Complete Solar Energy Masterclass For Electrical

COMPLETE SOLAR ENERGY

COURSE FOR ELECTRICAL

ENGINEERING

By Engineer Ahmed Mahdy

COURSE CONTENT

• Comparison between renewable and non renewable sources of energy.

• Comparison between their pros and cons.

• Difference between solar cell, module, string and array.

• Effect of insolation and temperature on v-i curve.

• Advantages and disadvantages of PV systems.

• PV system construction.

• PV cell construction and principle of operation.

• Effect of PV cells connection in series or parallel or combination.

• Types of photovoltaic cells.

• Construction of grid-tied system, its equipment's’ and advantages.

• Construction of off grid system, its equipment's’ and advantages.

• Construction of hybrid system, its equipment's’ and advantages.

• Construction and types of batteries.

- Charging batteries for first time and maintenance.
- Methods of charging battery and cycle of battery.
- Charge controller in PV system.
- Junction box and its wiring.
- Mounting of PV system.
- Tracking in PV system.
- Tilt Angle and shading analysis.
- Selection of panel.

COURSE CONTENT

- Selection of inverter.
- Determining PV array maximum voltage.
- PV energy according to Area.
- Off grid system design.
- On grid system design.
- Grounding in PV system.
- Protection of PV system.
- Types and selection of busbars in PV system.

RENEWABLE ENERGY

• Renewable energy is the energy which is generated from natural sources i.e. sun, wind, rain, tides.

• They can be generated again and again as and when required.

• They are the cleanest sources of energy available on this planet.

• For e.g.: energy that we receive from the sun can be used to generate electricity.

• Similarly, energy from wind, geothermal, biomass from plants, tides can be used to fulfil our daily energy demands.

NON-RENEWABLE ENERGY

• Non-Renewable energy is the energy which is taken from the sources that are available on the earth in limited quantity.

• They wil vanish fifty-sixty years from now.

• Non-renewable sources are not environmental friendly and can have serious effect on our health.

• They are called non-renewable because they cannot be re-generated within a short span of time.

• Non-renewable sources exist in the form of fossil fuels, natural gas, oil and coal.

PROS OF RENEWABLE ENERGY

• The sun, wind, geothermal, ocean energy are available in the abundant quantity and free to use.

• The non-renewable sources of energy that we are using are limited and wil expire one day.

• Renewable sources are green and environment friendly.

• Renewable helps in creating job opportunities, the money that is used to build these plants can provide jobs to thousands to mil ions of people.

• You don’t have to rely on any third country for the supply of renewable sources as in case of non-renewable sources.

• Renewable sources can cost less than consuming the local electrical supply.

• In the long run, renewable sources can cut your electricity bil s.

CONS OF RENEWABLE ENERGY

• Initial costs are quite high.

• Solar energy can be used during the day time and not during night or rainy season.

• Geothermal energy can bring toxic chemicals beneath the earth surface onto the top and can create environmental changes.

• Hydroelectric building dams across the river which is quite expensive can affect wildlife.

• To use wind energy, you have to rely on strong winds therefore you have to choose suitable site to operate them.

• Wind turbines can affect bird population as they are quite high.

PROS OF NON-RENEWABLE

ENERGY

• Non-renewable sources are cheap and easy to use.

• You can easily fil up your car tank and power your motor vehicle.

• You can use small amount of nuclear energy to produce large amount of power.

• Non-renewable have little or no competition at all.

• They are considered as cheap when converting from one type of energy to another.

CONS OF NON RENEWABLE

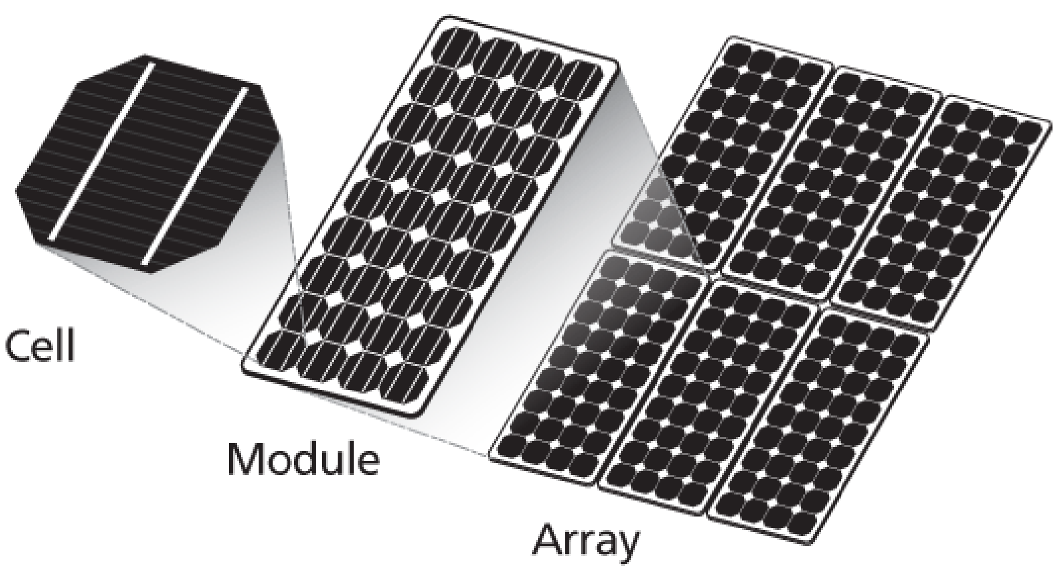
ENERGY

• Non-renewable sources wil expire some day and we have to us our endangered resources to create more non-renewable sources of energy.

• The speed at which such resources are being utilized can have serious environmental changes.

• Non-renewable sources release toxic gases in the air when burnt which are the major cause for global warming.

• Since these sources are going to expire soon



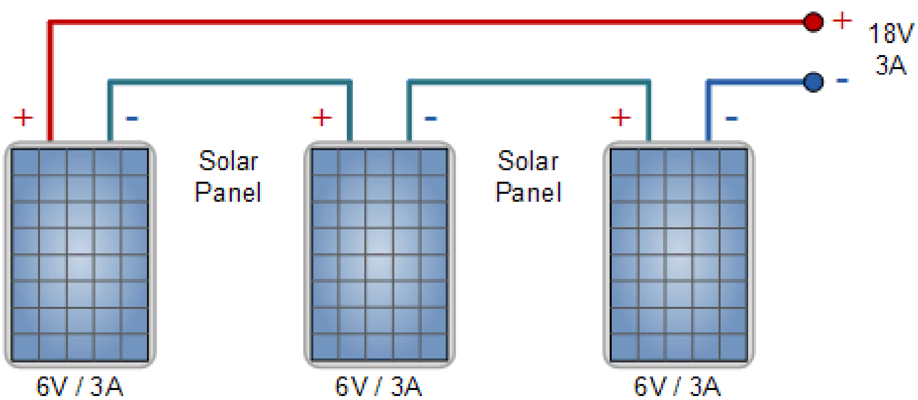
SOLAR CELLS , MODULES

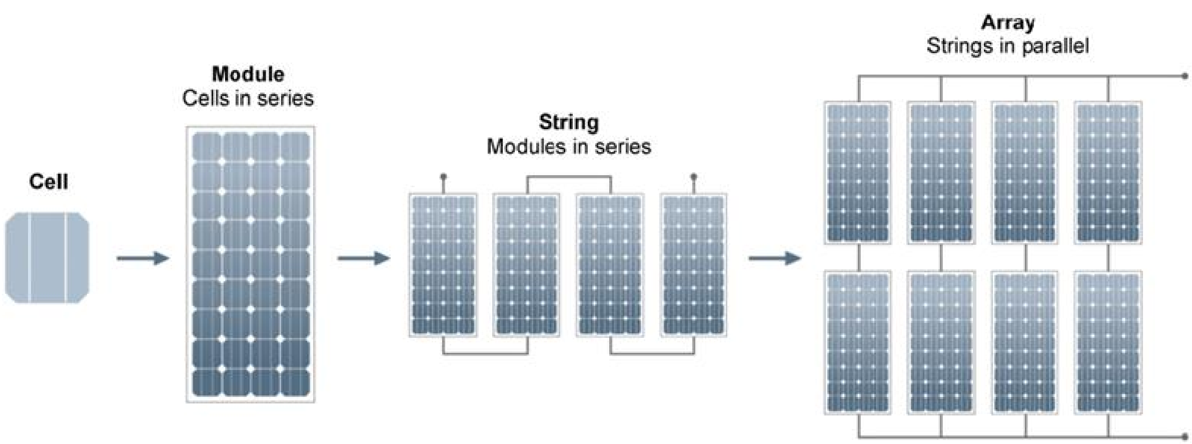
AND ARRAYS

• A **solar cell**, or photovoltaic **cell**, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect.

• A photovoltaic module is a packaged, connect assembly of typical y 6x10 photovoltaic solar cells.

• Modules are wired in series and parallel into what is cal ed a PV Array.





SOLAR CELL, ARRAY AND

STRING

Solar cell is the smallest unit which converts the solar energy into electrical energy.

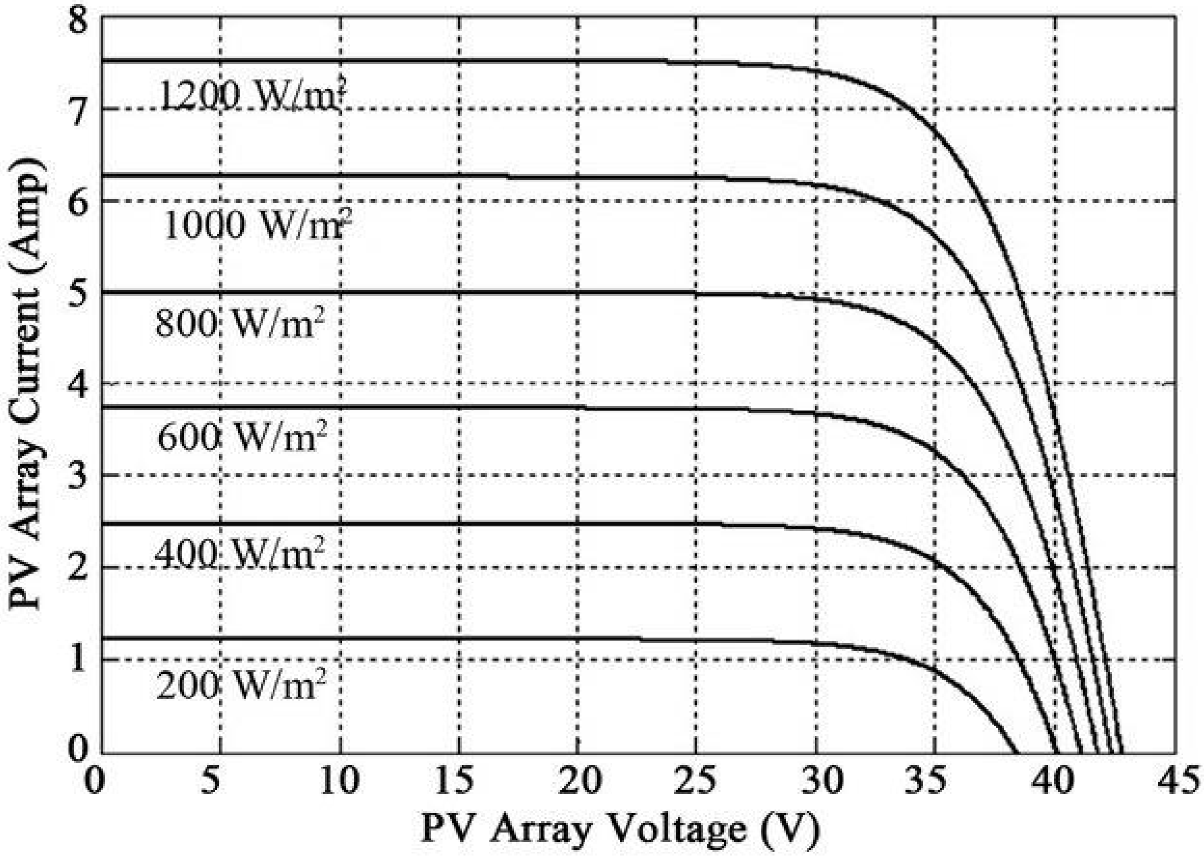
Group of cells form module.

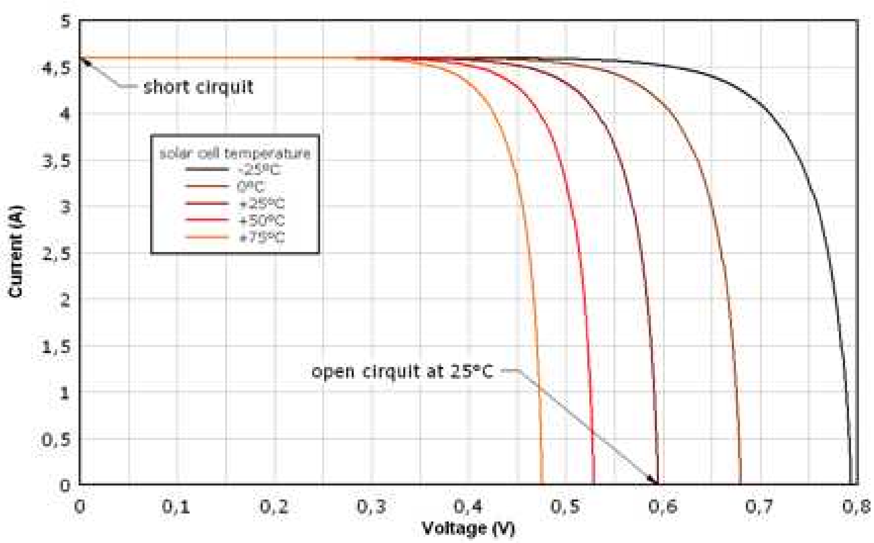
Group of modules in series form a string.

Group of modules in parallel form an array.

0.5 To 0.9

volt


1200 W/m2
1000 W/m2
800 W/m2
600 W/m2
400 W/m2
200 W/m2
PV Array Current (Amp)
PV Array Voltage (V)


short cirquit
solar cell temperature
-25ºC
0ºC
+25ºC
+50ºC
+75ºC
open cirquit at 25°C
Current (A)
Voltage (V)

EFFECT OF INSOLATION AND

TEMPERATURE ON V-I CURVE

Solar irradiance (SI) is the power per unit area received from the Sun in the form of electromagnetic radiation .

As temperature increases, the voltage decreases and current nearly remains constant.

As insolation increases, the voltage increases with small value but current increases rapidly so power generated increases.

ADVANTAGES OF PV

SYSTEMS

• It provides green energy.

• Free and available energy.

• Can be used locally which reduces losses.

• Operation and maintenance costs are low.

• PV is silent (No Noise).

• PV has no mechanical parts.

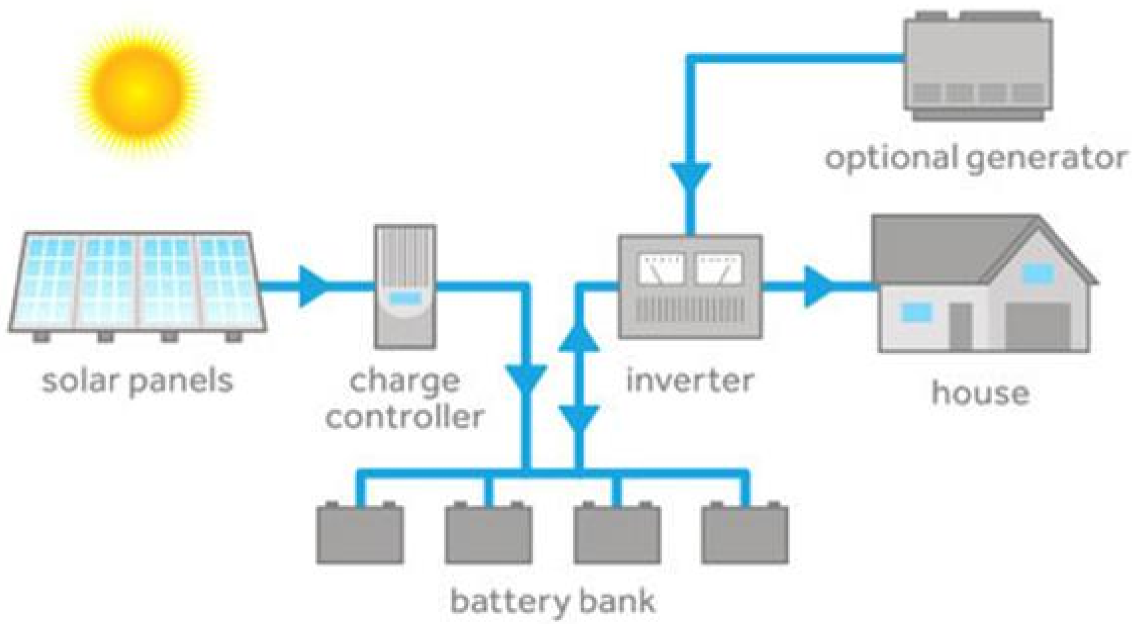
• Easy to install.

• Used in spacecraft applications.

DISADVANTAGES OF PV

SYSTEMS

- No power at night or during cloudy or rainy weather.
- It requires additional equipment as inverters and batteries.
- Low efficiency 15 to 18%.
- Needs continuous cleaning.
- For high power, PV requires large area which is difficult inside cities.

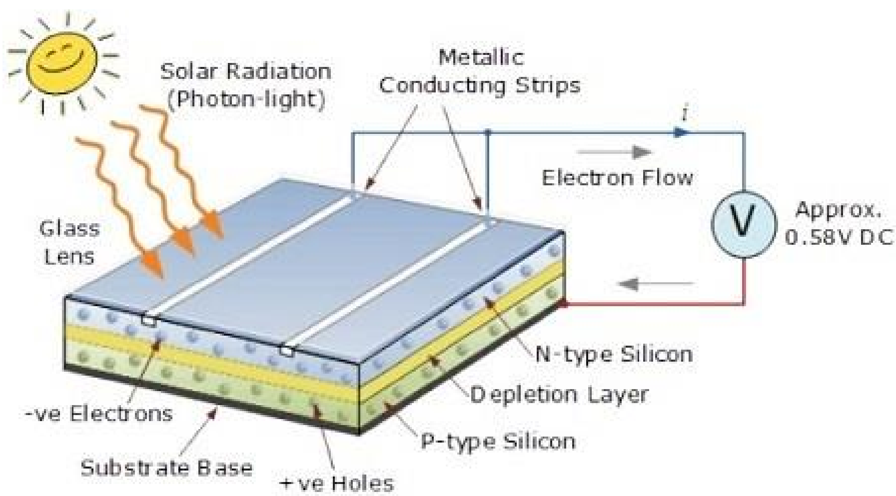


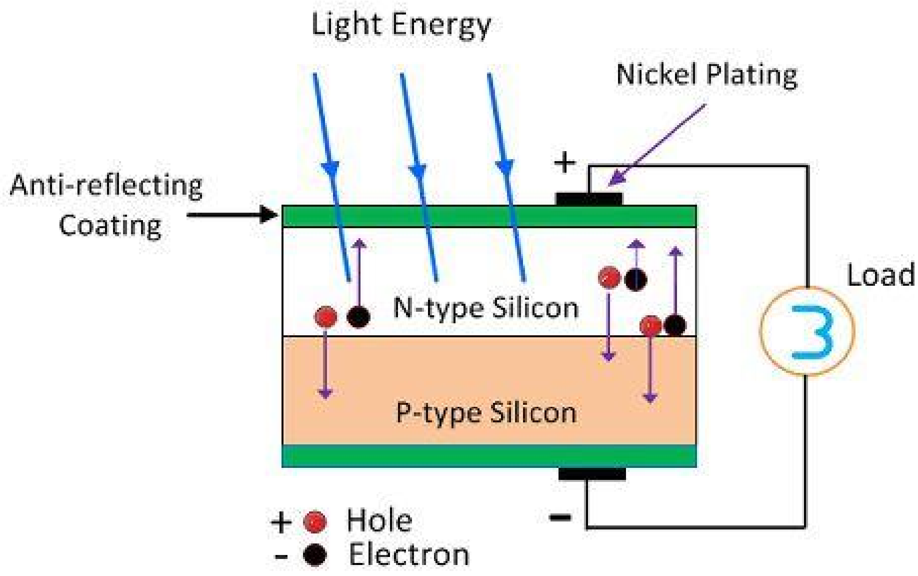
PV SYSTEM CONSTRUCTION

• A simple pv system as shown is consisting of : 1. Solar panels which converts sunlight to DC electricity.

2. Battery banks are charged by the charge control er which is supplied from solar panels.

3. Inverter converts DC power to AC power to be used for utilization at home.





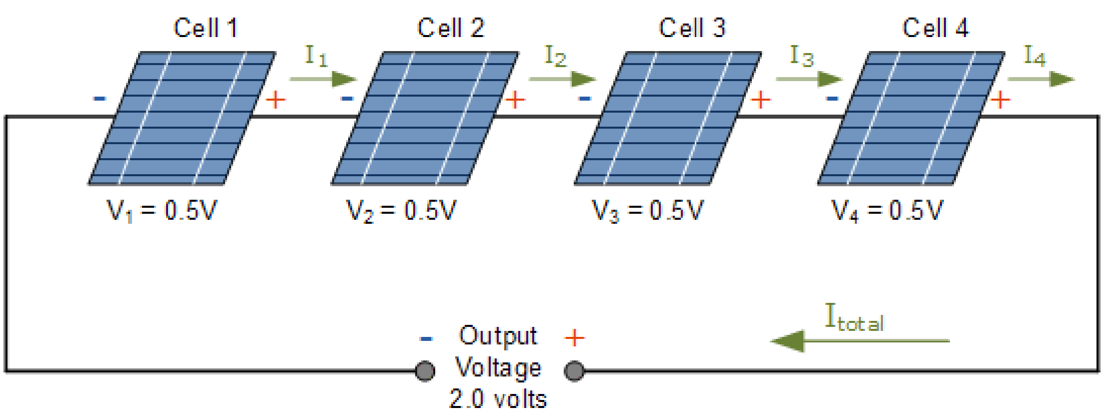
CONSTRUCTION OF PV

CELLS

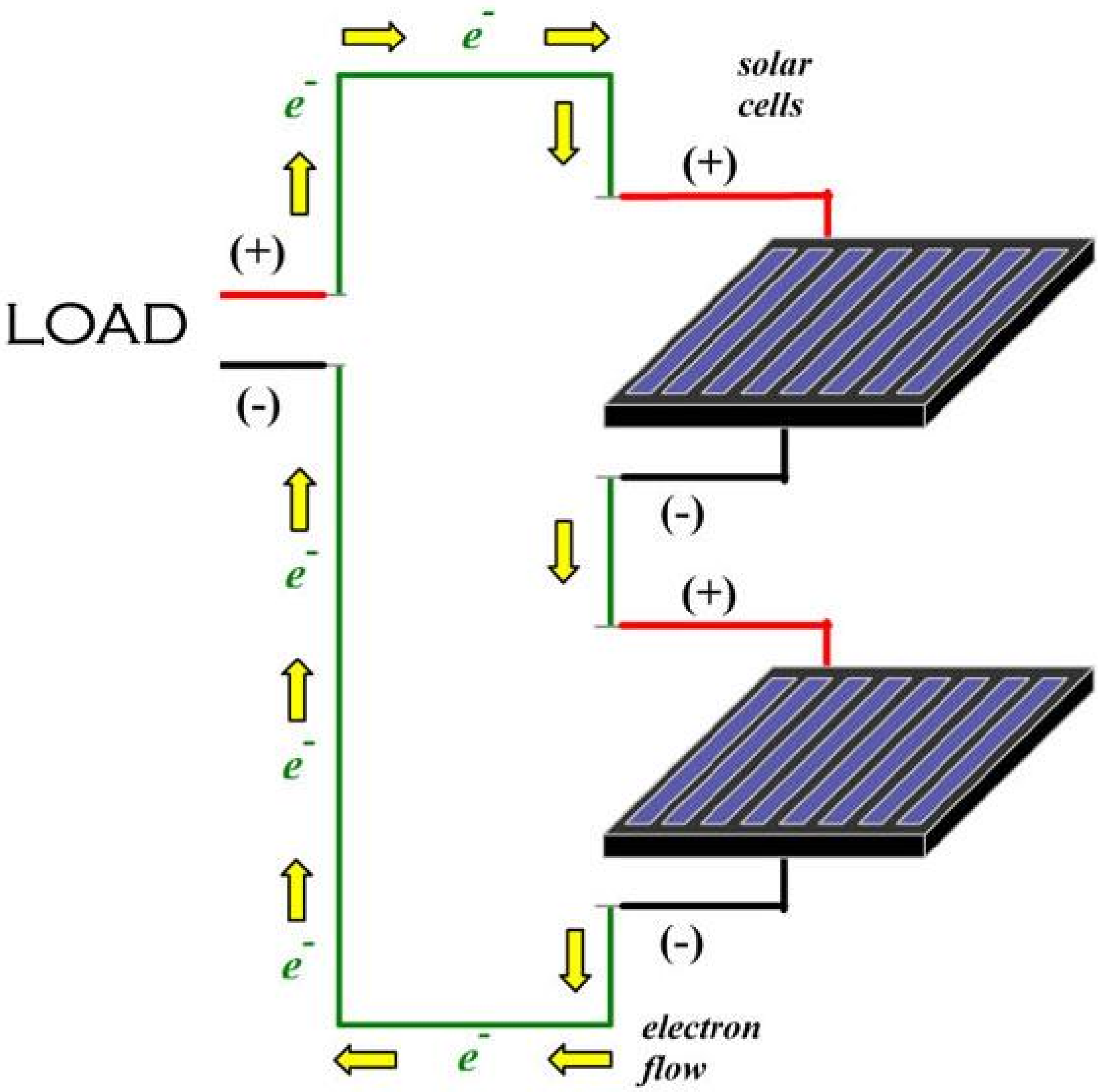
• N-Type silicon has excess amount of electrons but P-type has excess amount of holes

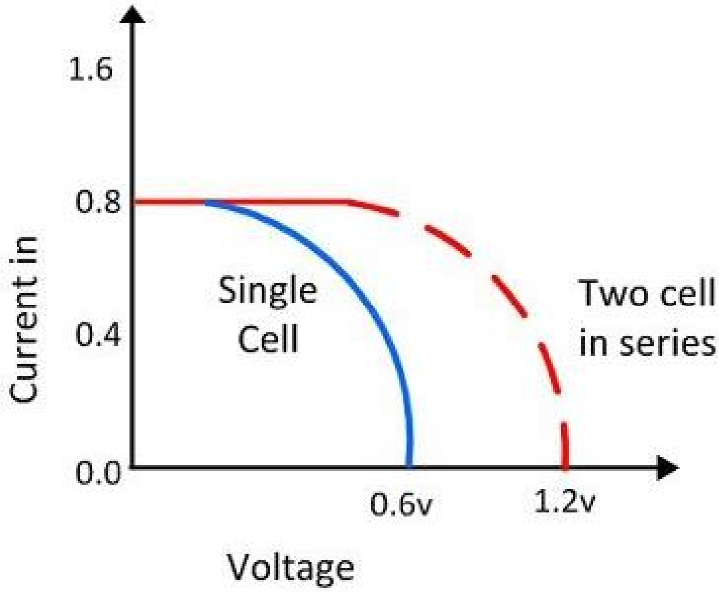
• When light fal s on N-Type, the electrons gain amount of energy enough to move from N-type to P-Type.

• Electrons go from N-Type to P-Type to fil the holes which causes flow of current.



Solar Cells in Series



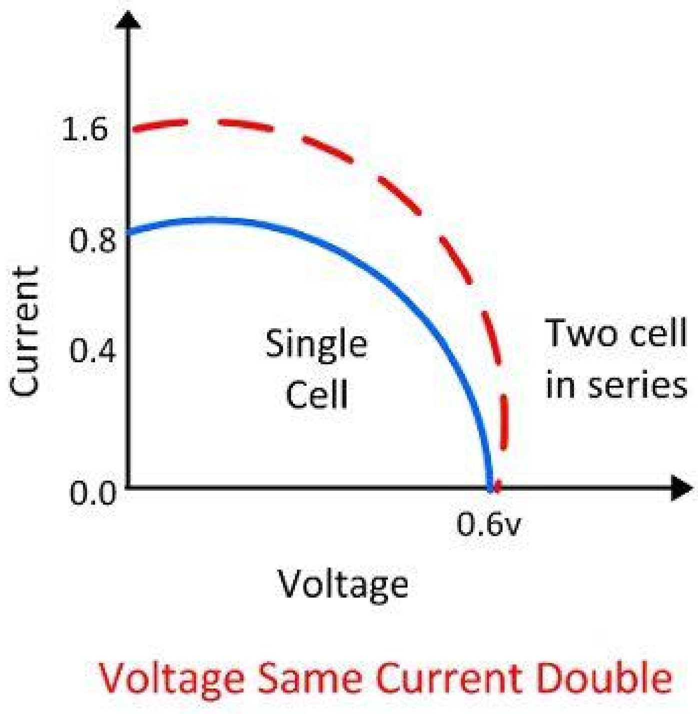


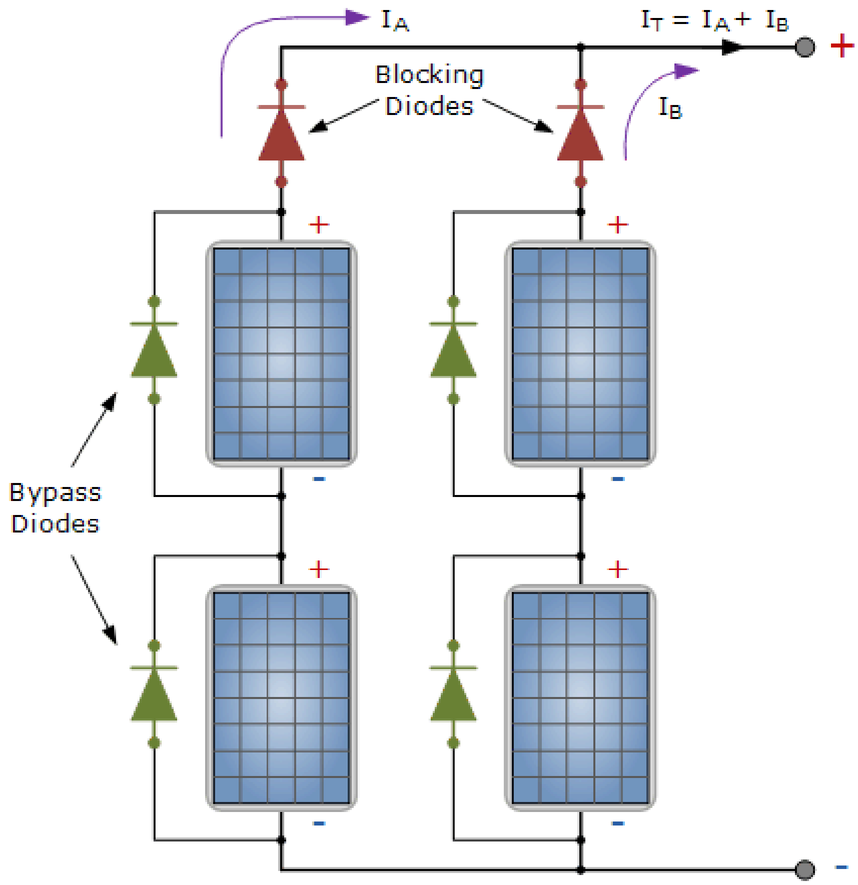
Current Same Voltage Double

PV CELLS IN SERIES

• Connection of PV cells in series is similar to connection dc voltage supplies in series, which increases the total voltage but having the same current.

• Same case here for PV cells, connection in series increases the total voltage required according to design.



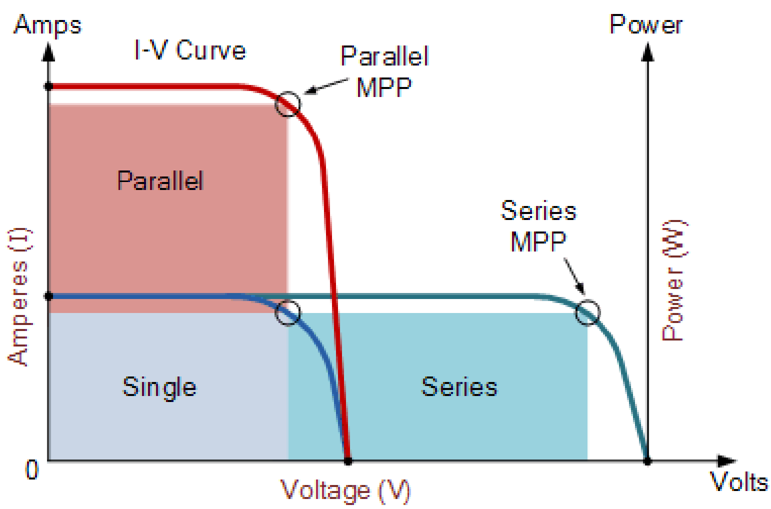


I_A
$I_T = I_A + I_B$
+
Blocking
Diodes
I_B
+
-
+
-
Bypass
Diodes
+
-
+
-
-

PV CELLS IN PARALLEL

• Connection of PV cells in parallel is similar to connection dc voltage supplies in parallel, which increases the total current but having the same voltage.

• Same case here for PV cells, connection in parallel increases the total current required according to design.



EFFECT OF SERIES AND

PARALLEL ON V-I CURVE

• Combination of parallel and series cells or modules or strings wil give us the required voltage and current in design.

TYPES OF SOLAR

PHOTOVOLTAIC CELLS

• Solar panels convert energy from the sun into the electricity we use in our homes, to power the lights on our streets, and the machinery in our industries.

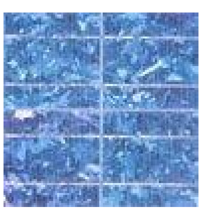
• Types of solar photovoltaic (PV) cells are as following:

• ***Monocrystalline silicon solar panels***

• ***Polycrystalline (or multi-crystalline) solar panels***

• ***Amorphous/thin film solar panels***

• ***Hybrid silicon solar panels***



MONOCRYSTALLINE

SILICON SOLAR PANELS

• One of the most effective of the solar PV cells with 15%

efficiency*

• Monocrystalline silicon is one of the expensive options.

• They require less space than other cells simply because they produce more energy and can yield up to four times more power than thin-film solar panels.

• They also last longer than other panels and perform better at low light.

• The main disadvantage is the cost which often means that it’s not the first choice for home owners.

• It can also be effected by dirt or shade, which can break the circuit.

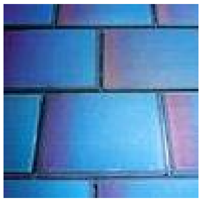
POLYCRYSTALLINE (OR MULTI-

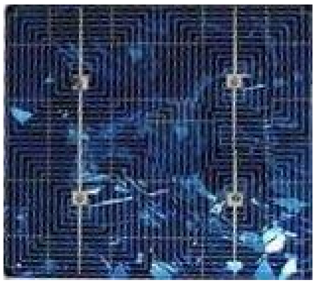
CRYSTALLINE) SOLAR PANELS

• With an efficiency of 13%, polycrystalline solar panels are often seen as a better economic choice, particularly for home owners.

• They are made from a number of smaller silicon crystals that are melted together and then recrystallized

• The main disadvantage for polycrystal ine solar panels is that you need more of them because of the lower energy conversion efficiency.





AMORPHOUS/THIN FILM

SOLAR PANELS

• At 7%, thin film solar panels are among the least efficient on the market but they are the cheapest option.

• They work well in low light, even moonlight, and are made from non-crystal ine silicone.

• The main advantage is that it can be mass produced at a much cheaper cost but is more suitable for situations where space is not a big issue.

• The main disadvantage for thin film solar panels are not generally used for residential purposes and wil degrade quicker than crystalline cells.

HYBRID SILICON SOLAR

PANELS

• With an efficiency of 18%, hybrid solar panels are made from a mix of amorphous and monocrystalline cells to generate maximum efficiency.

• There are a variety of types of hybrid cells and they are stil very much at the research and development stage which is why they are currently a more expensive option.

SUMMARY

• ***Monocrystalline silicon***

• Typical efficiency 15%. One of the most effective **PV**

cells currently available on the market

• ***Polycrystalline (or multicrystalline) silicon***

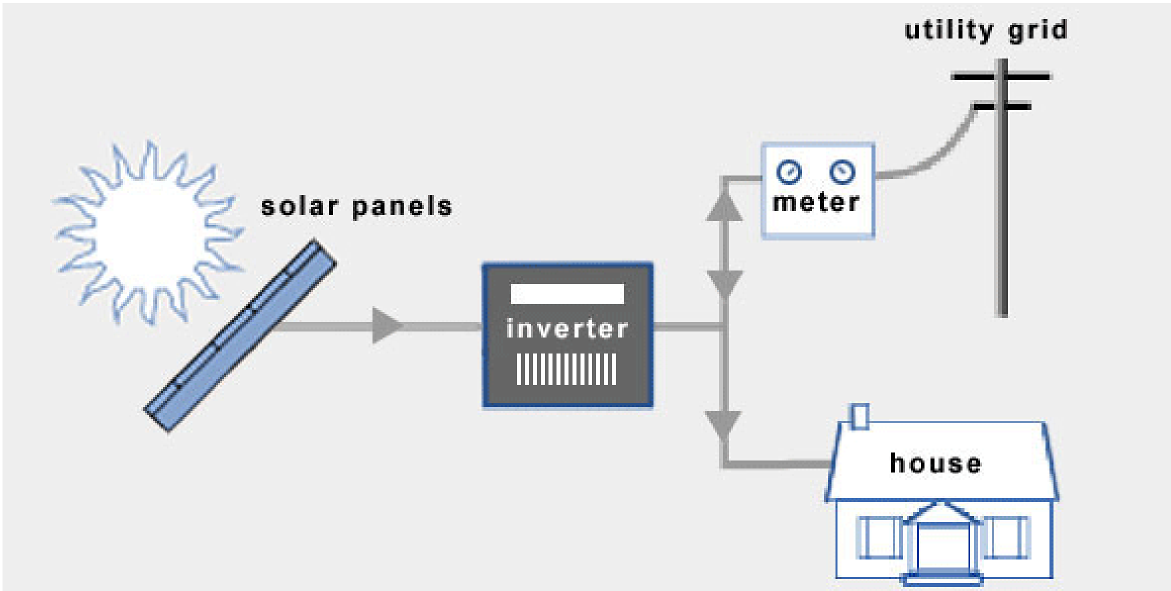
• Typical efficiency 13%. Although cheaper to produce and slightly less efficient than monocrystal ine cells.

• ***Amorphous/thin film silicon***

• Typical efficiency 7%. One of the least efficient cell types on the market, and consequently the cheapest.

• ***Hybrid silicon***

• Typical efficiency 18%. The most expensive PV cell type available on the market, but also the most efficient.



GRID-TIED SOLAR SYSTEMS

• Grid-tied or on-grid are all terms used to describe the same concept – a solar system that is connected to the utility power grid.

• This type of system supplies power to grid and take power required for the load from the grid and PV cells, the difference is defined by the meter which identifies whether you are going to pay or take money from the government.

Advantages of Grid-Tied Systems

• Save more money with net metering through better efficiency rates, net metering, plus lower equipment and installation costs

• Batteries, and other stand-alone equipment, are required for a fully functional off-grid solar system and add to costs as well as maintenance. Grid-tied solar systems are therefore generally cheaper and simpler to install.

• With net metering, homeowners can put this excess electricity onto the utility grid instead of storing it themselves with batteries.

• Many utility companies are committed to buying electricity from homeowners at the same rate as they sell it themselves.

• The utility grid is a virtual battery, more electricity (and more money) goes to waste with conventional battery systems.

EQUIPMENT FOR GRID-TIED SOLAR

SYSTEMS

1-Grid-Tie Inverter (GTI)

They regulate the voltage and current received from your solar panels.

Direct current (DC) from your solar panels is converted into alternating current (AC), which is the type of current that is utilized by the majority of electrical appliances.

In addition to this, grid-tie inverters synchronize the phase and frequency of the current to fit the utility grid (nominal y 60Hz).

2-Micro-Inverters

Micro-inverters go on the back of each solar panel.

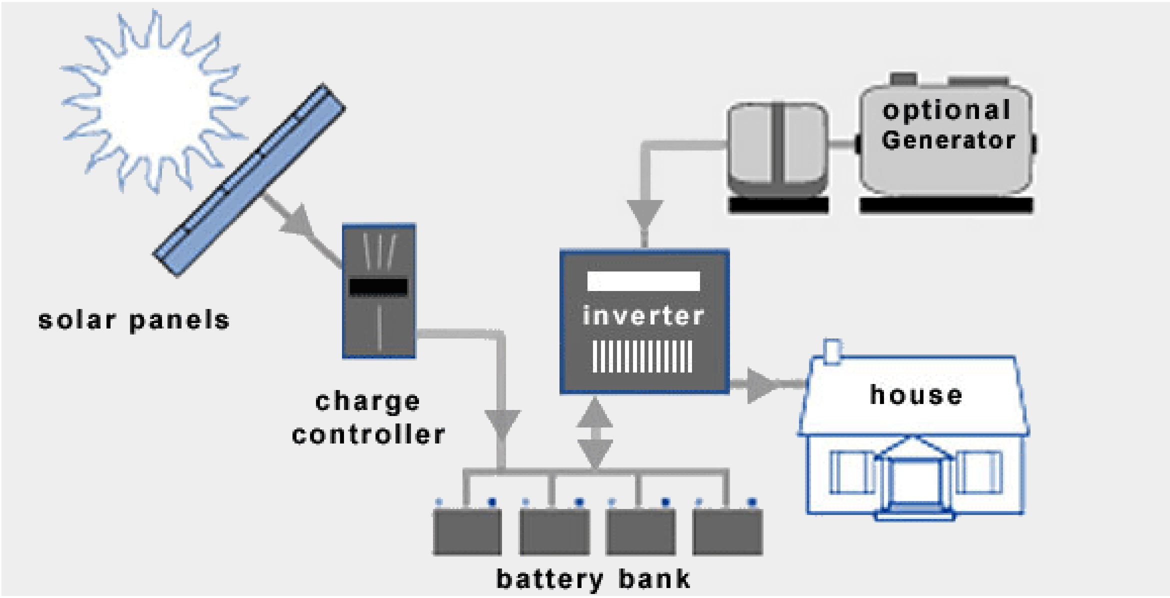
This is opposed to one central inverter that typical y takes on the entire solar array.

• Micro-inverters are certainly more expensive, but in many cases yield higher efficiency rates.

3-Power Meter

• Most homeowners wil need to replace their current power meter with one that is compatible with net metering.

• This device, often cal ed a net meter or a two-way meter, is capable of measuring power going in both directions, from the grid to your house and vice versa.



OFF-GRID SOLAR SYSTEMS

• An off-grid solar system (off-the-grid, standalone) is system which depends only on solar panels and does not have any connection with grid.

• Off-grid solar systems require battery storage and a backup generator (if you live off-the-grid) to supply power when sun is not available.

• On top of this, a battery bank typical y needs to be replaced after 10 years. Batteries are complicated, expensive and decrease overall system efficiency.

ADVANTAGES OF OFF-GRID

SOLAR SYSTEMS

1. No access to the utility grid

Off-grid solar systems can be cheaper than extending power lines in certain remote areas.

2. Become energy self-sufficient

• Living off the grid and being self-sufficient feels good.

• Power failures on the utility grid do not affect off-grid solar systems.

• On the flip side, batteries can only store a certain amount of energy and expensive.

EQUIPMENT FOR OFF-GRID

SOLAR SYSTEMS

1- Solar Charge Controller

• Charge regulators or battery regulators limit the rate of current being delivered to the battery bank and protect the batteries from overcharging.

• Good charge control ers are crucial for keeping the batteries healthy and increase their lifetime.

2- Battery Bank

• A battery bank is essentially a group of batteries wired together to store electrical energy before sunset.

3- DC Disconnect Switch

• AC and DC safety disconnects are required for all solar systems.

• This is important for maintenance, troubleshooting and protection against electrical fires.

4-Off-Grid Inverter

• Used to convert DC to AC for all other electrical appliances.

• Off-grid inverters do not need to match with grid as they are not connected to it.

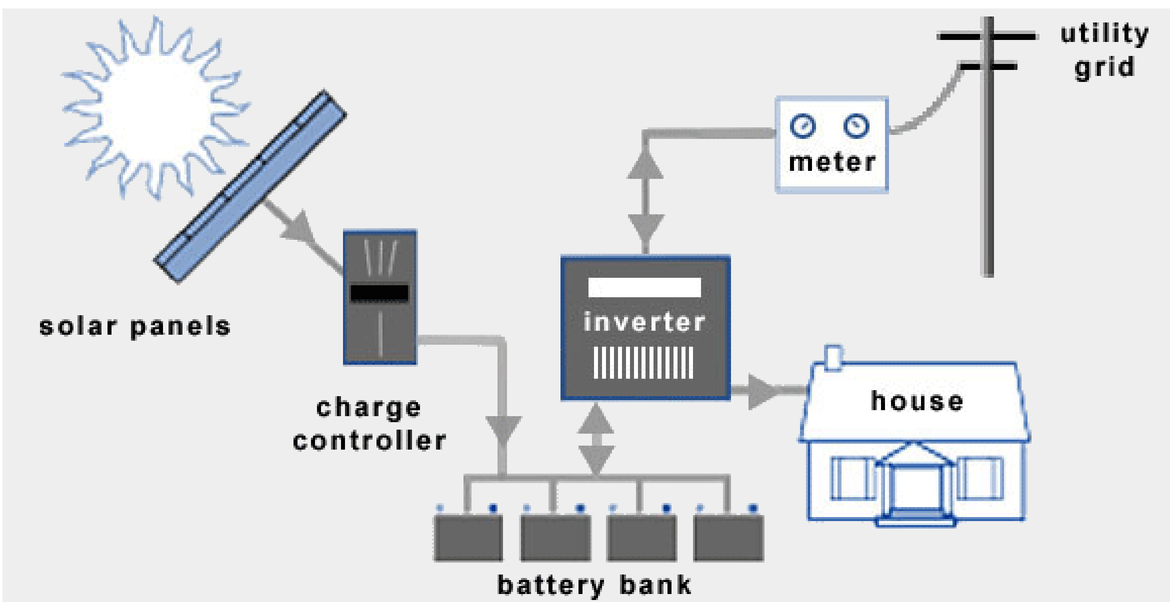
• Electrical current flows from the solar panels through the solar charge controller and the bank battery bank before it is finally converted into AC by the off-grid-inverter.

5-Backup Generator

• It takes a lot of money and big batteries to prepare for several consecutive days without the sun shining (or access to the grid), in this case we wil need a backup generator.

• In most cases, installing a backup generator that runs on diesel is a better choice than investing in an oversized battery bank that seldom gets to operate at it`s full potential.

• Backup generators typically output AC, which can be sent through the inverter for direct use, or it can be converted into DC for battery storage.



HYBRID SOLAR SYSTEMS

• Hybrid solar systems combines the best from grid-tied and off-grid solar systems. These systems can either be described as off-grid solar with utility backup power, or grid-tied solar with extra battery storage, this battery storage helps to prevent taking power from grid during peak hours and saving money.

ADVANTAGES OF HYBRID SOLAR

SYSTEMS

1. Less expensive than off-gird solar systems

• Hybrid solar systems are less expensive than off-grid solar systems.

• You don`t really need a backup generator, and the capacity of your battery bank can be downsized.

2. Solar panels happen to output the most electrical power at noon – not long before the price of electricity peaks. Your home and electrical vehicle can be programmed to consume power during off-peak hours (or from your solar panels).

• You can temporarily store whatever excess electricity your solar panels in batteries, and put it on the utility grid when you are paid the most for every kWh.

EQUIPMENT FOR HYBRID

SOLAR SYSTEMS

• Charge Controller

• Battery Bank

• DC Disconnect (additional)

• Battery-Based Grid-Tie Inverter

• Power Meter

Battery-Based Grid-Tie Inverter

• Hybrid solar systems utilize battery-based grid-tie inverters.

• These devices combine can draw electrical power to and from battery banks, as well as synchronize with the utility grid.

CONSTRUCTION AND TYPES

OF BATTERIES USED

Second Generation Batteries

• Lead acid batteries: The world's most recycled product.

• Used in the fol owing applications: Automotive and traction applications.

Standby/Back-up/Emergency power for electrical installations.

Submarines

UPS (Uninterruptible Power Supplies) Lighting

High current drain applications.

Sealed battery types available for use in portable equipment.


Maintenance-Free Battery
HI-POWER
75Ah - 12V


Trojan
31-GEL
DEEP-CYCLE GEL
12 VOLT
Pb

CONSTRUCTION

AND TYPES OF

BATTERIES USED

• Gel ed battery:

Gel batteries are best used in VERY DEEP

cycle application and may last a bit longer in hot weather applications.

Used in wheelchair and medical mobility batteries.

• AGM(absorber glass mat) battery:

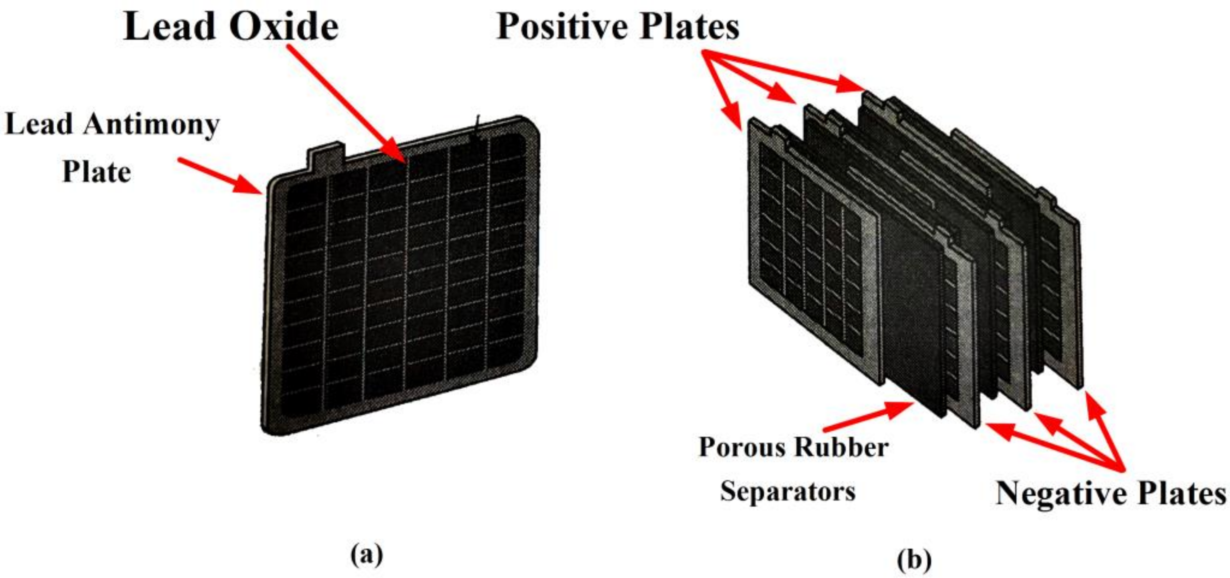
Used as boat batteries and motorcycle batteries.

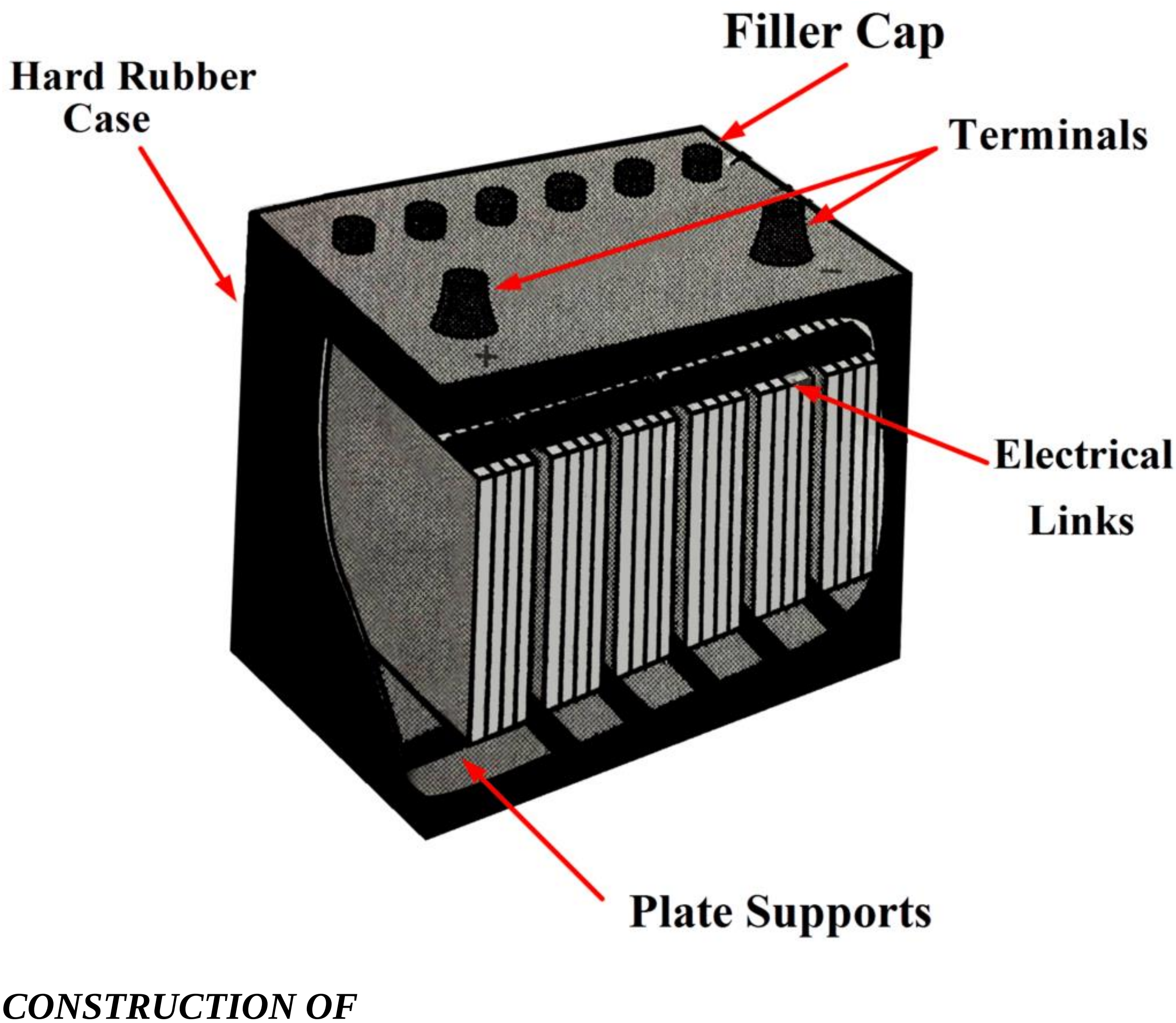
• Hybrid car battery:

Used in case of car using electric and mechanical motors.

• Alkaline battery:

They are most commonly **rechargeable household batteries**.





CONSTRUCTION OF

LEAD ACID BATTERY

• **Plates.**

• **Rubber Case.**

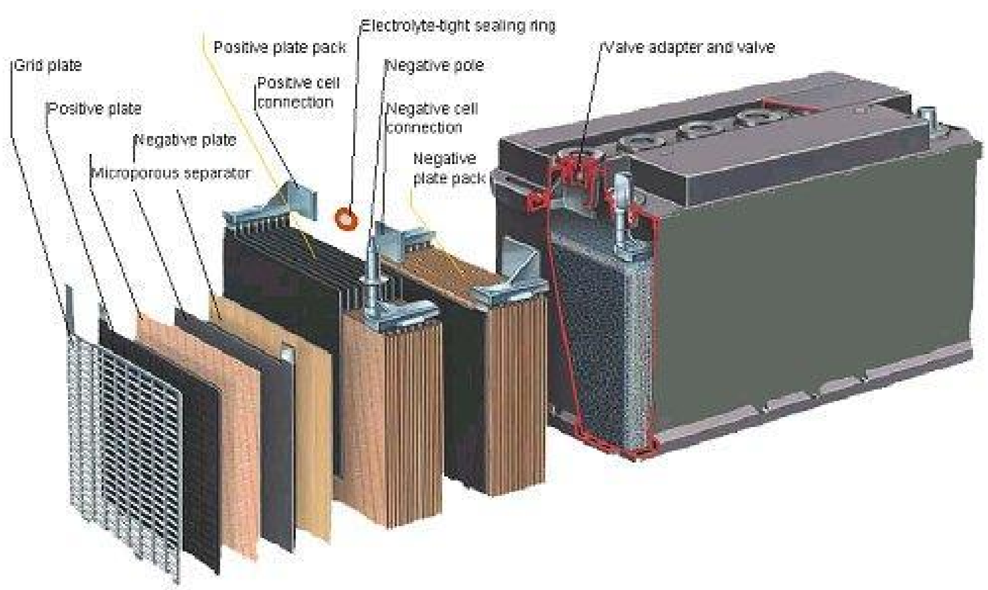
• **Filler Cap:**

Provide access for adding electrolyte Holes allow gases to be vented to the atmosphere.

• **Electrical Links**: connect cells to withstand heavy current.

• Electrolyte formed of H_2SO_4 with water, nearly up to 40%

H_2SO_4, rest is regular water.



CONSTRUCTION OF LEAD

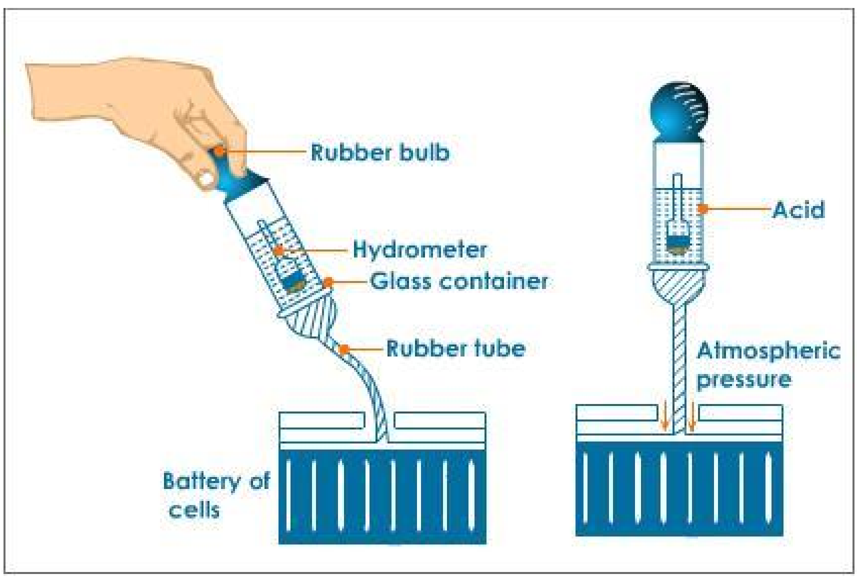
ACID BATTERY

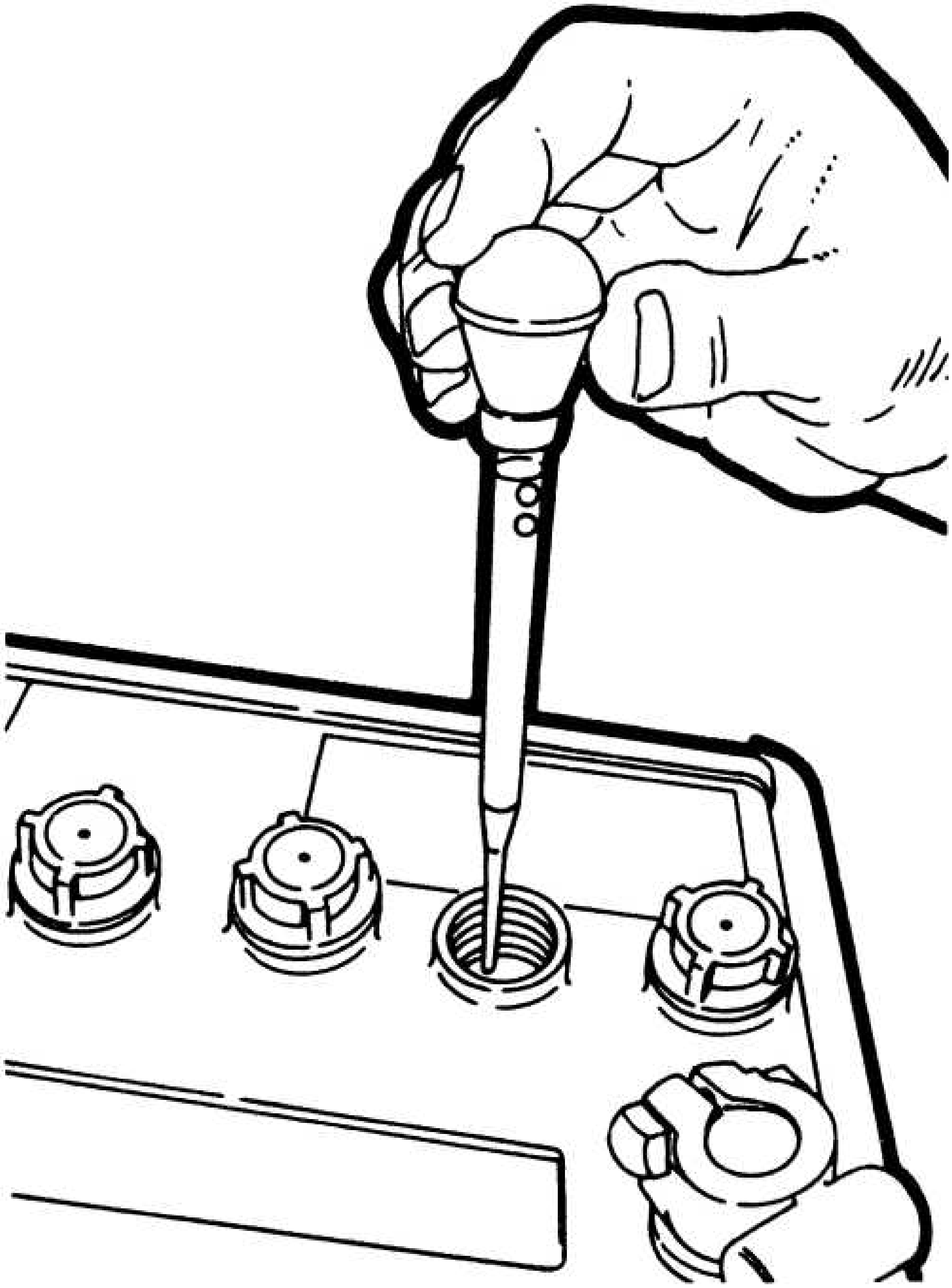
• Each cell or plate gives 2 volt.

• For 24 volt, we wil need 12 plates.

• Al +ve connected together and –ve are also connected together.

• We wil final y have one +ve and one –ve terminal.





CHARGING OF LEAD ACID

BATTERY

• After fil ing with H2SO4, we charge them.

• +ve terminal is with +ve of charger, -ve is with –ve of charger.

• Charge battery with voltage higher than battery voltage but not too high.

• Example : 14.5 volt for 12 volt battery.

• Use Hydrometer to know how much battery is charged.

• Table in next page provides the values obtained from hydrometer and their corresponding meaning.

State of Charge (S.O.C.)	Open Circuit Voltage (O.C.V.)			
	2V	6V	8V	12V
100	2.14	6.42	8.56	12.83
90	2.12	6.36	8.48	12.72
80	2.10	6.30	8.40	12.60
70	2.08	6.24	8.32	12.47
60	2.06	6.17	8.23	12.34
50	2.03	6.10	8.14	12.20
40	2.01	6.03	8.04	12.06
30	1.99	5.96	7.94	11.91
20	1.96	5.88	7.84	11.76
10	1.94	5.81	7.74	11.61

Specific Gravity	State of Charge
1.255 – 1.275	100%
1.215 – 1.235	75%
1.180 – 1.200	50%
1.155 – 1.165	25%
1.110 – 1.130	0%

CHARGING OF LEAD ACID

BATTERY

CHARGING OF LEAD ACID

BATTERY FOR FIRST TIME

• +ve terminal is with +ve of charger, -ve is with –ve of charger.

• Remove Fil er cap to allow gases to go out to atmosphere.

• Charge battery with voltage higher than battery voltage but not too high.

• Example : 14.5 volt for 12 volt battery.

• Use Hydrometer to know how much battery is charged.

• Leave battery to cold.

• Get back cover again.

• Wash and clean the battery.

MAINTENANCE OF BATTERY

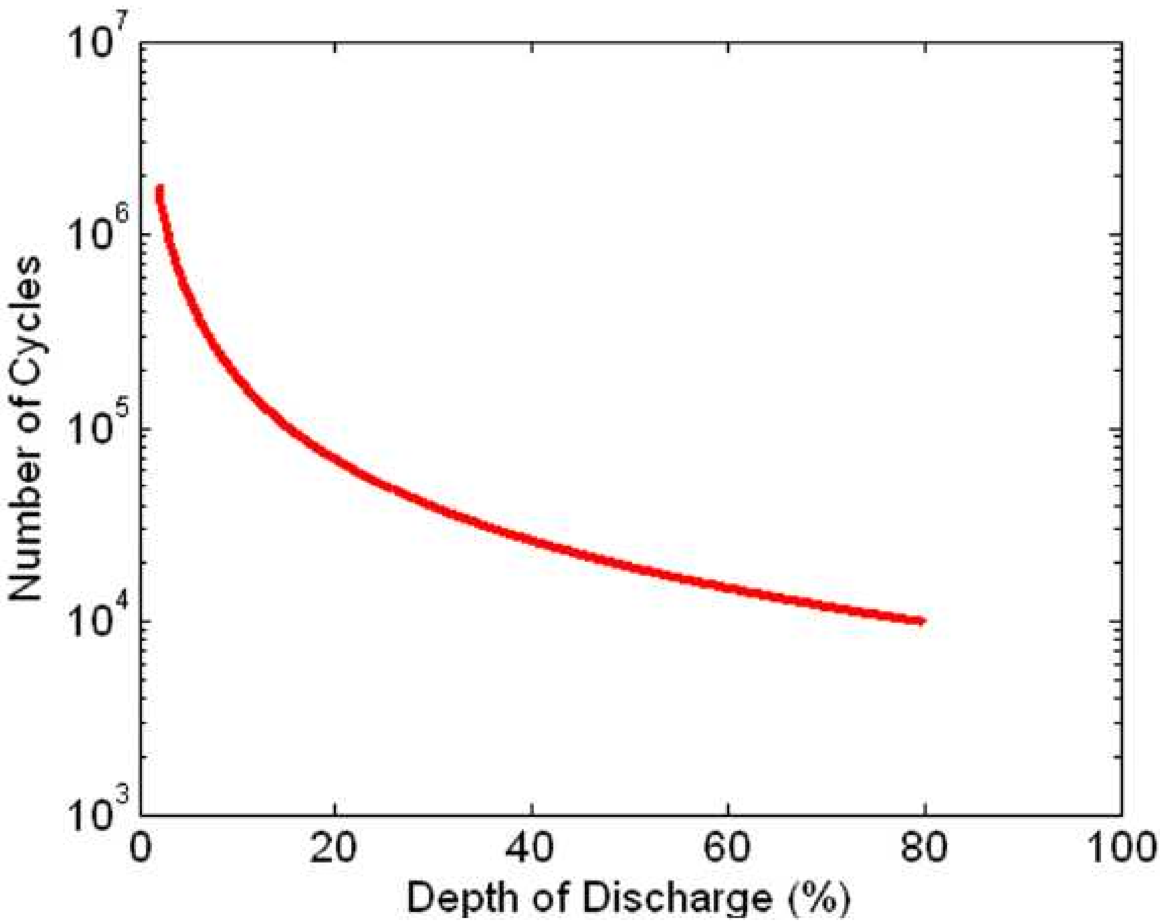
• Check rubber case from any damage to prevent any leaking of electrolyte.

• Check electrolyte by using hydrometer.

• After putting electrolyte, leave battery 4 hours before charging.

• After charging, check the density by hydrometer.

• Use a sponge with some soup and putting it on the battery, if there any bubbles then there is leaking.



10^7
10^6
10^5
10^4
10^3
Number of Cycles
0
20
40
60
80
100
Depth of Discharge (%)

METHODS OF CHARGING

- **Constant DC Current: low charging from 16 to 24 hours, very slow but very safe method.**

- **Constant DC Volt: Fast charging, not safe and decreases lifetime.**

CYCLE OF BATTERY

• Number of times we can charge and discharge the batteries.

Discharging from 100% to 20% then charging back again to 100%.

• DOD or depth of discharge: means how much we wil discharge the batteries.

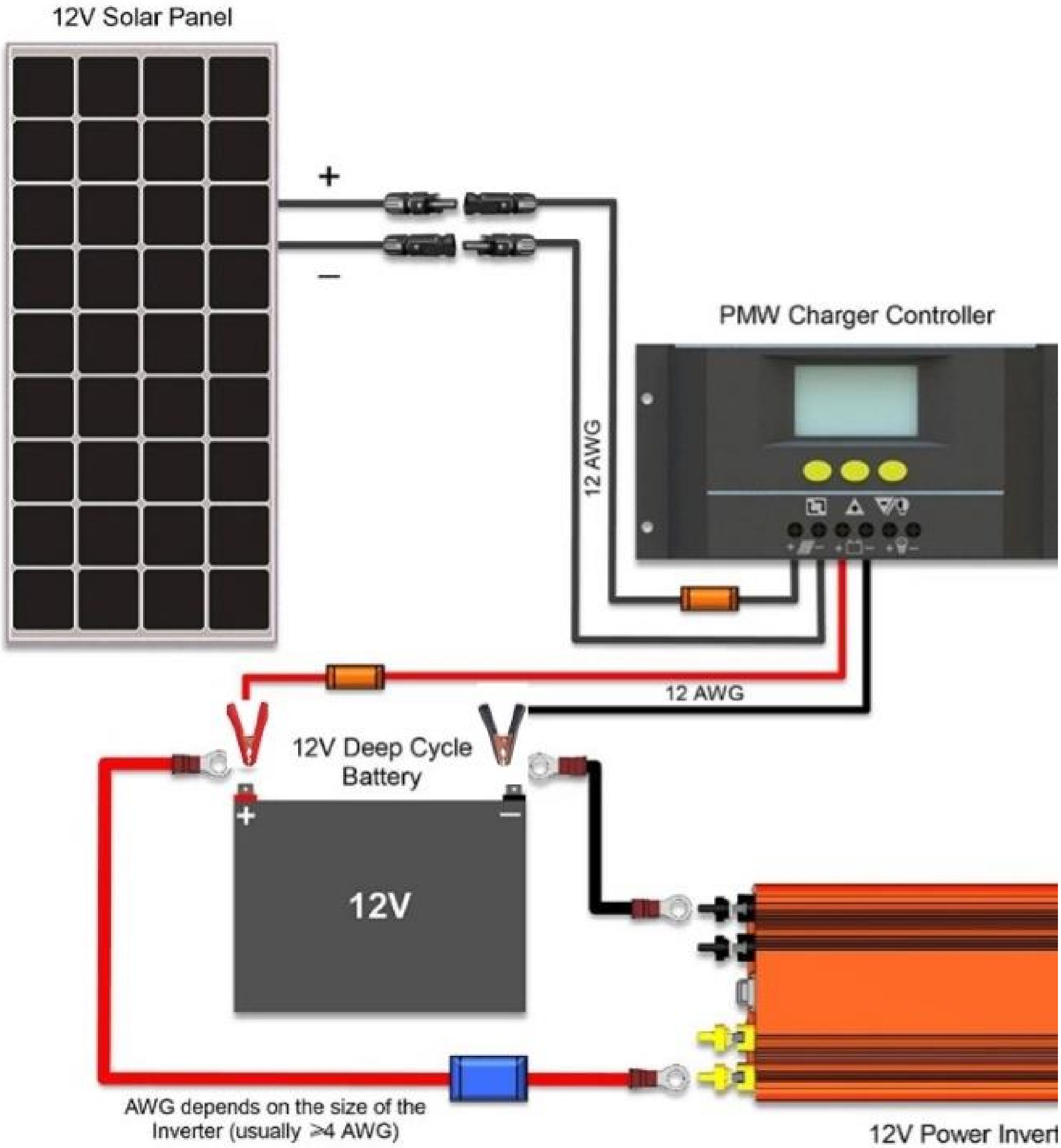
• Example 80% means we can discharge up to 80% of battery or up to 20% of battery capacity.

• DOD available: 10,20,50,80%

• Suggested DOD is 50%.

• As DOD increases, battery lifetime decreases.


SOLAR CHARGE CONTROLLER
88.8
V%
AH
USB
Solar panel
Battery
Load
+
−



12V Solar Panel
+
–
PMW Charger Controller
12 AWG
12 AWG
12V Deep Cycle
Battery
+
–
12V
AWG depends on the size of the
Inverter (usually ≥4 AWG)
12V Power Invert

CHARGE CONTROLLER

- Control current in and out of battery.
- Protects battery from overcharging.
- Regulate the voltage entering the battery.
- Protects battery from over discharging according to DOD.
- Contains sensors to protect battery from high temperature. , so Increase lifetime of battery.

JUNCTION BOX

• The junction box is an enclosure on the module where the PV strings are electrical y connected.

• It is attached to the back of the solar panel (TPT which is a layer firm)

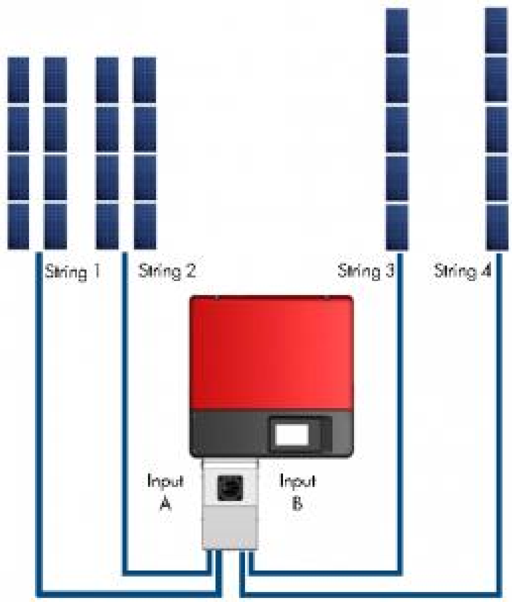
• It wires the (usually) 4 connectors together and is the output interface of the solar panel.

• When purchasing solar modules, always have a look at the IP of Junction Box. A completely water tight junction box carries IP 67.

• Most photovoltaic junction boxes have diodes.

• The function of the diodes is to keep the power flow going in one direction,

and prevent power from feeding back into the panels when there’s no sunshine.


String 1
String 2
String 3
String 4
Input
A
Input
B

WIRING OF JUNCTION BOX

• When wiring module strings together, which happens in series (e.g. positive to negative), voltage is increasing while current stays constant.

• When wiring multiple module strings together in parallel (e.g. positive to positive and negative to negative), current is increasing while voltage stays constant.

• Channel A and Channel B have two strings each that are wired in parallel on the DC combiner inputs at the inverter. The total number of modules on each channel is different, but the number of modules on each string within Channel A and B are the same (eight on Channel A, five on Channel B).

MOUNTING OF PV SYSTEM

- **Fixed:**

Roof

Pole

Ground

MOUNTING OF PV SYSTEM

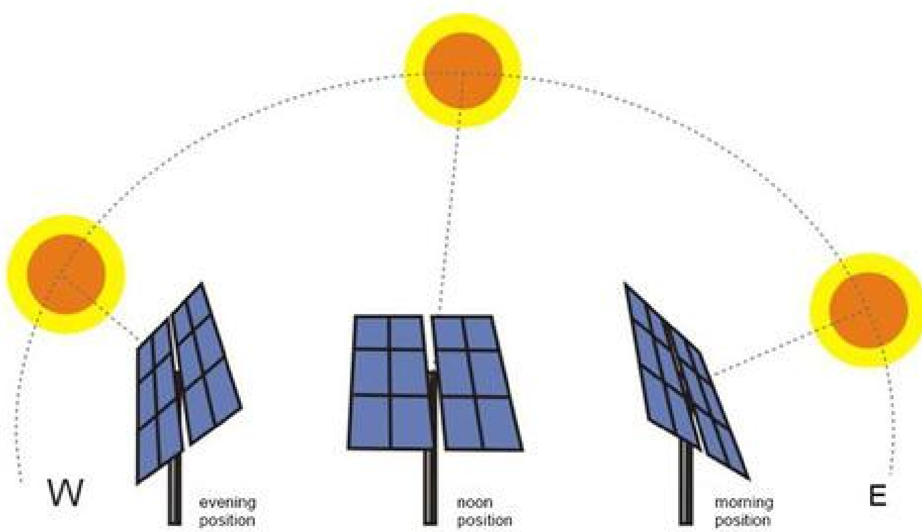
Roof Mount

• Simple and Cheap to install.

• No flexibility in orientation of PV system.

• Only support small PV systems

• Integrated: They use Thin film, give good look but have very low efficiency.



MOUNTING OF PV

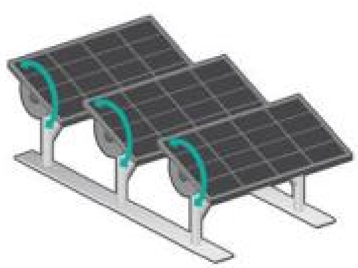
SYSTEM

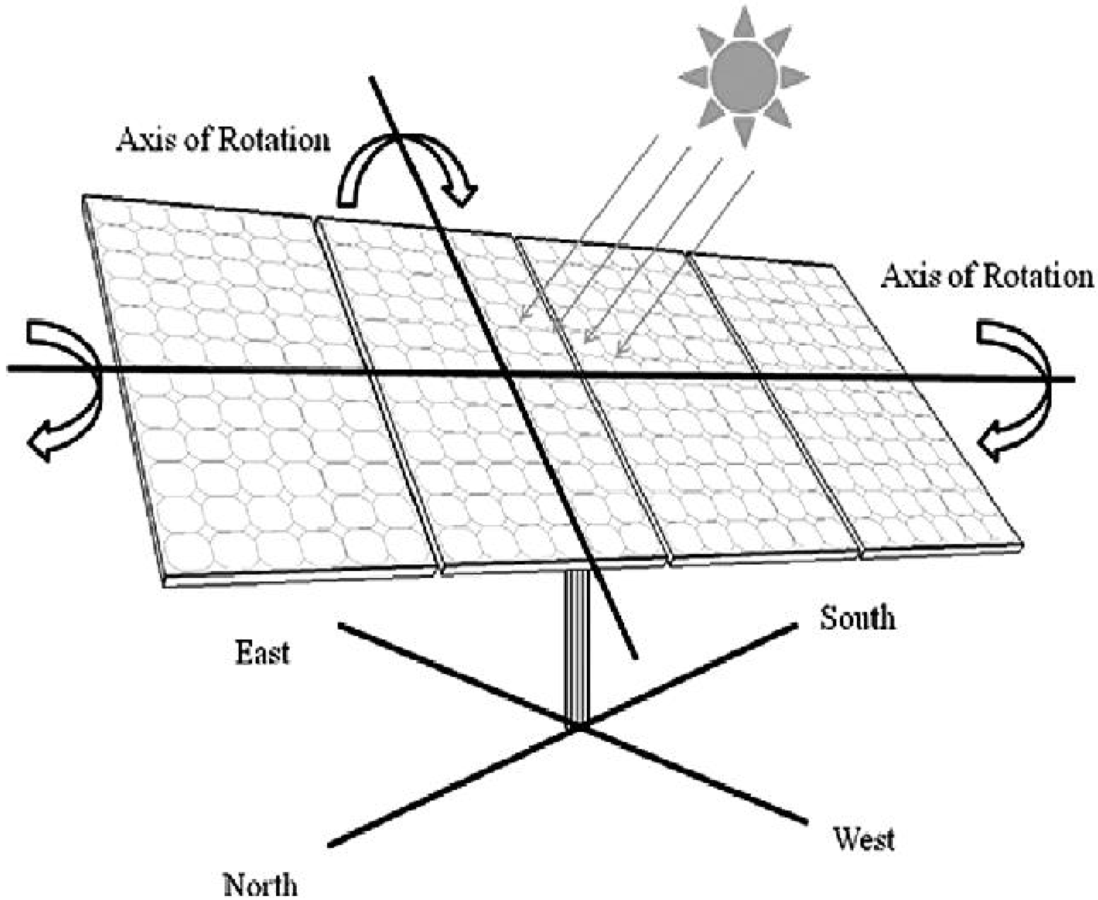
• Tracking: By using solar tracker.

• Solar tracker: device used for orienting the pv cell towards the sun by using light sensors connected with motor.

• Increases efficiency by 15% in winter and 30% in summer.

• Cost wil increase.

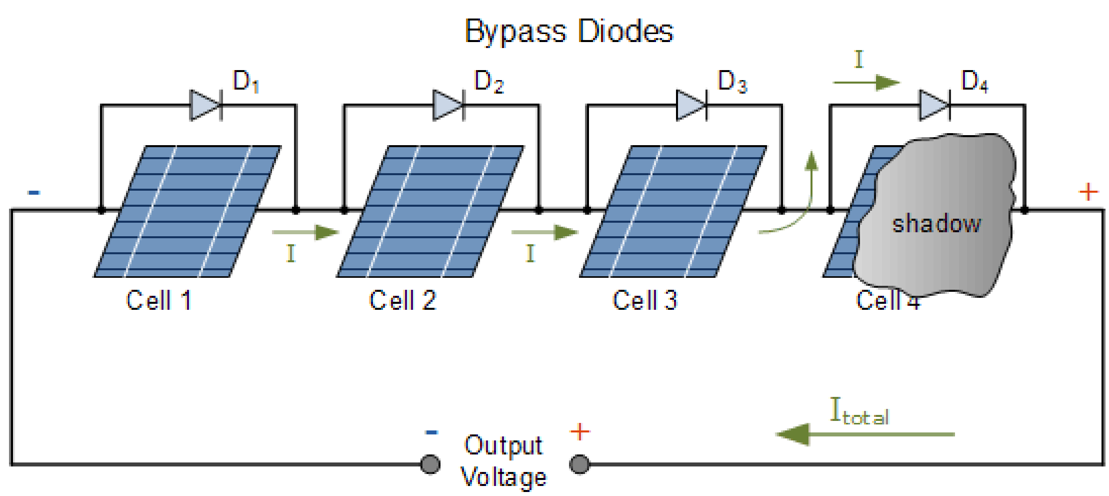


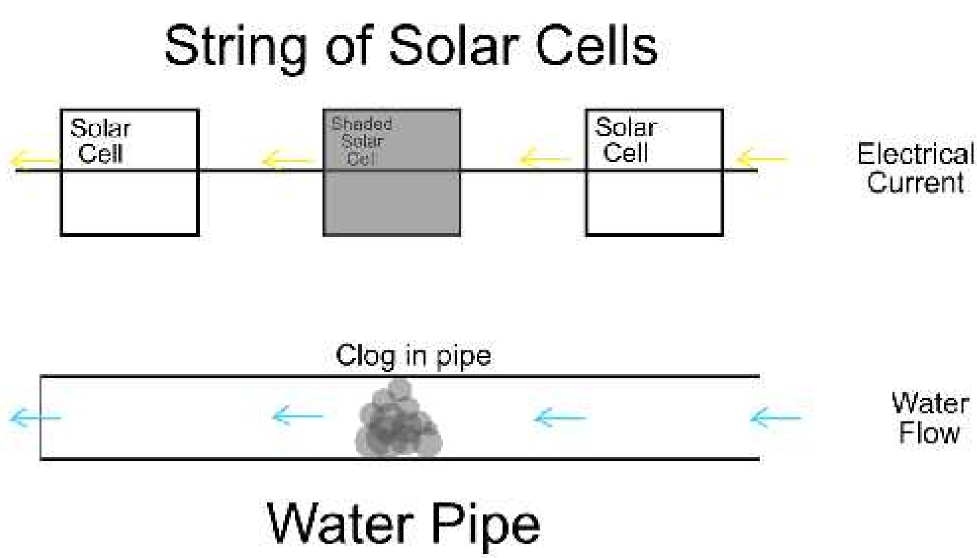

Axis of Rotation
Axis of Rotation
East
South
North
West

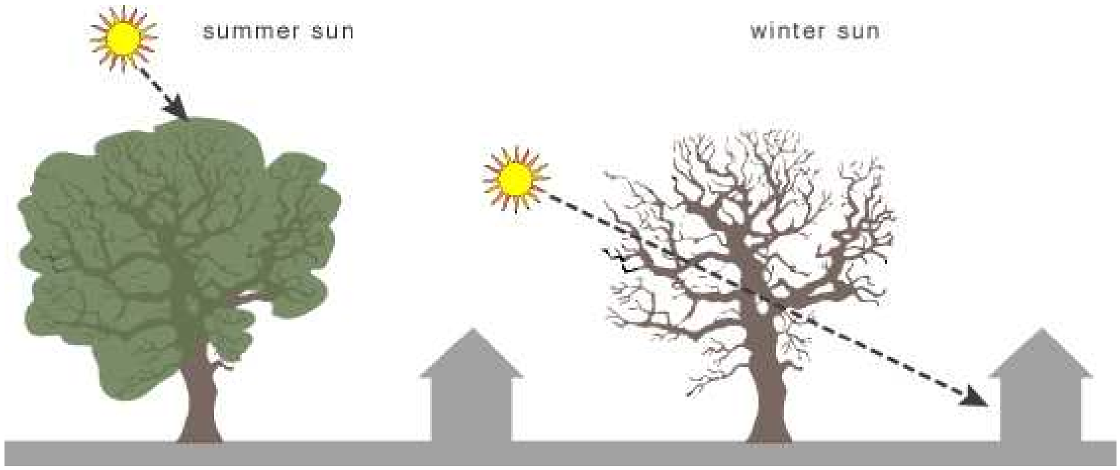
MOUNTING OF PV SYSTEM

• Single axis tracker: can be either vertical or horizontal.

• Dual axis tracker: have both vertical and horizontal axes.





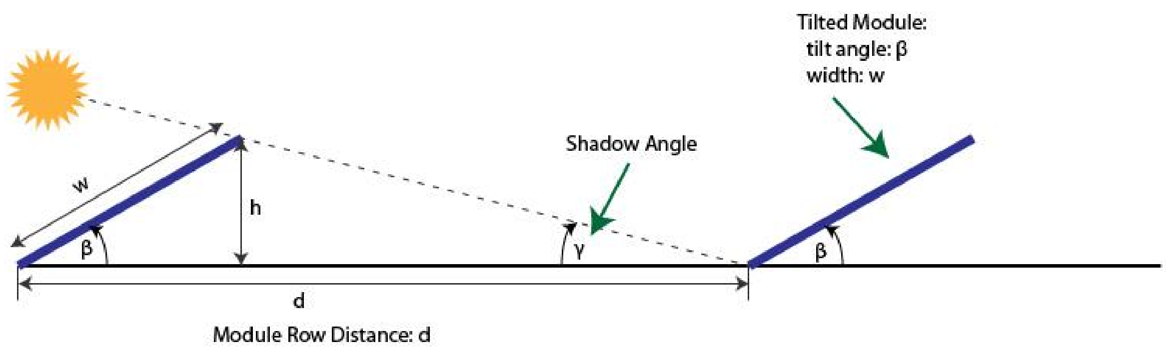

summer sun
winter sun

SHADING

- When a shadow is cast on a panel, whether by a tree or another building, it wil decrease the amount of electricity produced by the panel.

- Shading of just one cell in a module (which typical y consists of around 60 cells) can reduce power output by as much as 33%.

- So we use bypass diodes to form a short circuit path on the shaded cell, because shading causes cell to be open circuit and wil cause the whole module to be off.



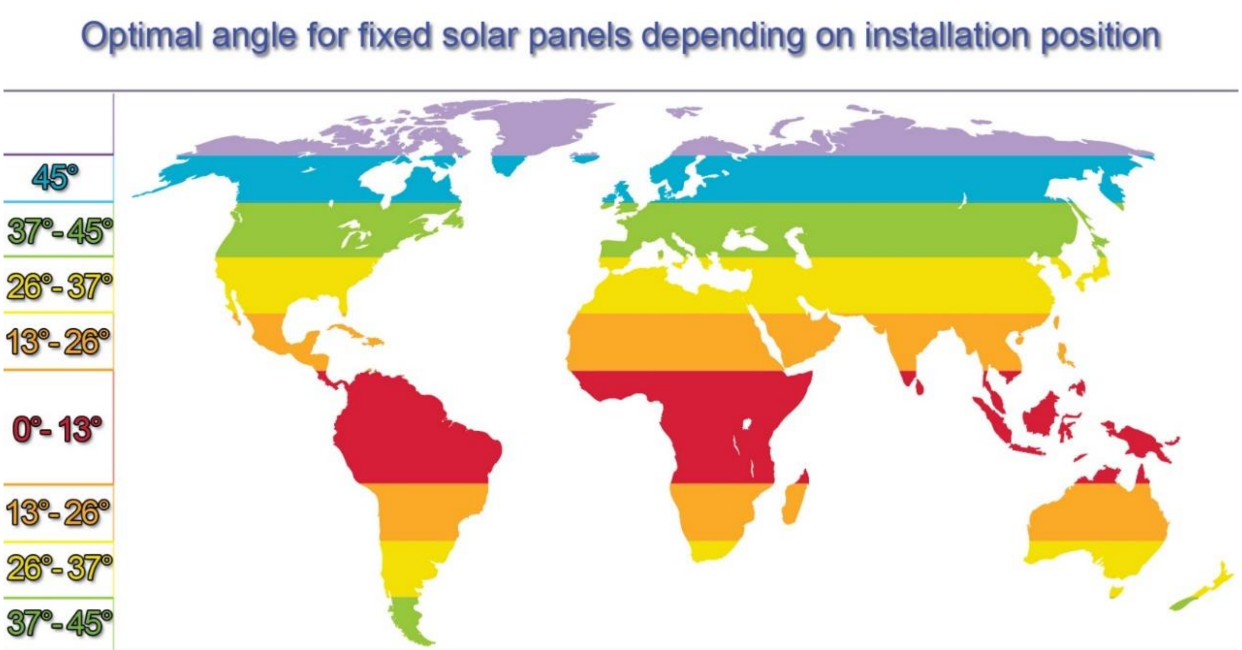
TILT ANGLE

The tilt angle of the photovoltaic (PV) array is the key to an optimum energy yield.

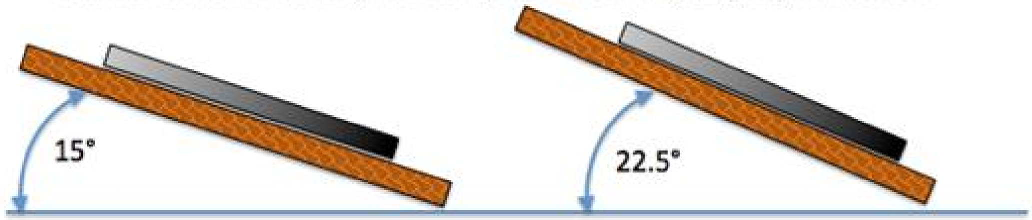
Solar panels or PV arrays are most efficient, when they are perpendicular to the sun's rays.

Self-Shading occurs due to PV panels so we have to move it to prevent self shading.

So distance should be at least = 3w (where d is the distance between rows and w is the width of a module)



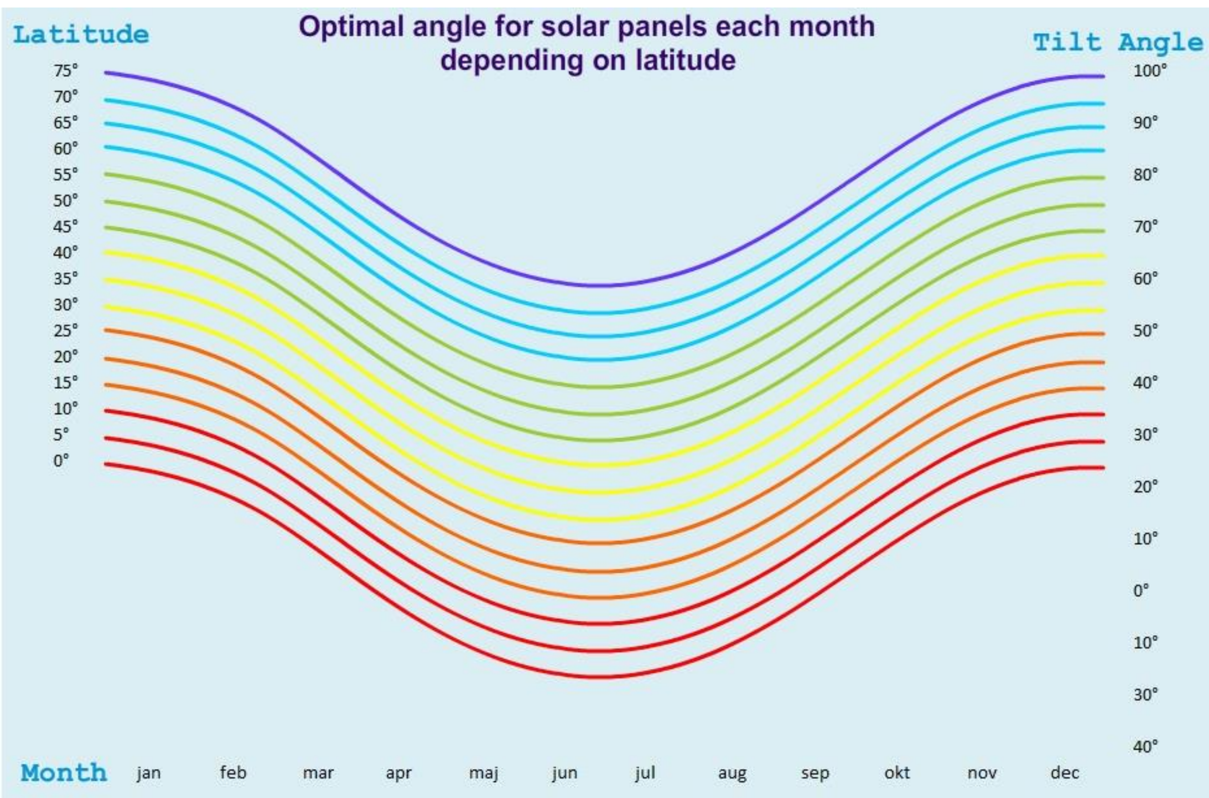
Standard Roof Pitches (and solar panel mounting angles) in Australia



TILT ANGLE

To give you a point of reference a 0° tilt angle would mean that the panel is lying flat down on its back facing directly upwards.

As the inclination increases the panel would be adjusted to face more and more to the front.



TILT ANGLE ACCURATE

METHOD

1- Go to https://power.larc.nasa.gov/data-access-viewer/ to find latitude of your place.

2-for a latitude up to 25° take your latitude and multiply it by 0,87.

for a latitude between 25° to 50° take your latitude multiply by 0,87

after that you wil add 3,1 degrees for a latitude over 50° the most ideal angle wil end up being approximately 45° degrees

3- Thanks to solarpanelsphotvoltaic.net for providing this awesome curve.

4- Another easier method by going to this website

http://solarelectricityhandbook.com/solar-angle-calculator.html

Angle is here between vertical not as before between horizontal and panel.

SELECTION OF PANEL

•

Number of modules depends on length and width of both of area and panel.

•

Space between modules between 6 and 10 mm2.

PV type

Efficiency

Space for 1kwh

Monocrystalline

11-16%

6-9 m2

silicon

Polycrystalline

10-15%

7-10 m2

silicon

Thin film

6-11%

9-17 m2

Hybrid silicon

16-18%

5-6 m2

Micromorphous

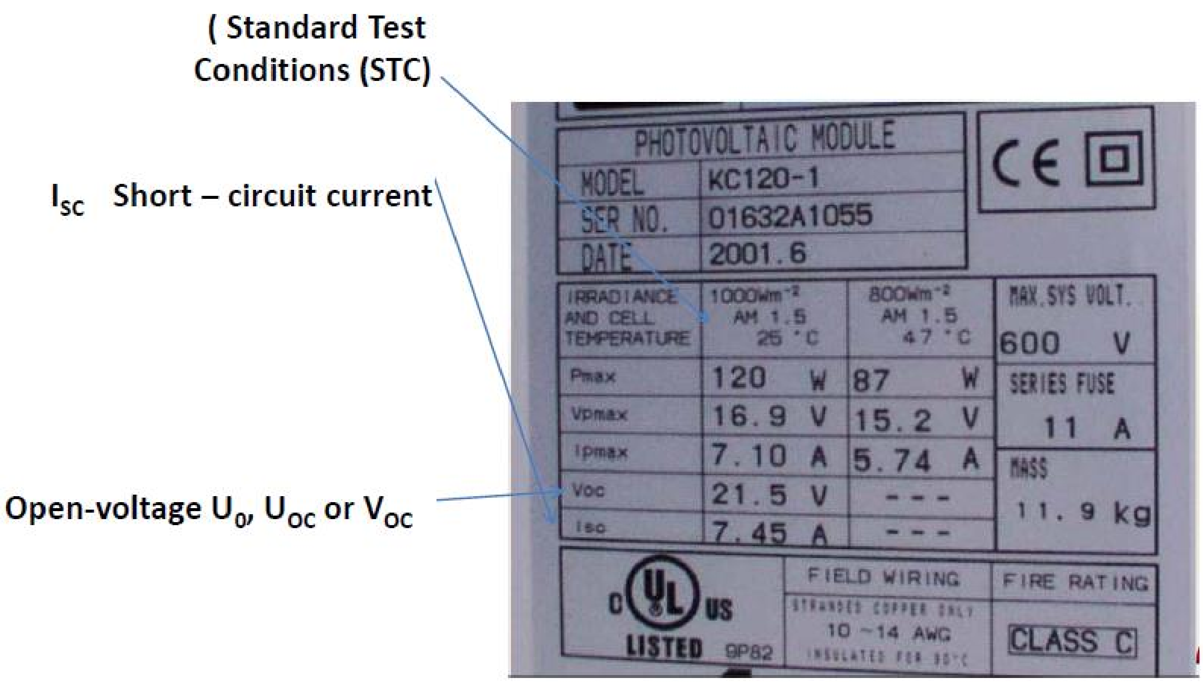
7-12%

8.5-15 m2

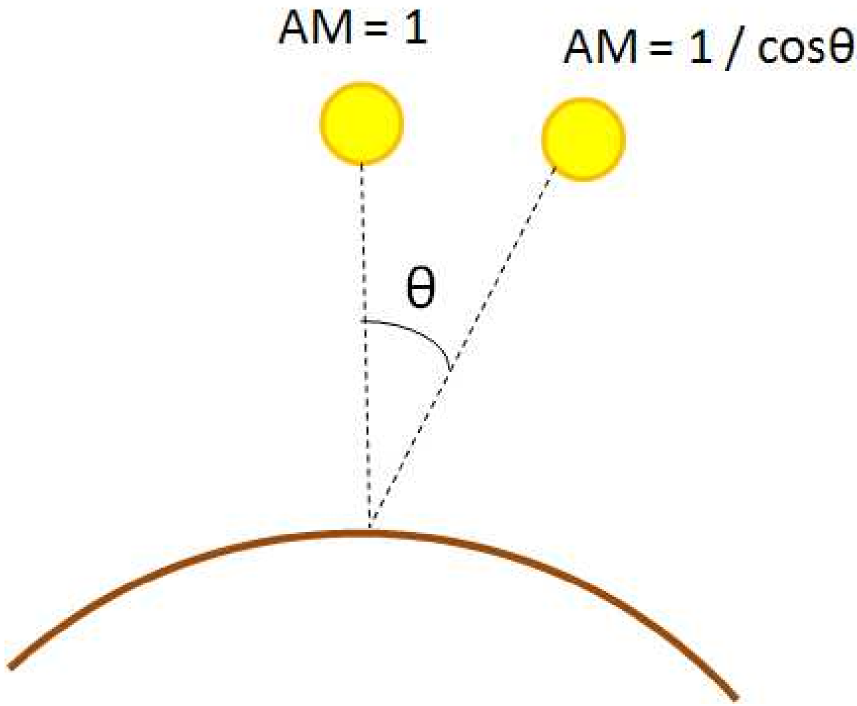
Amorphous

4-7%

15-26 m2



(Standard Test Conditions (STC)
I_{sc} Short – circuit current
Open-voltage U_0, U_{OC} or V_{OC}
PHOTOVOLTAIC MODULE
MODEL KC120-1
SER NO. 01632A1055
DATE 2001.6
IRRADIANCE AND CELL TEMPERATURE
1000Wm⁻² AM 1.5 25 °C
800Wm⁻² AM 1.5 47 °C
MAX. SYS VOLT. 600 V
Pmax 120 W 87 W
Vpmax 16.9 V 15.2 V
Ipmax 7.10 A 5.74 A
Voc 21.5 V ---
Isc 7.45 A ---
SERIES FUSE 11 A
MASS 11.9 kg
LISTED 9P82
FIELD WIRING
10 ~14 AWG
FIRE RATING
CLASS C


AM = 1
AM = 1 / cosθ
θ

DATASHEET OF PANEL

INVERTER SELECTION

To select inverter, sum all of the loads in kw and choose higher value for inverter.

If total load= 3.9 kw, then we choose inverter of 4 kw.

Type

Power in Kw

Efficiency

Usage

String

1-10 kw

96-98%

Single/three

inverters

phase

Mini central

10-30 kw

>97%

Three phase

inverters

Central

30-1200 kw

>97%

Three phase

inverters

up to 30kv

DETERMINING PV ARRAY

MAXIMUM SYSTEM

VOLTAGE

• Equipment used for residential and commercial PV systems in the United States is rated up to 600 VDC, so it is important to make sure a PV array is configured so that this 600-volt rating is not exceeded.

• In cold, sunny conditions, array voltage wil increase, you'll need to account for this when designing your system so the voltage stays below the limit and knowing the lowest expected ambient temperature at your site.

• PV module manufacturer provides a temperature coefficient of open-circuit voltage (TkVoc), it must be used in the calculation.

• This coefficient tells us how much a module's voltage wil increase per °C below the standard test condition (STC) of 25°C.

• The temperature coefficient wil be listed in volts per °C; mil ivolts (mV) per °C; or as a percentage per °C.

EXAMPLE

• If a module has a TkVoc of -0.120 V per ºC this means that, for each °C *below* 25°C, the module voltage wil *increase* by 0.120 volts.

• If you have a module with a TkVoc given in % per ºC, multiply this TkVoc by the module's open-circuit voltage (Voc).

• A module with a Voc of 36.9 volts and a TkVoc of -0.36% per ºC will have a 1.333 voltage increase for each degree below 25°C.

• **0.0036 × 36.9 V = 0.133 V**

• Once we have this calculation, we must determine the lowest expected ambient temperature.

PROBLEM

• Let’s assume our array uses modules with a Voc = 36.9 volts and a TkVoc = -0.36% per ºC, and is located in Albany, New York. The extreme minimum temperature for this location is listed as -23°C.

• This is 48°C lower than the STC temperature.

• **-23ºC - 25ºC = -48ºC**

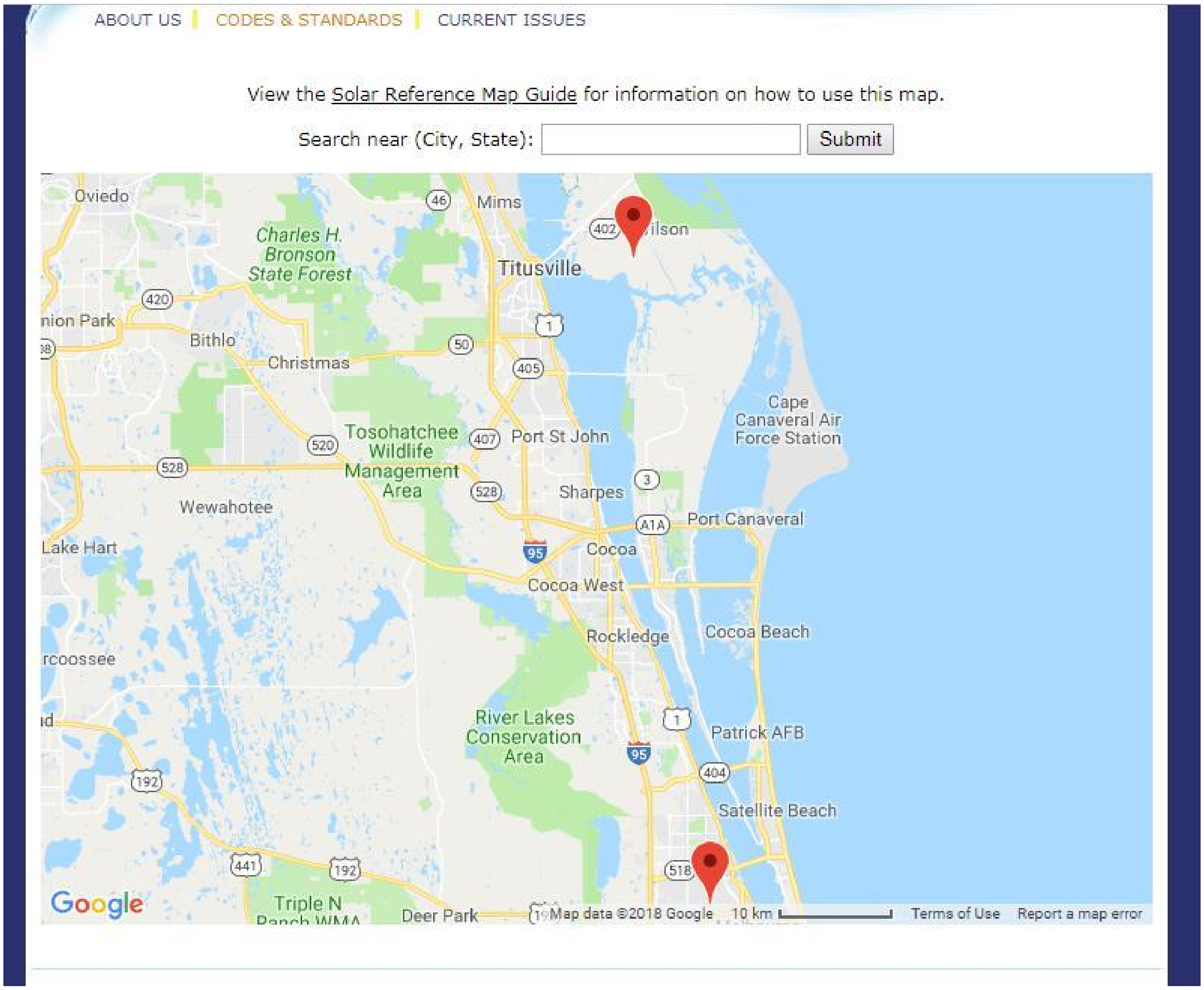
• (48ºC × 0.133 V = 6.38 V).

• That means our maximum module Voc is now 43.28 V.

• **36.9 V + 6.38 V = 43.28 V**

• If our array consists of 12 of these modules in series, the resulting maximum system voltage is 519.4 volts, which is under the 600-volt limit.

• However, if we had 14 of these modules in series, the 600-volt limit could be exceeded (43.28 V × 14 = 605.9 V) given this location and these modules.



• You can check this website to identify maximum and minimum temperatures:

• http://www.solarabcs.org/about/publications/reports/e xpedited-permit/map/

METHOD 1 OF SOLAR PV

SYSTEM SIZING OF OFF GRID

SYSTEM

1. Determine power consumption demands.

2. Size the PV modules.

3. Inverter sizing.

4. Battery sizing.

5. Solar charge controller sizing.

Step 1: Determine power consumption demands: Find out the total power and energy consumption of all loads that need to be supplied by the solar PV system as fol ows: **1.1 Calculate total Watt-hours per day for each appliance used.**

Add the Watt-hours needed for all appliances together to get the total Watt-hours per day which must be delivered to the appliances.

1.2 Calculate total Watt-hours per day needed from the PV

modules.

Multiply the total appliances Watt-hours per day times 1.3 (the energy lost in the system) to get the total Watt-hours per day which must be provided by the panels.

EXAMPLE

A house has the fol owing electrical appliance usage:

• One 18 Watt fluorescent lamp with electronic bal ast used 4 hours per day.

• One 60 Watt fan used for 2 hours per day.

• One 75 Watt refrigerator that runs 24 hours per day with compressor run 12 hours and off 12 hours.

• The system wil be powered by 12 Vdc, 110 Wp PV

module.

Total appliance use = (18 W x 4 hours) + (60 W x 2 hours) + (75 W x 24 x 0.5 hours)

= 1,092 Wh/day

Total PV panels

energy

= 1,092 x 1.3

needed

= 1,419.6 Wh/day.

SOLAR PV SYSTEM SIZING

2. Size the PV modules:

•

Different size of PV modules will produce different amount of power.

•

To find out the sizing of PV module, the total peak watt produced needs.

•

The peak watt (Wp) produced depends on size of the PV module and climate of site location.

•

“Panel generation factor” which is different in each site location.

•

Example For Thailand, the Panel generation factor is 3.43.

•

To determine the sizing of PV modules, calculate as follows: **2.1 Calculate the total Watt-peak rating needed for PV modules** Divide the total Watt-hours per day needed from the PV modules (from Step 1) by 3.43 to get the total Watt-peak rating needed for the PV

panels needed to operate the appliances.

2.2 Calculate the number of PV panels for the system

• Divide the answer obtained in item 2.1 by the rated output Watt-peak of the PV modules available to you.

• Increase any fractional part of result to the next highest full number and that will be the number of PV modules required.

• Result of the calculation is the minimum number of PV panels.

• If more PV modules are installed, the system will perform better and battery life will be improved.

• If fewer PV modules are used, the system may not work at all during cloudy periods and battery life will be shortened

EXAMPLE

2.1 Total Wp of PV

= 1,419.6 / 3.4= 413.9 Wp.

panel capacity

needed

2.2 Number of PV

panels needed

= 413.9 / 110= 3.76 modules.

Actual requirement = **So this system should be powered by at** 4 modules

least 4 modules of 110 Wp PV module

SOLAR PV SYSTEM SIZING

3. Inverter sizing

• An inverter is used in the system where AC power output is needed.

• The input rating of the inverter should never be lower than the total watt of appliances.

• The inverter must have the same nominal voltage as your battery.

• For stand-alone systems, the inverter must be large enough to handle the total amount of Watts you wil be using at one time.

• The inverter size should be 25-30% bigger than total Watts of appliances.

• In case of appliance type is motor or compressor then inverter size should be minimum 3 times the capacity of those appliances and must be added to the inverter capacity to handle surge current during starting.

• For grid tie systems or grid connected systems, the input rating of the inverter should be same as PV array rating to allow for safe and efficient operation.

EXAMPLE

- Total Watt of all appliances = 18 + 60 + 75 = 153 W
- For safety, the inverter should be considered 25-30% bigger size.
- **The inverter size should be about 190 W or greater**

SOLAR PV SYSTEM SIZING

4. Battery sizing

• The battery type recommended for using in solar PV system is deep cycle battery.

• Deep cycle battery is specifical y designed for to be discharged to low energy level and rapid recharged or cycle charged and discharged day after day for years.

• The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days.

• To find out the size of battery, calculate as fol ows:

•

4.1 Calculate total Watt-hours per day used by appliances.

•

4.2 Divide the total Watt-hours per day used by 0.85 for battery loss.

•

4.3 Divide the answer obtained in item 4.2 by 0.6 for depth of discharge.

•

4.4 Divide the answer obtained in item 4.3 by the nominal battery voltage.

•

4.5 Multiply the answer obtained in item 4.4 with days of autonomy (the number of days that you need the system to operate when there is no power produced by PV panels) to get the required .

• Ampere-hour capacity of deep-cycle battery.

• Battery Capacity (Ah) = (Total Watt-hours per day used by appliances x Days of autonomy)Divided by (0.85 x 0.6 x nominal battery voltage)

EXAMPLE

• Total appliances use = (18 W x 4 hours) + (60 W x 2 hours) +

(75 W x 12 hours).

• Nominal battery voltage = 12 V.

• Days of autonomy = 3 days.

• Battery capacity = [(18 W x 4 hours) + (60 W x 2 hours) + (75

W x 12 hours)] x3

Divided by

(0.85 x 0.6 x 12).

• Total Ampere-hours required 535.29 Ah

• **So the battery should be rated 12 V 600 Ah for 3 day autonomy.**

SOLAR PV SYSTEM

SIZING

5. Solar charge controller sizing Its function is to regulate the voltage and current from the solar arrays to the battery in order to prevent overcharging and also over discharging.

• The solar charge controller is typically rated against Amperage and Voltage capacities.

• Select the solar charge control er to match the voltage of PV

array and batteries.

• Make sure that solar charge control er has enough capacity to handle the current from PV array.

• For the Series Charge Controller type, the sizing of controller depends on the total PV input current which is delivered to the controller and also depends on PV panel configuration (series or parallel configuration).

• According to standard practice, the sizing of solar charge controller is to take the short circuit current (Isc) of the PV

array, and multiply it by 1.3

• Solar charge controller rating = Total short circuit current of PV array x 1.3

• **Remark**: For MPPT , the Situation is Completely Different.

EXAMPLE

• PV module specification

Pm = 110 Wp

Vm = 16.7 Vdc

Im = 6.6 A

Voc = 20.7 A

Isc = 7.5 A

• Solar charge controller rating = (4 strings x 7.5 A) x 1.3 =

39 A

• **So the solar charge controller should be rated 40 A at 12**

V or greater.

HOW TO CHOOSE MPPT

CHARGE CONTROLLER?

• **SPT-XXYY** (**XX** is nominal battery voltage, **YY** is maximum charge current)

• Find out what is nominal battery voltage that charge controller wil charge and select **XX**

• Find out what is Wp of PV module and

• Select the suitable charge current (**CC**) = (Wp) / **XX**

• Find out **YY** by multiply **CC** by safety factor (NEC requirement) =

(**CC**) x 1.2

• Select **SOLARCON SPT-series** model that covers **YY**

• Check that **Vpm(system)** is in range that **SPT-XXYY** can handle (MPPT

voltage range)

• If PV modules are in series, need to check that **Vpm(system) =**

Vpm(module) x Module in series

• If PV modules are in parallel, need to check that **Vpm(system) =**

Vpm(module)

• Check that **Voc(system)** is not more than **SPT-XXYY** range (Maximum open circuit voltage)

• If PV modules are in series, need to check that **Voc(system)** = **Voc(module)** x Module in series

• If PV modules are in parallel, need to check that **Voc(system)** = **Voc(module)**

Table 1 Specifications of PV modules separated by manufacturers

PV Manufactures	Model	Wp	Vpm	Ipm	Isc	Voc
SHARP [View Specifications]	NE-78T1	78	17.1	4.57	5.08	21.4
	ND-130T1	130	17.4	7.48	8.09	22
Kaneka [View Specifications]	GPA	64	68	0.94	1.17	92
SANYO [View Specifications]	HIP-180B2	190	54	3.33	3.15	66.4
Bangkok Solar [View Specifications]	BS 40	40	44.8	0.9	1.16	62.2

Standard Test Condition: Irradiance = 1000 W/m^2, Cell temperature = 25°C, Air mass = 1.5

MODEL		SPT-1206	SPT-1212	SPT-1220	SPT-1230	SPT-2412	SPT-2420	SPT-2430	SPT-4812	SPT-4820	SPT-4830
PV INPUT	Maximum input power (W)	80 W	160 W	240 W	400 W	320 W	520 W	800 W	520 W	1000 W	1600 W
	Maximum open ciruit vitage (V_{oc})	96Vdc							192 Vdc		
	MPPT tracking voltage range (V_{mp})	26 - 75 Vdc				30 - 75 Vdc			65 - 150 Vdc		
DC OUTPUT TO BATTERY (at 25 °C)	Nominal battery voltage	12 Vdc				24 Vdc			48 Vdc		
	Boost charging voltage* (LA / VRLA)	15.0 V ±0.2 / 14.2 V ±0.2				30.0 V ± 0.4 / 28.4 V ±0.4			60.0 V ±0.8 / 56.8 V ±0.8		
	Float charging voltage* (LA / VRLA)	13.8 V ±0.2 / 13.5 V ±0.2				27.6 V ± 0.4 / 27.0 V ±0.4			55.2 V ±0.8 / 54.0 V ±0.8		
	Low battery disconnect voltage	10.8 V ±0.2				21.6 V ±0.4			43.2 V ±0.8		
	Battery reconnection voltage	12.5 V ±0.2				25.0 V ±0.4			50.0 V ±0.8		
	Maximum charging current (A)	6 A	12 A	20 A	30 A	12 A	20 A	30 A	12 A	20 A	30 A
DC LOAD CONTROL	Nominal voltage	12 V				24 V			48 V		
	Maximum current	10 A									
	Protection	Over voltage disconnected and short circuit (Type electronics switch not moving parts and no contact surface)									
PROTECTION		Hight battery voltage / Overcharge and overdischarge PV transient voltage surge PV reverse polarity / Battery reverse polarity									
	Approx. Power Consumption	less than 25 mA							less than 35 mA		
INDICATOR	LED	Charging (green), Battery status (yellow),Low battery / Low voltage disconnect (red)									
BATTERY	Type (Selectable)	Deep Cycle Lead Acid (LA) or Sealed Lead Acid (VRLA)									
VENTILATION	Automatic cooling fan (outside enclosure)	no	no	no	yes	no	no	yes	no	yes	yes
OPERATING CONDITION	Temperature	0 - 45°C									
	Relative humidity	0 - 95 % (non-condensing)									
DIMENSION	W x H x D (mm.)	160 x 92 x 65	192 x 210 x 115								
WEIGHT	Approximate in kg.	0.9	2.8		3.0	2.8		3.0	2.8	3.0	

SPECIFICATIONS OF PV

MODULES

Specifications of the SOLARCON SPT-

series MPPT solar charge controller

EXAMPLE

• **Example of choosing MPPT solar charge controller for a 128 Wp solar home system**

by using 2 modules of 64 Wp Kaneka GPA PV module connected in parallel

SPT-XXYY

• Find out what is nominal battery voltage that charge controller wil charge and select **XX = 12**

• Find out what is Wp of PV module and select the suitable charge current (**CC**) = (128 Wp) / **12 = 10.67 A**

• Find out **YY** by multiply **CC** by safety factor (NEC requirement) =

(**10.67**) x 1.2 = **12.8 A**

• Select **SOLARCON SPT-series** model that covers **YY**, **SOLARCON**

SPT-1212

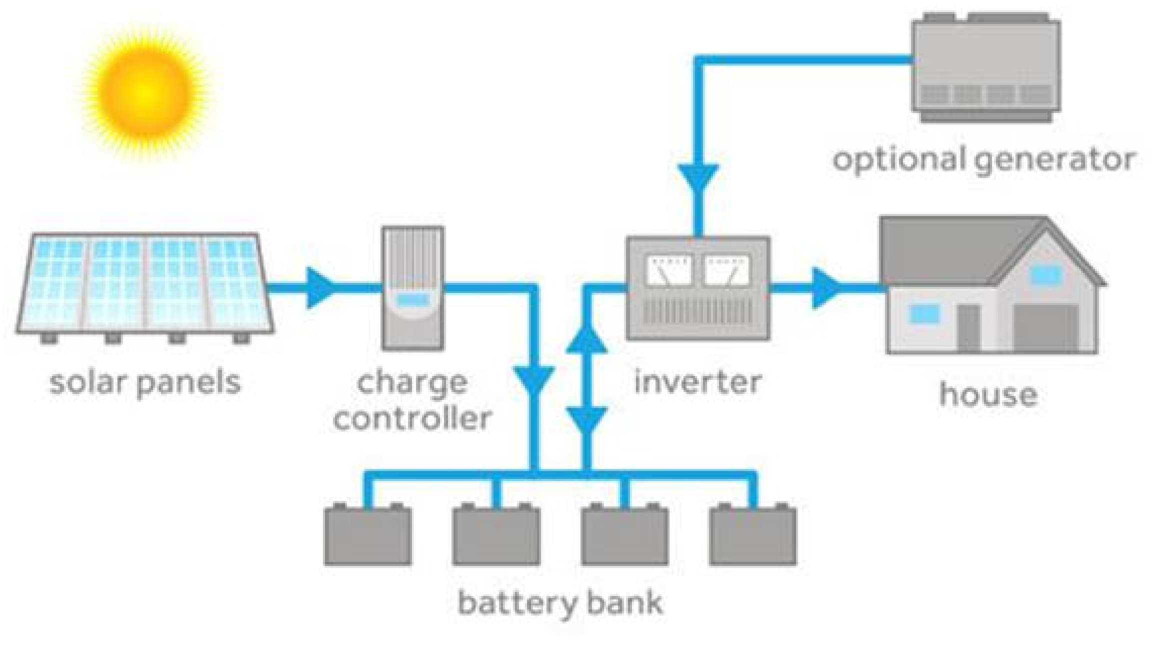
• Check that **Vpm(system)** is in range that **SPT-XXYY** can handle (MPPT

voltage range)

If PV modules are in parallel, need to check that **Vpm(system) = Vpm(module) = 68 Vdc** (MPPT voltage range = 26-75 Vdc)

• Check that **Voc(system)** is not more than **SPT-XXYY** range (Maximum open circuit voltage)

If PV modules are in parallel, need to check that **Voc(system) = Voc(module) = 92 Vdc** (Maximum open circuit voltage = 96 Vdc)



optional generator
solar panels
charge
controller
inverter
house
battery bank

METHOD 2 ON PV SIZING

Load consisting of air conditioner 2500 watt for 8 hours.

5 lamps each of 60 watt for 12 hours.

Refrigerator of 200 watt for 24 hours.

TV of 200 watt for 2 hours.

1- Find total power and total kwh:

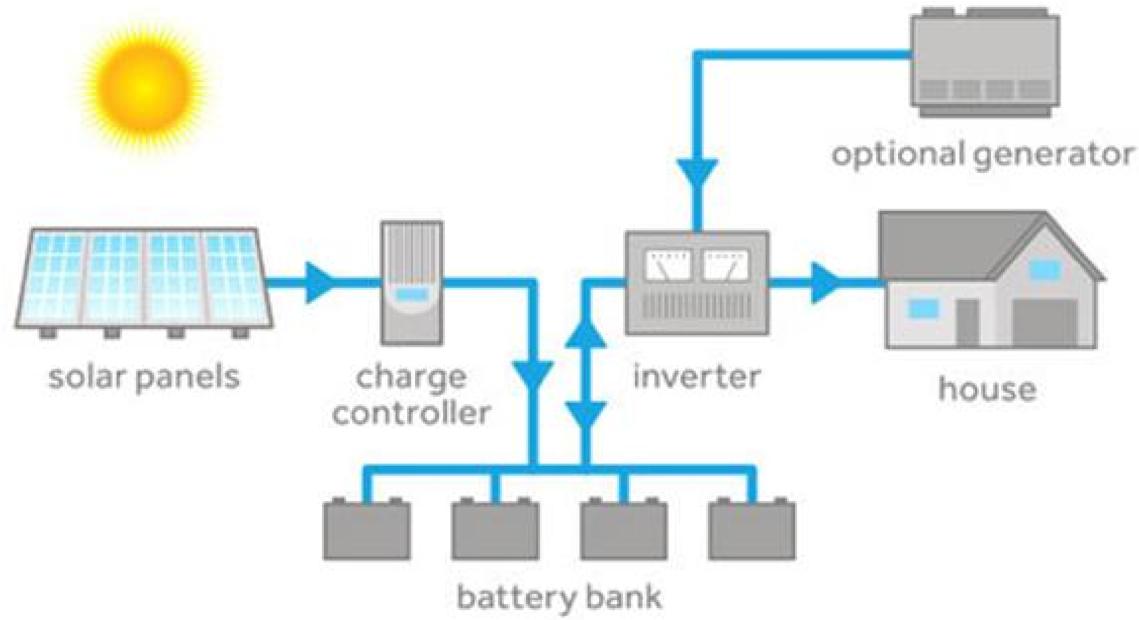
Total power=2500+60*5+200+200= 3.2 kw Total energy=2500*8+5*60*12+200*24+200*2= 28.8 kwh 2- Inverter should by greater by 25% or 30%

So Minimum inverter =1.25 *3.2=4 kw ,its efficiency=97%.

This inverter minimum input is 96 volt.

3.2 KW

28.8 KWH


optional generator
solar panels
charge controller
inverter
house
battery bank

EXAMPLE ON PV SIZING

3- As efficiency =Pout/Pin or energy out/energy in.

Input power to inverter=Pout/efficiency Input energy to inverter=28.8/0.97=30 kwh.

4- we have efficiency of battery with charge controller combined=85%

So input energy to charger and battery=30 kwh/0.85=35.29 kwh.

35.29

30

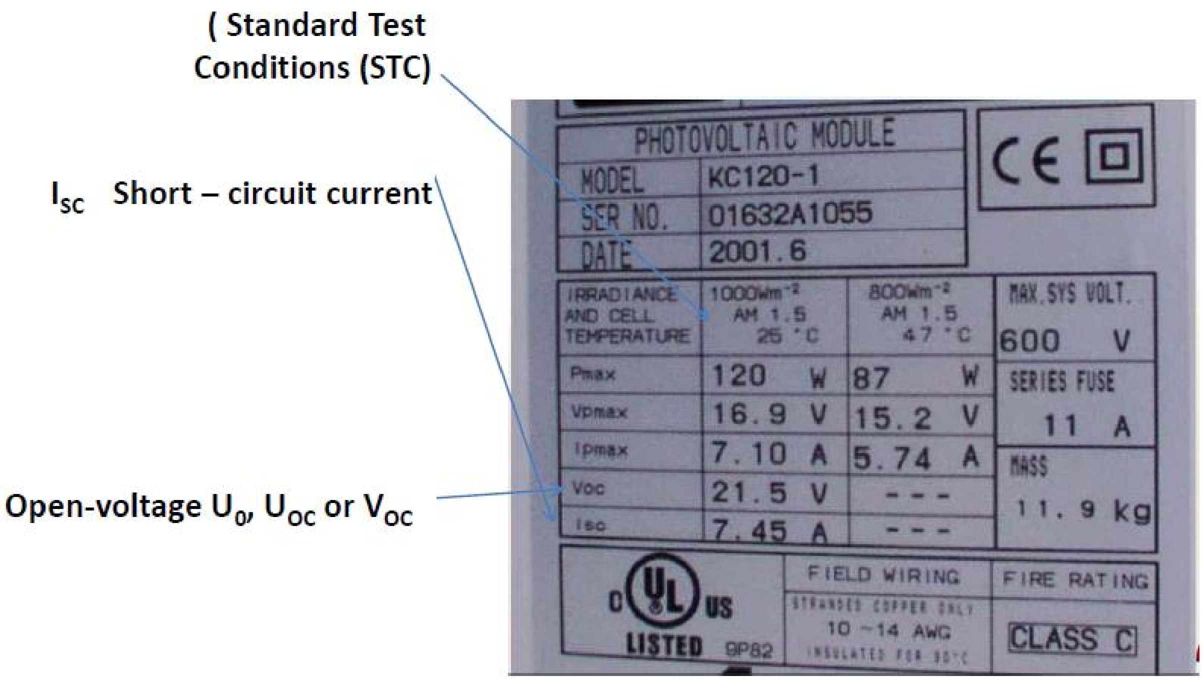
KWH

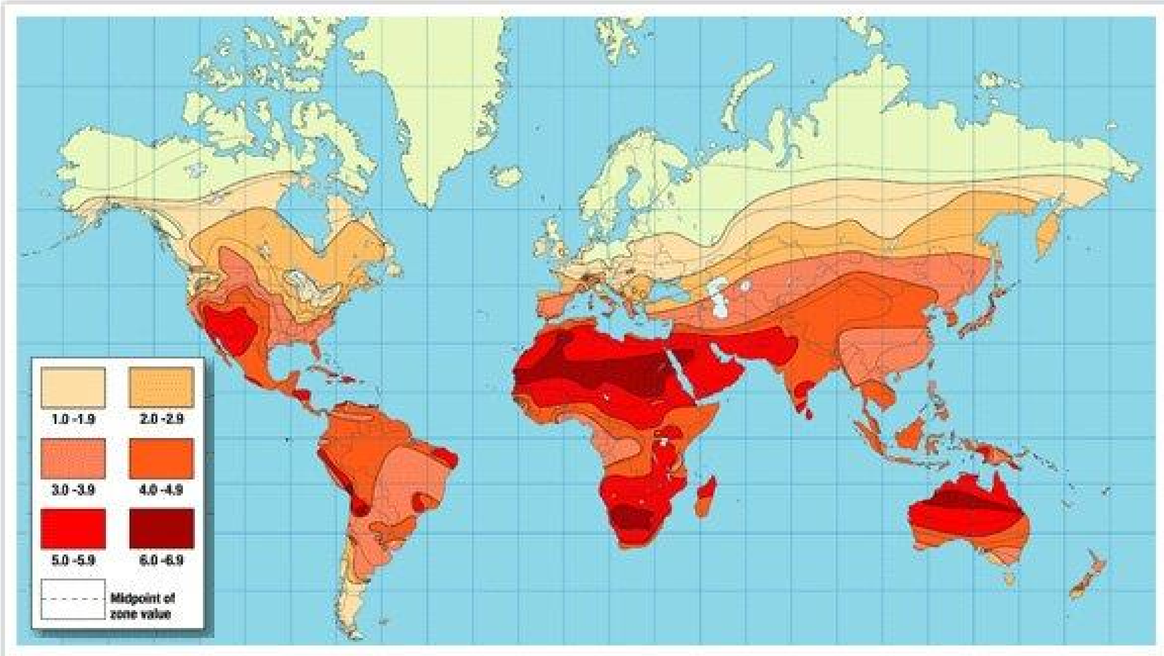
KWH

3.2 KW

28.8

KWH


(Standard Test Conditions (STC)
I_{sc} Short – circuit current
Open-voltage U_0, U_{OC} or V_{OC}
PHOTOVOLTAIC MODULE
MODEL KC120-1
SER NO. 01632A1055
DATE 2001.6
IRRADIANCE AND CELL TEMPERATURE
1000Wm⁻² AM 1.5 25 °C
800Wm⁻² AM 1.5 47 °C
MAX.SYS VOLT. 600 V
Pmax 120 W 87 W
Vpmax 16.9 V 15.2 V
Ipmax 7.10 A 5.74 A
Voc 21.5 V ---
Isc 7.45 A ---
SERIES FUSE 11 A
MASS 11.9 kg
LISTED 9P82
FIELD WIRING
STRANDED COPPER ONLY
10 ~14 AWG
FIRE RATING
CLASS C


1.0 -1.9
2.0 -2.9
3.0 -3.9
4.0 -4.9
5.0 -5.9
6.0 -6.9
Midpoint of zone value

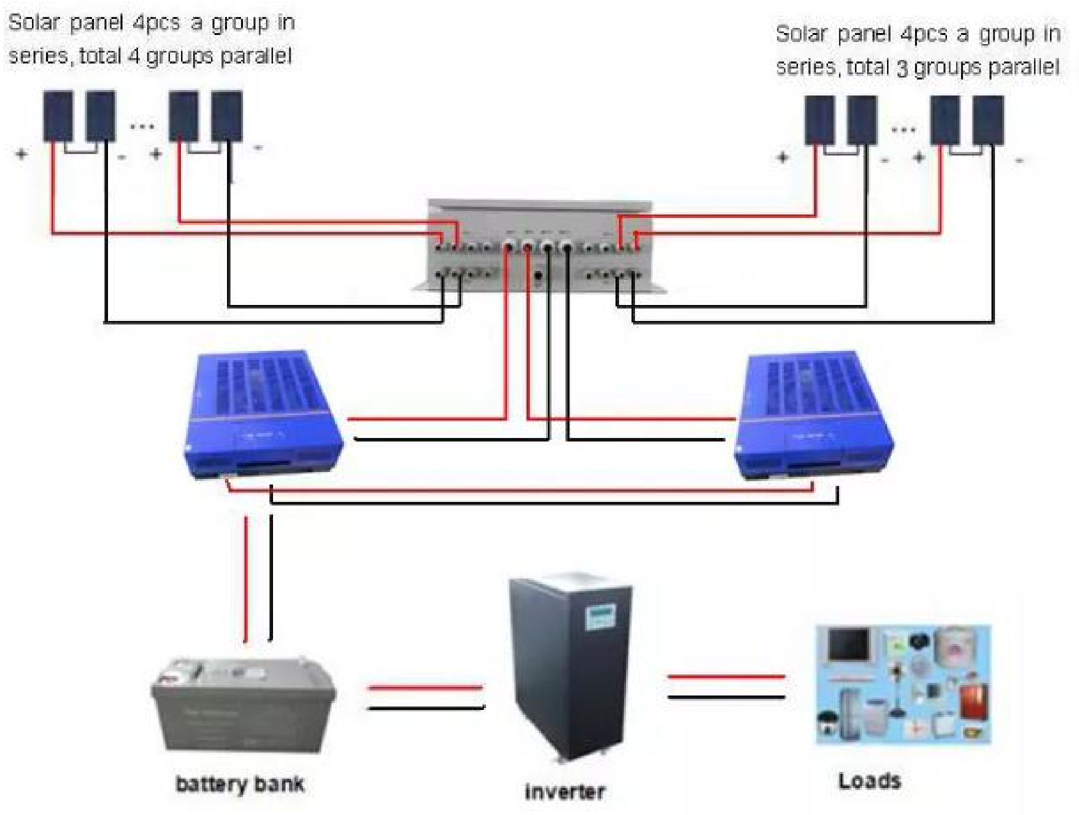
EXAMPLE ON PV SIZING

5- Power needed per hour from panels at 5 hours of sun=35.29/5=7 kw.

6- PV Panel available

Pm=250 watt, voc=30v, isc=8.3 A.

No of panels=7000/250=28 panels.



EXAMPLE ON PV SIZING

7- batteries :we need to find days of autonomy where sun is not available.

Assume 1 days of autonomy.

Battery AH required= (Total kwh entering battery*Days of autonomy)/(Volt*DOD)

DOD of battery= 80%, each battery 200 AH.

So AH required=35.29*1/12*0.8=3.67 KAH.

Number of series batteries=96/12=8 batteries.

Number of parallel=3670/8*200=2.29=2 strings of batteries batteries which equal to 16 batteries.

For charge controller , each PV panel is 30 V and 8.3 A.

We have 28 panels, we have in market 3.8kw charge controller with specification: 96v and 40 A.

2 of them wil give us 7.68kw.

First Group: 4 series and 4 parallel which is 16 panels Total current=4*8.3=33.2A

Total Voltage=4*30=120V.

Second Group: 4 series and 3 parallel is 12 panels.

Total current=3*8.3=25A

Total Voltage=4*30=120V.

$$E = A * r * H * PR$$

E = Energy (kWh)
A = Total solar panel Area (m2)
r = solar panel yield or efficiency(%)
H = Annual average solar radiation on tilted panels (shadings not included)
PR = Performance ratio, coefficient for losses (range between 0.5 and 0.9, default value = 0.75)

PV ENERGY ACCORDING

TO AREA

1- Find total area=number of panels*area of one panel.

2- to find radiation go to

https://power.larc.nasa.gov/data-access-viewer/

3- 0.75 for losses.

4- From the efficiency of panel table, get efficiency of panels.

Or go to this website with values for many companies: https://news.energysage.com/what-are-the-most-efficient-solarpanels-on-the-market/

DESIGN OF ON GRID

SYSTEM

Primary goal of a grid-tied PV system is to remove some or all of your electricity usage.

So we wil design according to our kwh of our load.

1- Determine monthly usage then calculate daily requirement.

2- Calculate array wattage.

3- Select array and size the inverter.

4- Size Protection devices.

Electric Usage History

Month	kWh	Month	kWh
Jul 13	2193	Feb 14	1212
Aug 13	2173	Mar 14	1166
Sep 13	1967	Apr 14	1146
Oct 13	1115	May 14	1384
Nov 13	1791	Jun 14	1550
Dec 13	1179		
Jan 14	1606		

DESIGN OF ON GRID

SYSTEM

Electricity bill throughout a year 1- Determine annual daily average=

Summation of all months kwh/365

=18485/365=50.6356 kwh/day

2- Remember to select tilt angle according to the Map which we discussed or accurate method.

3- Assume efficiency of system to be 77%

Due to losses in DC and AC wires, panels, mismatch, Diodes and connection, inverter,…..

4- Get the kw required from PV System

=Kwh/Peak sun hours=50.6356/4.5=11.254 KW.

Peak sun hours are from the map which we discussed before.

5- Considering system losses, P required= 11.254/0.77=14.615 KW.

DESIGN OF ON GRID

SYSTEM

So Based on my own budget or space, I only need to cut 50% of bil

So required power=14.615*50%=7.308 KW.

Available inverter should be equal or greater than PV Power, so available is 6kw

Or 8 kw , so I wil choose 8 kw.

This inverter has input DC from at 300-480V.

we wil choose 360 volt as average.

Pm=300 watt, voc=27v, isc=11.1 A.

No of panels=7308/300=24.36=25 panels.

Number of series panels=360/27=13.3=13 series panels.

Number of parallel=25/13=1.92=2 parallel.

Number of panels=2*13=26 panels.

So power=26*300=7.8 kw < inverter kw.

PROTECTION OF INVERTER

• **Overload Protection:** Inverter Must have overload Protection Circuit which works Automatical y, to trip the whole circuit against power overloading.

• when incoming power reaches beyond the Set Value, Overload Protection Circuit should give automatic trip to the DC Circuit as well as Breaker on the AC Side.

• **Over Temperature Protection:** It is termed as thermal Protection System. When power reaches beyond set value, then internal components of the Inverter gets heated and it starts to melt.

• To Prevent this problem, Proper Heat Sensing Device should present in the Inverter.

• **Ground Fault Protection:** Earthing is mandatory for all Electrical Equipment. Inverter acts as a Main source for the solar pv plant.

• It should be Earthed with Two Distinctive Earth Pits with proper cable size.

• **Short Circuit Protection:** This problem wil happen either DC

side or AC side. Inverter wil Cut-off the Circuit Automatical y when Inverter detects Short Circuit happens either DC or AC.

• **Output Over Voltage & Under Voltage:** Most of the Three Phase Grid Inverter having AC Output voltage Range as 350V - 415V.

• Inverter should Automatical y shut down the Internal Circuit, if Inverter experiences Either Over Voltage or Under Voltage problem at the Output end with the Grid.

• Inverter should incorporated with Proper Alarm Signal, specifical y for Under Voltage and Over Voltage problem.

• **Anti-Islanding:** Inverter should Automatical y Cut - off the Circuit, If the Grid Connection is Cut-off.

• Inverter Should not feed the power, if Grid is not available.

• Inverter, with an anti-Islanding function, which senses when a power outage occurs and shuts itself off.

PROTECTION OF

TRANSFORMER

• **Over Voltage [59]:** The Breaker Should Trip the Transformer from the Grid, When it experiences over voltage against set value. Otherwise Transformer Coil gets Damaged, due to high voltage presence.

• **Under Voltage [27]:** Proper Trip signal wil be given by the Breaker to the Master Trip Relay, if Breaker Experiences under voltage against Set Value.

• **Over Frequency [81O]:** Standard Frequency in the AC

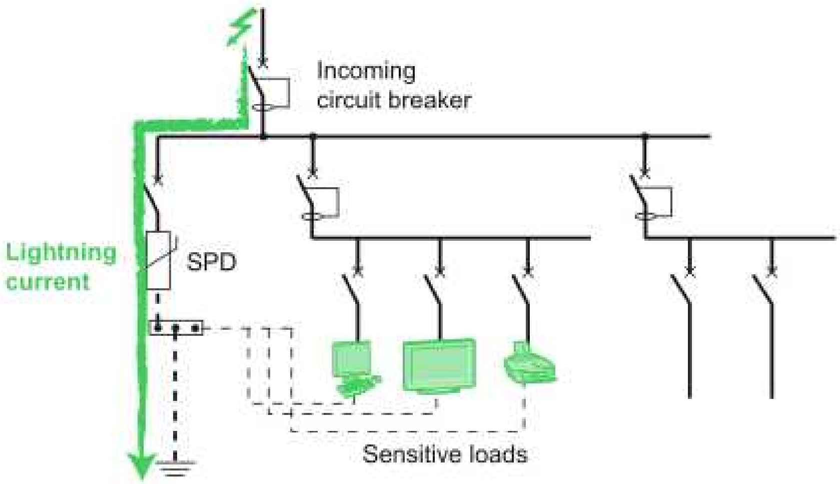
Power System is 50Hz in all the Countries except America

[Their Frequency level is 60Hz]. Breaker experiences over frequency say 51 to 53Hz, Breaker wil give trip signal to the Master Trip Relay, to shut down the system.

• **Under Frequency [81U]:** Breaker experiences under frequency say 47 to 49Hz, Breaker wil give trip signal to the Master Trip Relay, to shut down the system.

• **Instantaneous Over Current & Earth Fault [50 / 51]:** This Relay works based on the Current sensed by the Current Transformer. Here Voltage wil not takes place. Ideally, the relay operates as soon as the current in the coil gets higher than pick up setting current. There is no intentional time delay applied. Operating Time for this relay is of the Order of a few milliseconds.

• **IDMT Over Current & Earth Fault [50N / 51N]:** IDMT Termed as Inverse Definite Minimum Time lag, This relay having higher resolution when compare than Instantaneous, it operates when CT gets saturated, due to the fault current presence. This relay wil operate as quick as to trip the circuit against Over Current and Earth Fault.


Incoming
circuit breaker
Lightning
current
SPD
Sensitive loads

SURGE PROTECTIVE DEVICE

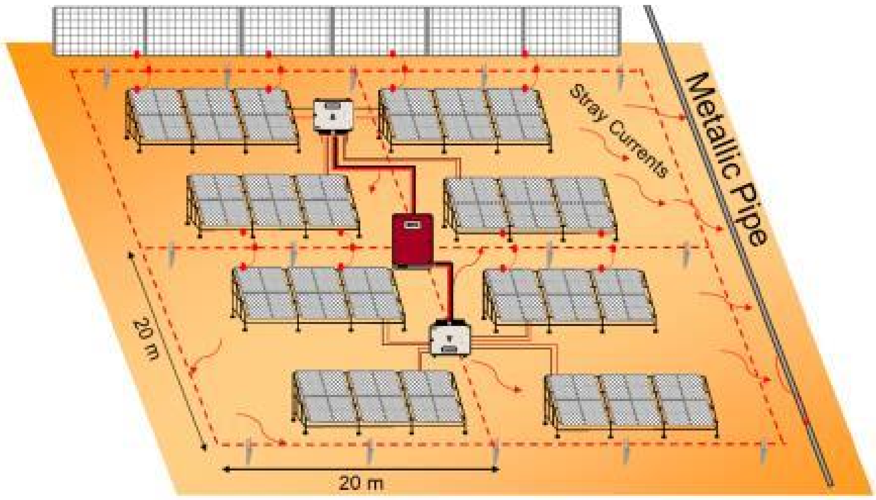
• The Surge Protection Device (SPD) is a component of the electrical installation protection system.

• SPD is designed to limit transient over voltages of atmospheric origin and divert current waves to earth

• According to standards a surge protective device should be at the entrance of the Inverter.

When installing a solar PV system, it is extremely important all the equipment is grounded correctly. Failure to ground the entire system to include all the individual pieces, can be devastating, especially in an area that experiences lightning on a regular basis. Earthing offers following advantages:

- **It forms a primary line of protection for equipment and the operator from the damaging effects of fault current.**
- **It provides safe path to dissipate lightning current, short circuit current, fault or leakage current to the ground.**
- **It offers stable platform for operation of electrical equipments.**



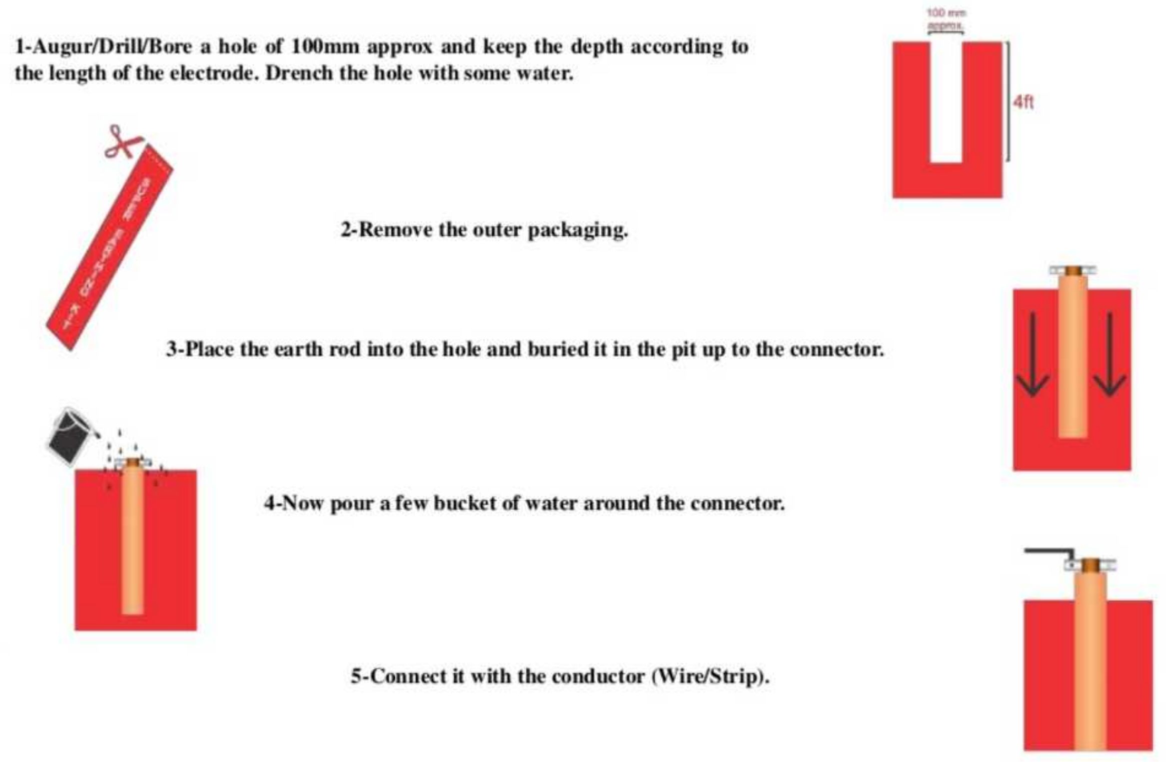
Metallic Pipe
Stray Currents
20 m
20 m

GROUNDING

An innovative solution designed specifically for solar panel grounding for doing hassle free, reliable and economical grounding. Based on Solid Rod Technology, Solar Earthing Kit works in extreme soil conditions, providing a low impedance path to the excessive current to dissipate easily into the ground.

▪**Made up of solid steel rod with 250 micron coating 99.99% pure copper.**

▪**Excellent Fault Current Carrying Capacity upto 18 kA.**

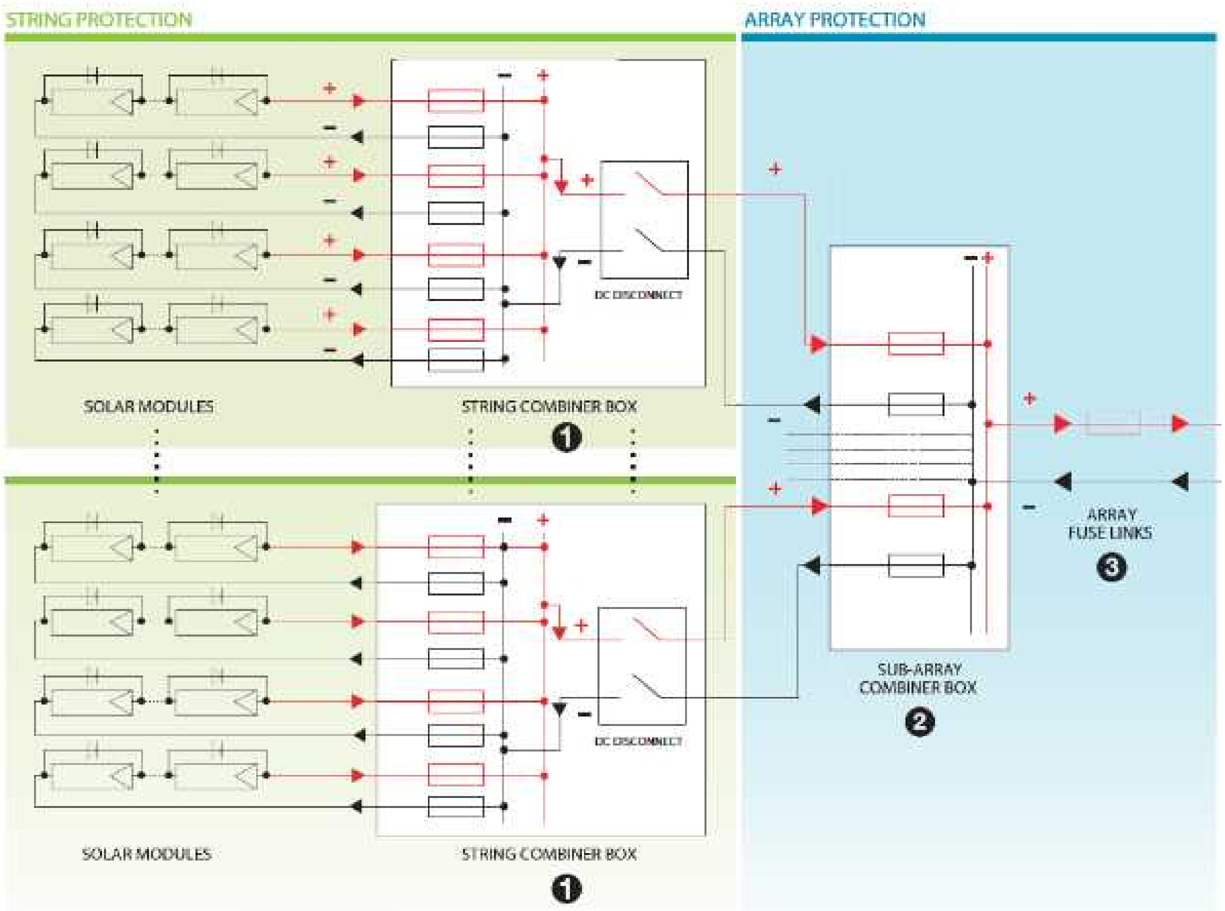


SOLAR

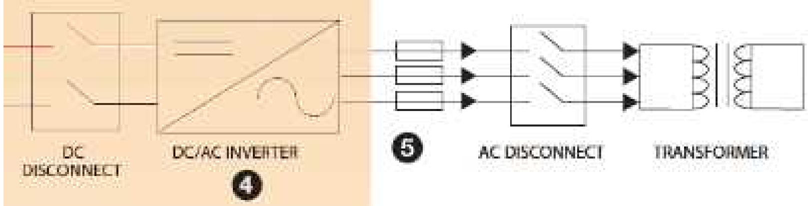
EARTHING KIT

INSTALLING THE SOLAR

EARTHING KIT



NVERTER PROTECTION



XL Photovoltaic
Fuse Links & Fuse Bases

2 3

Square Body, BS & UL
High Speed Fuse Links

4

NH Low Voltage
Fuse Links & Fuse Holders

5

PVM, 10 x 38, 14x51,14x65
Photovoltaic Fuse Links

1

CHPV
Fuse Holder

1

In-Line
Fuse Holder

1

BM Series
Fuse Block

1

Surge Protective
Device

1 2 3

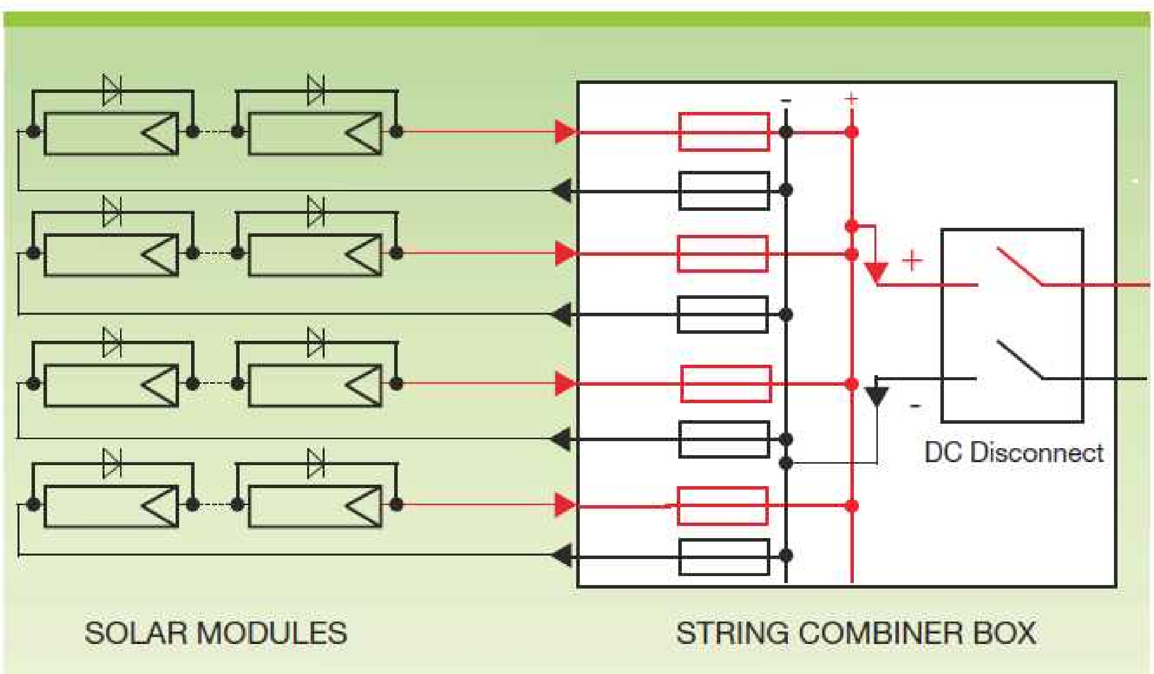
Wireless

1

NH Photovoltaic
Fuse Links & Fuse Holde

2 3

PROTECTION OF PV SYSTEM



STRING PROTECTION

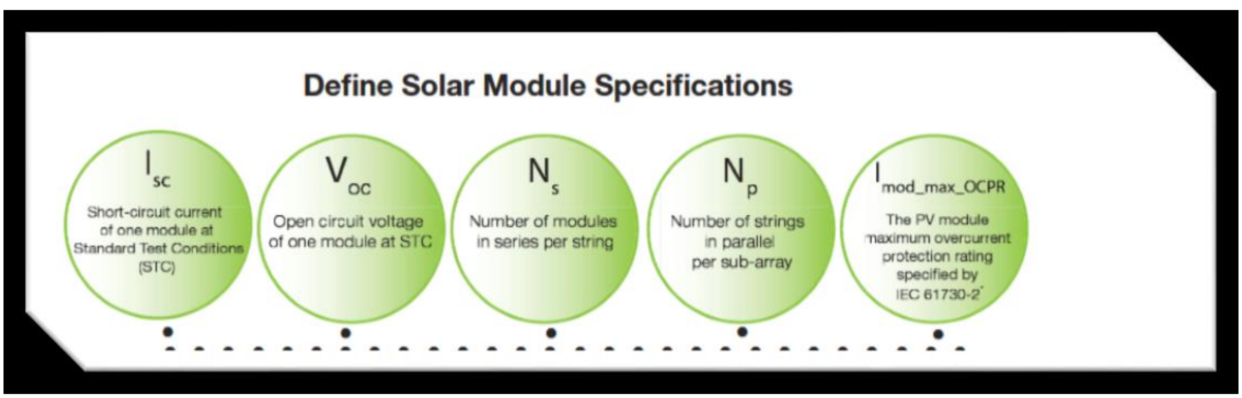
• PV systems that have three or more strings connected in parallel need to have each string protected.

• Systems that have less than three strings wil not generate enough fault current to damage the conductors, equipment or modules.

• Where three or more strings are connected in parallel, a fuse link on each string wil protect the conductors and modules from overcurrent faults.

• It wil also isolate the faulted string so that the rest of the PV

system can continue to generate electricity.



If $N_p \geq 3$

The fuse link's ratings should be selected as follows:

- Voltage rating $\geq 1.20 \times V_{oc} \times N_s$
- Current rating $> 1.56 \times I_{sc}$
- Current rating $\leq I_{mod\_max\_OCPR}$

If $N_p < 3$ and the cable is rated at $1.56 \times I_{sc}$

For PV installations with only one or two parallel strings and string cables adequately sized, fusing may be needed if local installation regulations or codes require them.

If $N_p < 3$ and the cable is not rated at $1.56 \times I_{sc}$

Select fuse link to protect cable:

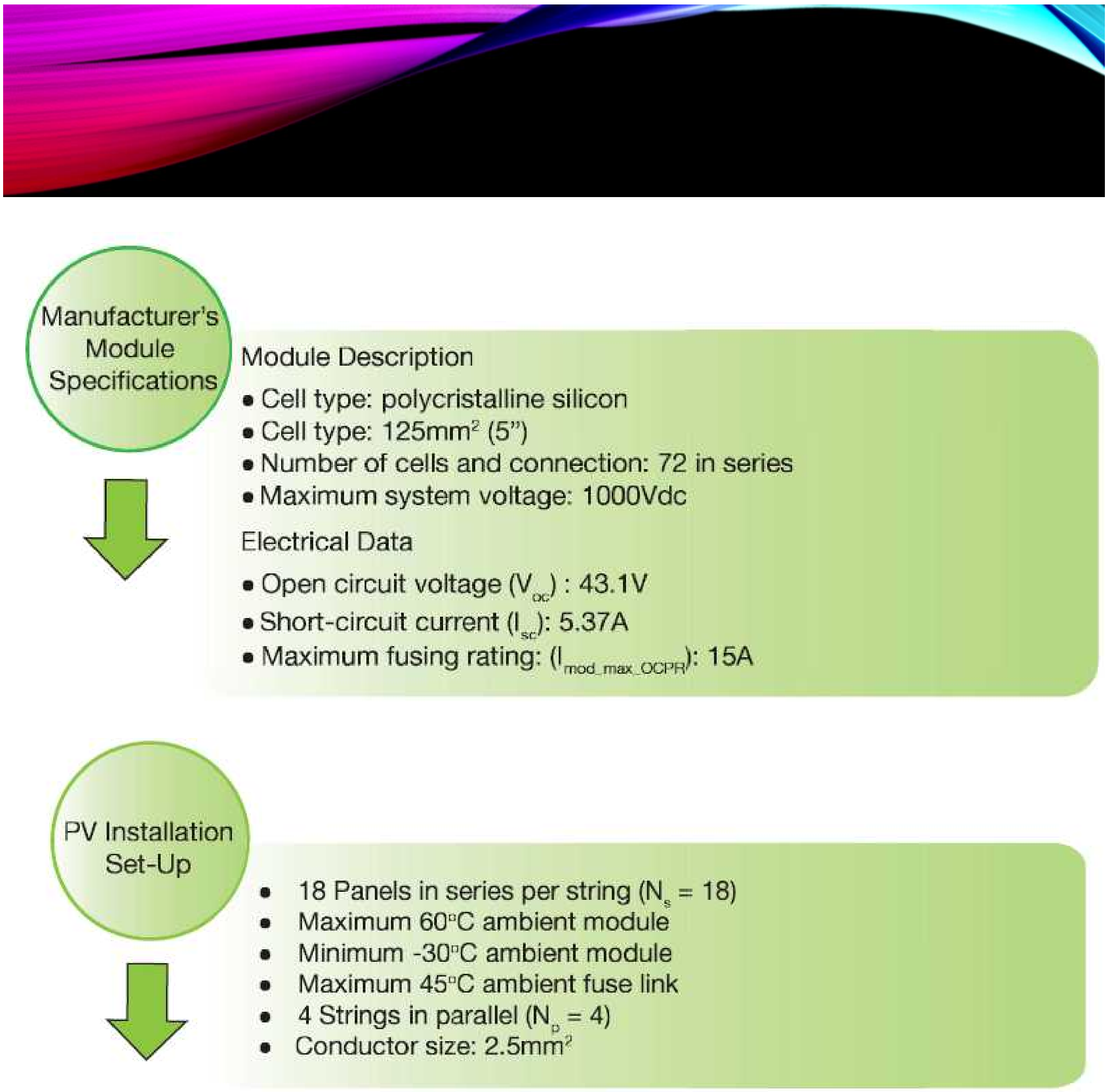
- Fuse link current rating $\leq 1I_{z''}$ = string cable rating
- Voltage rating $\geq$ l.20 x V_{oc} x N_s especially if a battery is connected

HOW TO SELECT FUSE

LINKS FOR STRING

PROTECTION

Whilst a full study of all the parameters is recommended, the fol owing factors should be used: 1.56 for current and 1.2 for voltage when selecting the fuse link which covers most variation(module temperature as well as the amount of sun it is exposed to, incline as well as shading effect from trees/buildings or clouds. In operation, fuse links, as thermal devices, are influenced by ambient temperature.) due to installation.



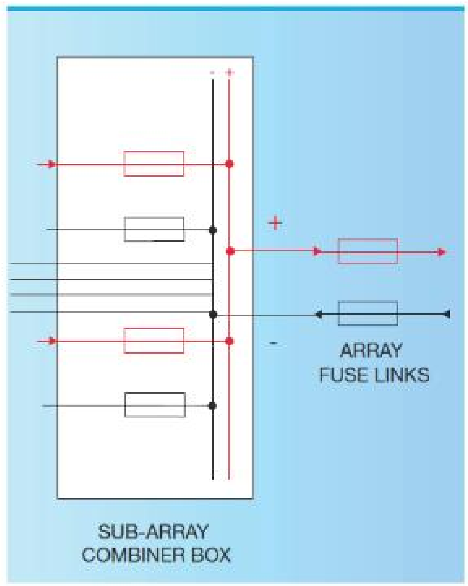
Calculation

- Conductor size formula ≥ 1.56 x I_{sc} = 1.56 x 5.37 = 8.38A
- Conductor size: 2.5mm^2 = 11.5A at 60^{o}C

- I_n ≥ 1.56 x I_{sc} = 8.38A min fuse rating
- Maximum system voltage = 120% x V_{oc} x N_s
  = 120% x 43.1 x 18 = 931V

The fuse link required needs to be 1000Vdc and 10A.

STRING WORK EXAMPLE



Surge Protective Device
NH PV Fuse Links
NH Fuse Holders
XL PV Fuse Links
XL PV Fuse Base

ARRAY PROTECTION

Manufacturer's Module Specifications

- V_{oc} = 43.1V
- I_{sc} = 5.37A

PV Installation Set-Up

- 18 Panels in series per string (N_s = 18)
- Maximum 60°C ambient module
- Minimum -30°C ambient module
- Maximum 45°C ambient fuse link
- Sub-array sub-conductor size: 10mm²
- 3 Sub-array in parrallel (N_{sub} = 3)

Calculation

- Conductor size formula ≥ $1.56 \times I_{sc} \times N_p$
  $= 1.56 \times 5.37 \times 8 = 67A$
- Conductor size: 10mm² = 98A at 60°C
- Fuse link voltage rating ≥ $1.2 \times V_{oc} \times N_s$
  $= 1.2 \times 43.1 \times 18 = 931V$

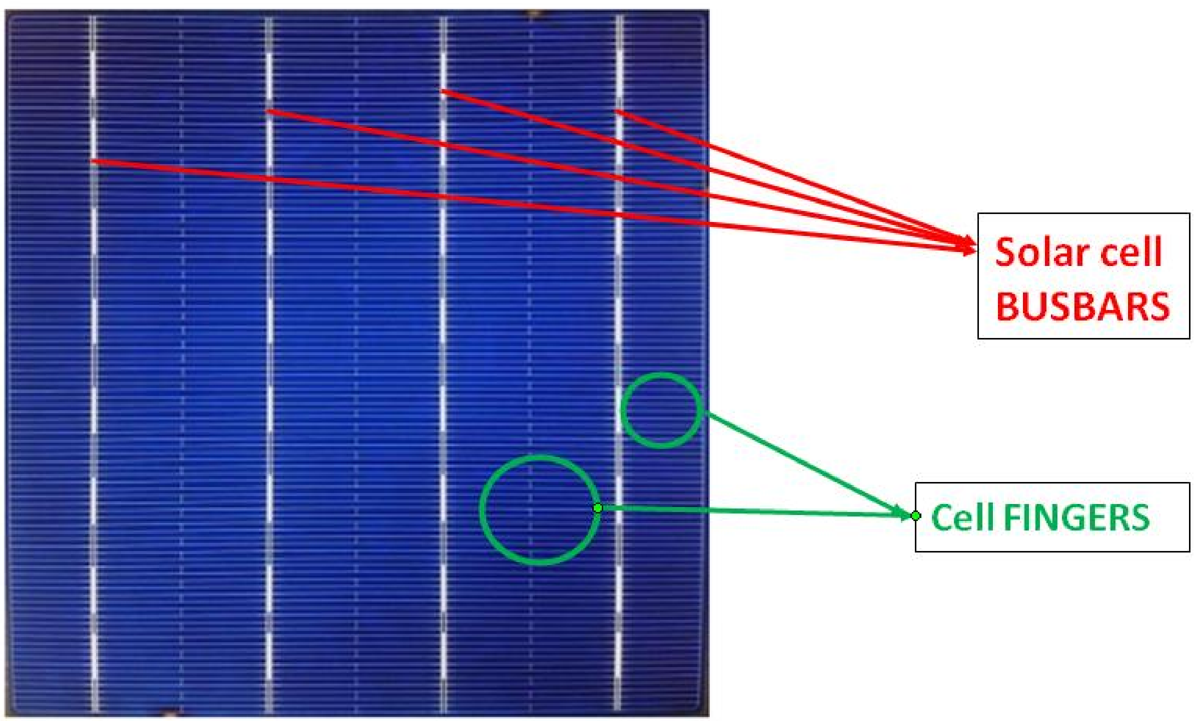
Therefore, select standard rating of 80A:

$1.56 \times I_{sc} \times N_p \times N_{sub} = 1.56 \times 5.37 \times 8 \times 3 = 201A$.

Therefore, a 250A fuse

ARRAY PROTECTION -

WORKED EXAMPLE



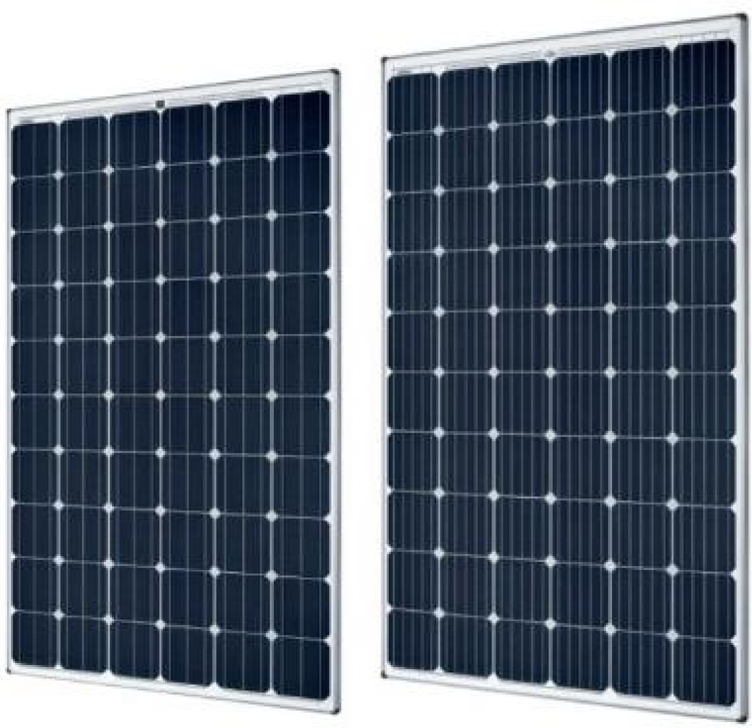
BUSBARS IN PV

SYSTEM

• The purpose of busbars in solar cells is to conduct the electric DC power generated by the cell when photons hit the cells.

• They are the wires that connect each cell to the other, allowing the current to flow.

• Basical y the fingers col ect the generated DC current and deliver it to the busbars.



3BUS BARS VS 5 BUS BARS

• Additional busbars creates lower resistance between cells.

Ohms Law tells us that as resistance (ohms, R, or Ω) go down, the current (amps) goes up. And when current goes up for the same voltage, power (which is volts times amps) goes up.

• This increased number of busbars **reduces the internal resistance losses**

• The result of the additional busbars is that the solar panels are about 2% more efficient

•

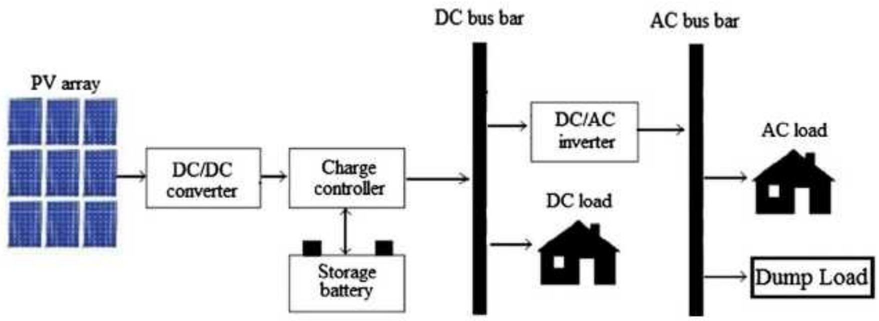


Fig. 1. A typical basic components of a standalone PV system.

BUS BARS IN PV SYSTEM

An electrical bus bar is defined as a conductor or a group of conductor used for col ecting electric power from the incoming feeders and distributes them to the outgoing feeders.

The most common of the bus-bars are 40×4mm (160 mm2); 40×5 mm (200 mm2) ; 50×6 mm (300mm2) ; 60×8 mm (480

mm2) ; 80×8 (640 mm2) and 100×10 mm (1000 mm2).

$$(1.25 \times \text{Inverter FLA}) + \text{Main OCPD} \leq \text{Bus Rating} \times 1.20$$

SELECTION OF DC BUS BAR

• Rating wil be equal to or greater than Fuse of Array

• Ratings of Bus Bars are

100,250,400,500,750,1000,1250,1600,2000,2500,3000,4000 A

SELECTION OF AC BUS BAR

• According to NEC

• **The code:**

Where two sources, one a utility and the other an inverter, are located at opposite ends of a busbar that contains loads, the sum of 125% of the inverter(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed 120% of the ampacity of the busbar.

• **(Busbar Rating (A) x 1.2) - Main Breaker Rating (A) = Max PV**

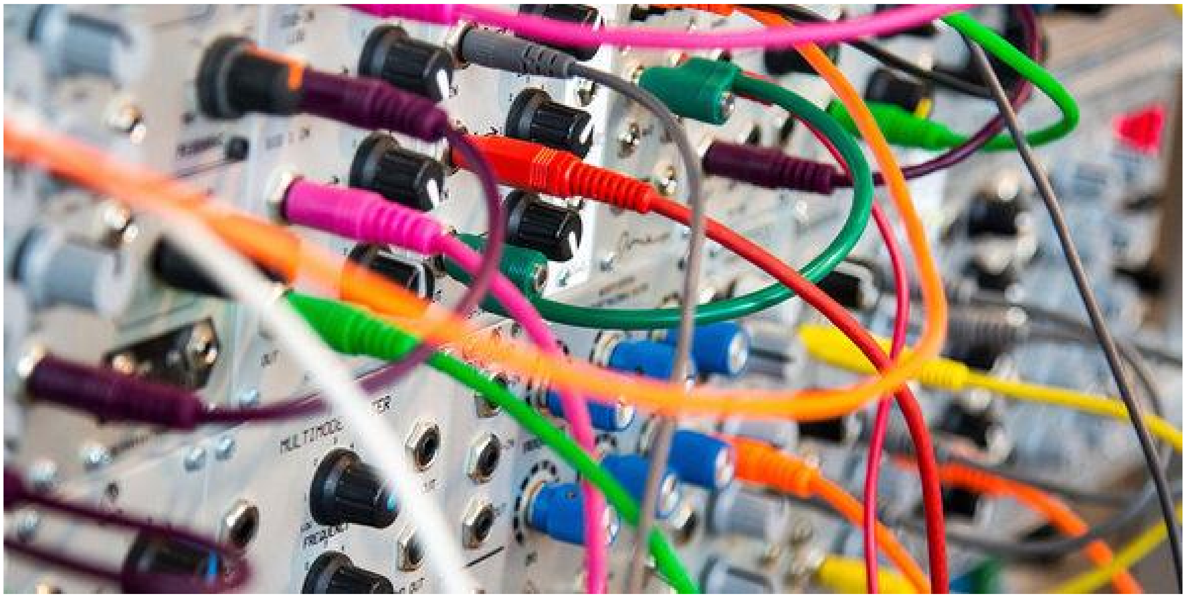
(A)

• We have a 200 Amp bus rating for our service panel. In it, we have a 200 Amp main breaker.

•

200A x 1.2 - 200A = 40A

• the maximum output of our PV system can be 40A or approximately 9.6kW (40x240Volt)



YouTube Channel

https://www.youtube.com/channel/UCwJ4

Dv-AqT8Ei-k_0PLv8ZQ

ABOUT THE AUTHOR

Ahmed Mahdy is an electrical power engineer, Instructor at Udemy, Skil share, Stackcommerce and Stacksocial with 13 courses and 7 Bestsellers.

He has a YouTube educational engineering channel called “Khadija Academy”, he regularly posts videos related to electrical engineering.

He also created Khadija Academy website in 2019, His Mission is " ***Learn the Fundamentals of Electrical***

Engineering Branches from absolute Beginner to

Advanced level."