss.**
   Partial shadow will do more harm to the panels than full shadow. There must be shadow free area between 9AM to 3PM for best performance.
5. **What if we already have a inverter with battery at home, should that be removed for installing a GTI.**
   The existing inverter is no way connected to GTI. GTI will stop when grid fails, your existing inverter will start supply of power when the grid fails.
6. **Can the GTI be synched to an inverter.**
   No , GTI cannot feed power to an inverter al all.

7. **Which season of the year we get more power from the panels?**
   Solar panel output depends on temperature and radiation. Ideally low temperature with clear sky produces better output than summer where the heat is more.
8. **Should the grid tie inverter (GTI) be operated every day?**
   No, the GTI will turn On when the solar panels produce power and turn OFF in the evening when the sun sets. No manual operation is required.
9. **What should be done when we are not at home for many days ? Should the GTI be disconnected and turned OFF.**
   No. The unit will export all the power produced when there is no load in the house.
10. **How much power will the GTI consume during night?**
    There will be 4-5 W consumption during night as the GTI will work only during day when the solar power is available.
11. **What are the regular maintenance required.**
    a. Clean the solar modules regularly depending on the dust accumulation on the panels.
    b. Wipe any dust accumulation on the GTI, do not use wet cloth.
    c. Ensure electrical connections are secure and checked once in six months.
    d. Allow adequate air flow around the GTI so that it is cool.

On-site Risk Assessment

Prior to Starting any on-site work it is recommended that the installer undertake an on-site risk Assessment

1. **Identify all possible risks, ---Name a few…..**
2. **How have you eliminated the risks and how have you communicated it to your team ….**
3. **What risks cannot be removed but we have a mitigation…..**

What could be the risks???

1. **Falling from roof when installing the PV modules**
2. **Potential electric shock when the solar array is wired in series creating a voltage that reaches deadly 1000Vdc .**
3. **Working on AC mains grid.**
4. **Injuries from lifting and installing heavy inverters**
5. **Injuries from falling objects from roof or high location**

Use of PPE…..

- Wear Helmets .
- Wear Goggles.
- Wear safety Shoes
- Wear Gloves

USE RIGHT PPE FOR YOUR JOB

Let’s List out the jobs we do and the PPE……..

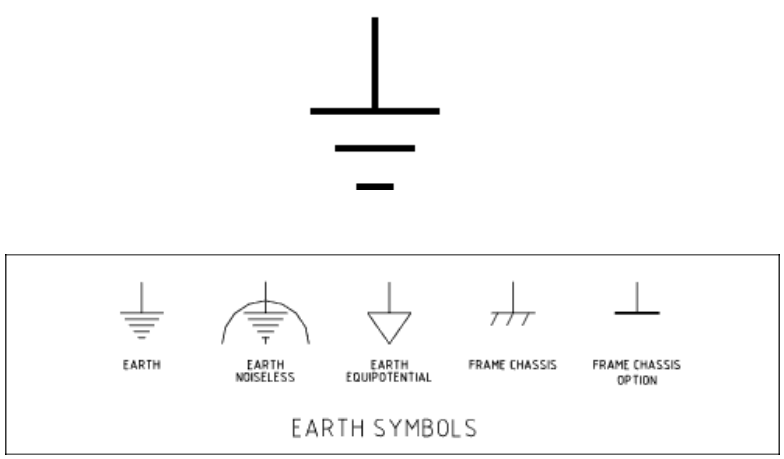
Safety related to individual PV system Components

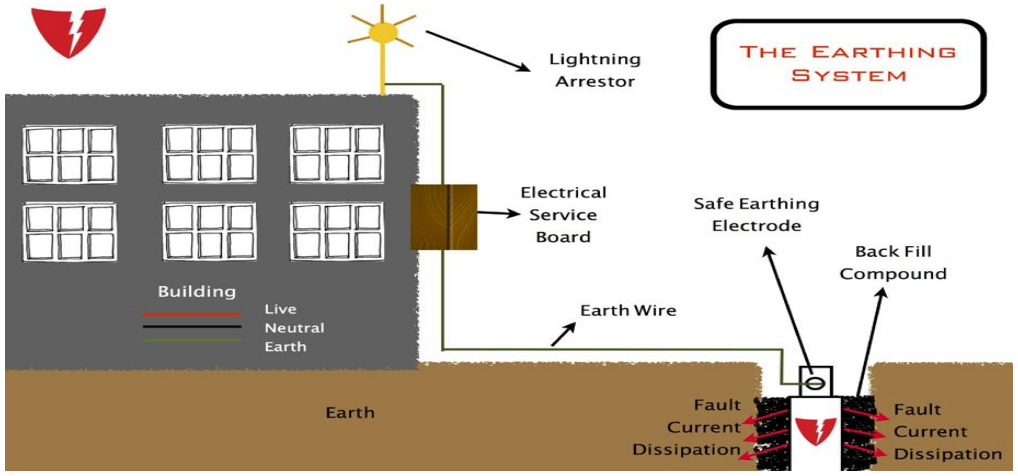
- You are your best safety guide, be alert , check everything and work carefully….
- Study and understand what system you will be working on
- Review the safety procedure, installation procedure, connection/disconnection procedure with everyone in the team.
- Make sure your tools and test and measurement equipments are in proper working condition.
- Wear appropriate PPE, like Safety helmet and eye goggles before commencing work.
- Remember to remove all jewellery that can come in contact with live wires, DC voltage can produce significant arc and high voltage can give you very painful electric shock.
- Dry insulating glows should be worn when working on grid and high voltage DC.
- Measure everything that will ascertain safety, leakage to ground and in junction boxes.
- Expect the unexpected, do not assume anything, measurement only will provide you with facts.

Earthing

- Earthing is the process of creating an alternative path for the flow of fault/excessive currents safely into the ground in the presence of minimal resistance or impedance.
- Earthing is to reduce the risk of serious electric shock from current leaking into uninsulated metal parts of an appliance, power tool, or other electrical devices
- Earthing also provides protection from large electrical disturbances like lightning strikes and power surges. It also aids in the dissipation of hazardous static electrical charges.

Most electrical systems have fuses or circuit breakers for protection against a fault current, the human body may be fatally electrocuted by a current of less than one ampere which is well below the point at which a fuse or breaker will operate. Earthing helps minimize such hazards from occurring.





Safety related to individual PV system Components

PV Modules:

- PV modules produce electricity and should be considered electrically live, as long as light falls on them .
- When many panels are connected in series they produce very high Voltage as in case of most grid connect PV system.
- The aluminum frame of the PV module can become very hot, when exposed to sun light, care must be taken while handling.
- PV array is often mounted on roof top and care must be taken while lifting and fixing on high structures and ladders and scaffolding must be used to prevent a fall.

Safety related to individual PV system Components

Inverter

- Higher the power , more is the weight of the inverter.
  1KW- 6 kg
  2KW- 12 kg
  3KW- 12.5 kg
  5KW-21 kg
  30KW – 40 kg
  50KW – 60 kg
  60KW – 70 kg
  80kW – 75 kg

- Care must be taken while carrying the Inverter. Please ensure the inverter is properly mounted and the mounting can safely take the weight

- Output of the inverter is normally connected to the grid via a circuit beaker, Care must be taken to ensure the user is not exposed to live wires.