

PROFESSIONAL TRAINING REPORT
at
Sathyabama Institute of Science and Technology
(Deemed to be University)

Submitted in partial fulfilment of the requirements for

Professional Training –I of
Bachelor of Engineering Degree in
Electrical and Electronics Engineering

By

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS
SCHOOL OF ELECTRICAL AND ELECTRONICS
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VATIO ENERGY INDIA PRIVATE LIMITED

VATIO Energy is an efficiency-driven entrepreneurship inspired by a vision of creating a greener tomorrow by harnessing the power of solar energy. In doing so, we seek to improve our customers' daily lives by significantly reducing your electricity bills.

VATIO has provided solar panels and inverters to large corporations and government agencies, and has also helped thousands of individual homeowners with tailor-made solar and energy systems.



1.SOLAR ENERGY

1.a.What is solar energy?

Solar energy is radiant light and heat from the Sun that is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaics, solar thermal energy, solar architecture, molten salt power plants and artificial photosynthesis.



1.b.Why solar energy?

Energy from sun is free and the sun will continue to shine for billions of years to come. While the solar energy is inexhaustible and renewable, its irradiance is environment-friendly. The solar power system does not emit CO₂, which is environmentally damaging. In addition, silicon, the raw material in making solar cells, is the second most abundant element in the earth's crust. Since the solar industry has been developing and the technology is maturing, the PV power systems are efficient for both commercial and residential use. The price of PV systems is also more affordable now due to recent price cuts.

In contrast, fossil fuels, as our main sources of energy, are depleting. Our high dependence on fossil fuels is inevitably going to push up their prices

continuously until they are used up. Fossil fuels are nonrenewable and environmentally damaging. Recent climate change is in part a

consequence from the increased CO₂ concentration in the atmosphere caused by burning fossil fuels.

Therefore, it is essential for us to seek alternative renewable energy resources for guaranteed energy supply and environmental protection. Solar is the answer.

How solar energy compares to other renewable sources of energy

➤ Solar Energy versus Wind:

Despite wind technology being in the market for a long time, it has experienced some issues. The initial power gathered from wind is less expensive to produce, but wind turbines require much more maintenance than photovoltaic cells. Also, wind generating plants are set up at distant locations, with little or no access to the actual consumer. The discoms (distribution companies), for the fear of losing business, have levied huge wheeling charges over the years, which has made the proposition unviable in recent times.

They are also more disruptive than their solar counterpart, since they are prone to making lots of noise

➤ Solar Energy versus Hydro :

Hydroelectricity, though effective, is generally supplied through the use of large dams which also mean initial installation cost will be very high. Also, building a dam has the ability to alter an entire ecosystem. Hydro plants often change the natural flow of the waterways they take over, creating new lakes and reducing water flow downstream. These installations can also affect wildlife in the area, blocking fish migration and altering habitats.

Photovoltaic panels, on the other hand, do not change the environment and are small in comparison to dams. One of the advantages of solar power is its versatility. A land or roof installation can be set up in regions that many would think don't receive enough sunlight.

➤ Solar Energy versus Biomass

Burning biomass to generate electricity has some appeal as biomass is renewable in some sense. However, the logistics and overall energy balance undermine this argument, as a lot of energy – mostly oil based – is required to harvest and move the crops to the power station.

The use of biomass, such as the burning of wood, waste, alcohol fumes, or landfill gases produces less waste energy than fossil fuels or coal.

Unfortunately, biomass creates volatile organic compounds like carbon monoxide and nitrogen oxides. On the positive side, its pollution is modest in comparison to traditional fuels. Photovoltaic cells prove superior again in that they create no emissions and do not require land that could be used for crops.

In addition, solar panels have efficiencies as high as 19%, meaning that much of the sun's energy is converted into electricity. The efficiency of biomass is much, much lower – perhaps less than 1%. Solar energy is at par with the grid tariffs for most commercial and industrial consumers in India. If you've been thinking about going solar, now is the time to make the change. Government financial incentives are still ripe for the picking, and you stand to gain a lot as one of the early adopters of solar energy. Adding solar power plant in your factory is an excellent project for several reasons: You'll save loads on electricity, you'll reduce your carbon footprint; and if you're installing in a remote location (such as a cabin), you'll have much less to worry about than you would with a gasoline generator. You'll also support a growing industry, and in doing so, help contribute to the worldwide adoption of this wonderful new energy source.

2.SOLAR PV

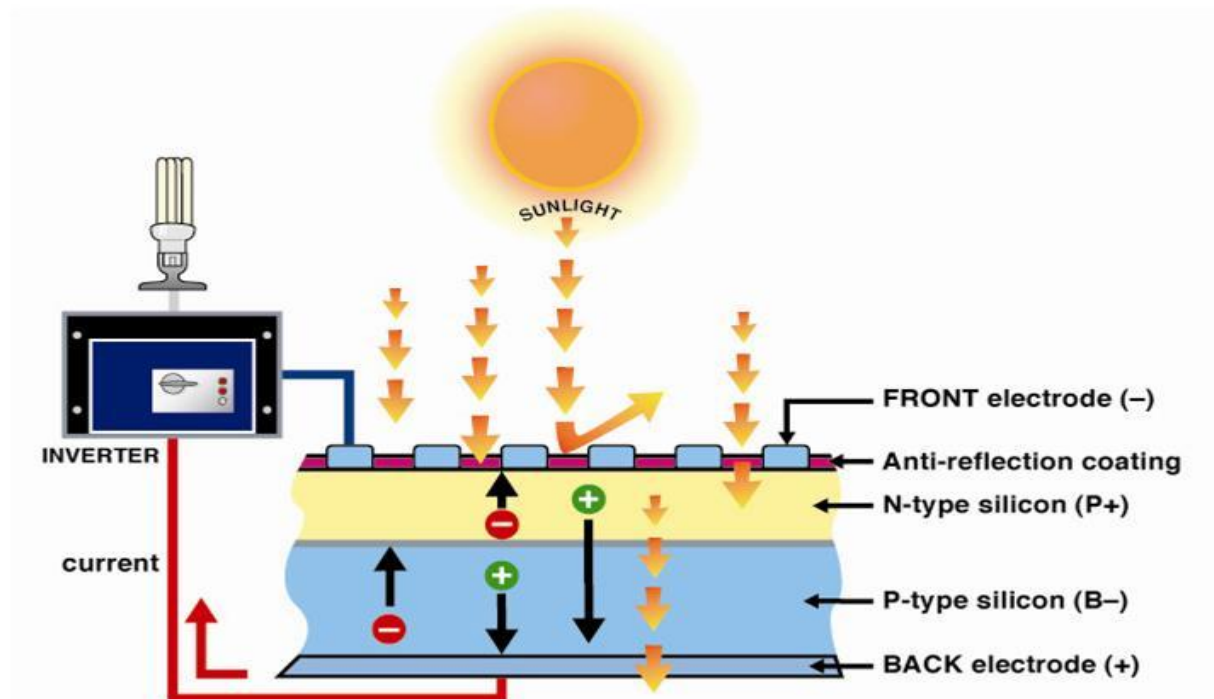
2.a.Working Principle of Solar PV

Principle of solar energy: The Photovoltaic effect

Photovoltaic (PV) effect is the conversion of sunlight energy into electricity. In a PV system, the PV cells exercise this effect. Semi-conducting materials in the PV cell are doped to form P-N structure as an internal electric field. The p-type (positive) silicon has the tendency to give up electrons and acquire holes while the n-type (negative) silicon accepts electrons. When sunlight hits the cell, the photons in light excite some of the electrons in the semiconductors to become electron-hole (negative-positive) pairs. Since there is an internal electric field, these pairs are induced to separate. As a consequence, the electrons move to the negative electrode while the holes move to the positive electrode. A conducting wire connects the negative electrode, the load, and the positive electrode in series to form a circuit. As a result, an electric current is generated to supply the external load. This is how PV effect works in a solar cell.

How the Electricity is Converted for use

Direct Current (DC) needs to be converted into alternating current (AC) so it can be used in a domestic building; this is performed by an inverter. The AC electricity then passes via the generation meter, which measures how much electricity has been created, and on to the consumer unit where it can be fed into the property for use or exported back to the national grid via the electricity meter.



2.b Solar PV systems are categories into

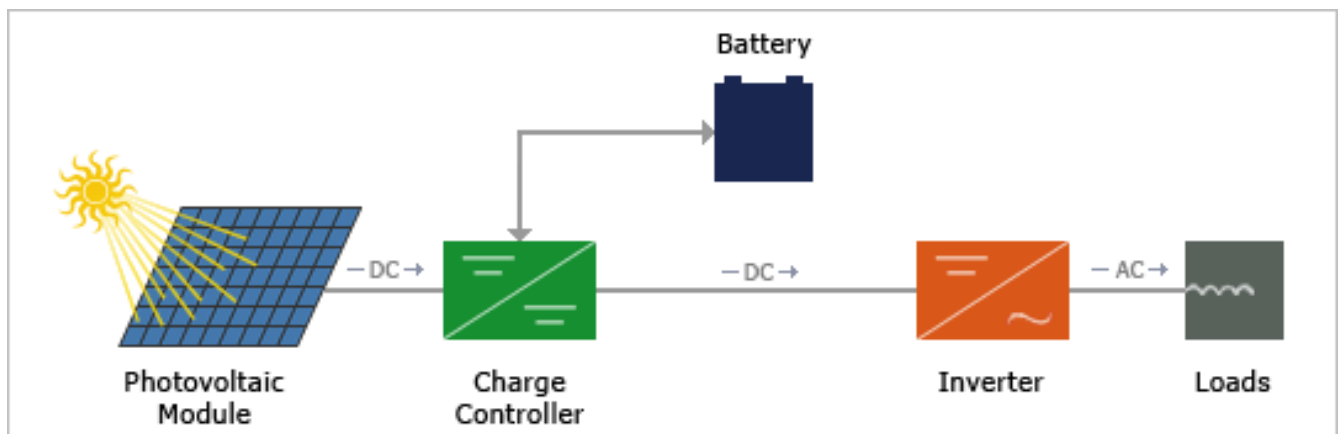
- Stand – alone PV system (also called off-grid systems)
- Grid connected PV system (also called on-grid systems)
- Hybrid systems

1. Stand-alone PV systems :

Stand-alone systems are not connected with utility power lines and these are self sufficient systems. These systems could either be used to charge the batteries that serve as an energy storage device or could work directly using the solar energy available in the daytimes. These systems consist of the following:

- Solar panels mounted on the roof or in open spaces. Photovoltaic modules produce direct current (DC) electrical power.
- Batteries to store DC energy generated by the solar panels.
- Charge controller to prevent overcharging the battery.
- Inverter to convert electricity produced by the system from DC to AC power

The following diagram shows PV system powering AC loads with battery bank. DC loads can also be connected directly to the battery bank. It is also possible to power the AC load without battery, but in that case it would be confined only to daytime when solar radiation is sufficient to generate required electricity.

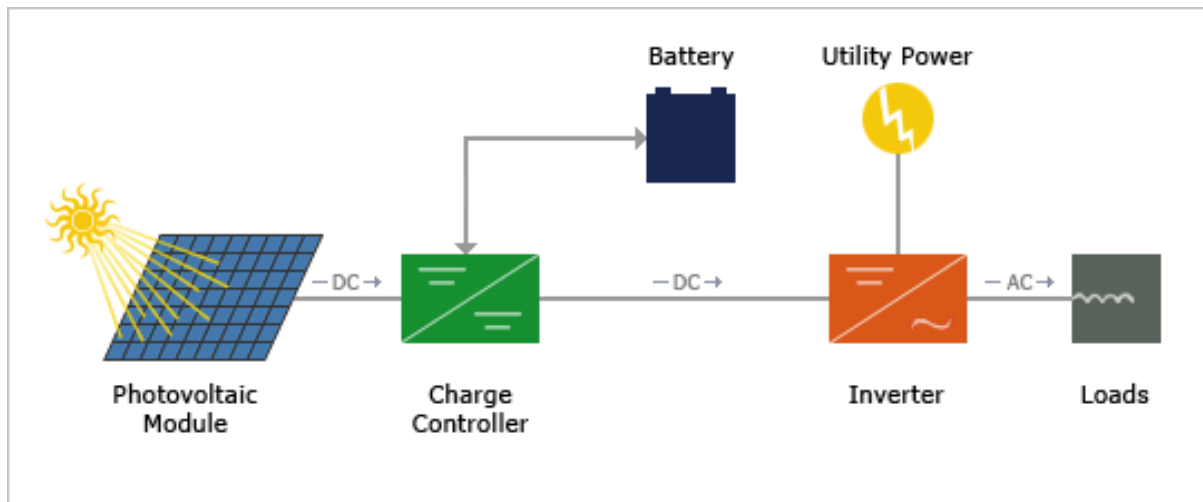


2.Grid connected PV systems :

A grid connected photovoltaic system will be interacted with utility grid. The main advantage of this system is that power can be drawn from the utility grid and when power is not available from grid, PV system can supplement that power. These grid connected systems are designed with battery or without battery storage. These systems consist of the following:

- Solar panels mounted on the roof or in open spaces. Photovoltaic modules produce direct current (DC) electrical power.
- Batteries to store DC energy generated by the solar panels.
- Charge controller to prevent overcharging the battery.
- Specially designed inverter to transform the PV generated DC electricity to the grid electricity (which is of AC) at the grid voltage.

The following diagram shows PV system powering AC loads. This system is connected to utility power supply and having battery storage for backup.

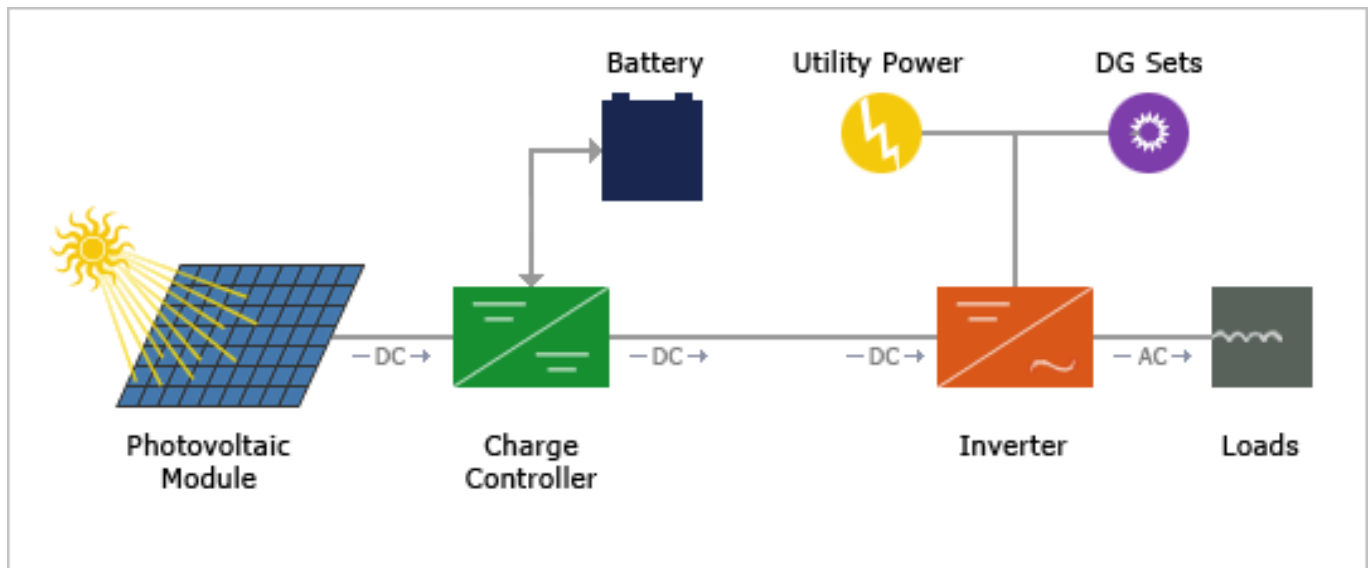


3. Hybrid systems :

System with more than one source of power is called Hybrid system. It is often desirable to design a system with additional source of power. The most common type of hybrid system contains a gas or diesel powered engine generator. Another hybrid approach is a PV/Wind system. Adding a wind turbine to a PV system provides complementary power generation. These systems consist of the following:

- Solar panels mounted on the roof or in open spaces. Photovoltaic modules produce direct current (DC) electrical power.
- Batteries to store DC energy generated by the solar panels.
- Charge controller to prevent overcharging the battery.
- Specially designed inverter to transform the PV generated DC electricity to the grid electricity (which is of AC) at the grid voltage.

The following diagram shows PV system powering AC loads. This system is connected to utility power supply & diesel generator and having battery storage for backup.



2.cThe Main Elements in a Solar PV System

a. Photovoltaic Solar Panels or Tiles

Solar panels form the heart of every PV system. We are able to offer a choice of industry leading solar panels made by Solarworld AG, LG, Axitec, SunForte, BenQ, Panasonic, Phonosolar REC, kyrocera, as well as award winning traditional solar slates, manufactured in Wales by Solar Slate Ltd.



b. Inverters

Inverters convert the DC current produced by the solar panels into AC current which is then fed into the electricity supply for use in the home, with any surplus electricity fed back into the national grid. We supply and fit industry leading inverters from SMA, Schneider, PowerOne, Samil Solar River and Solis, Plus Enphase Micro Inverters when necessary .



c. Generation Meters / MonitoringSystem

In order to conform to regulations and qualify for feed in tariff payments you need a meter or system that will accurately register the total kWh of PV electricity generated by the solar panels. We offer a range of compliant systems from industry leaders SMA



d. Mounting System

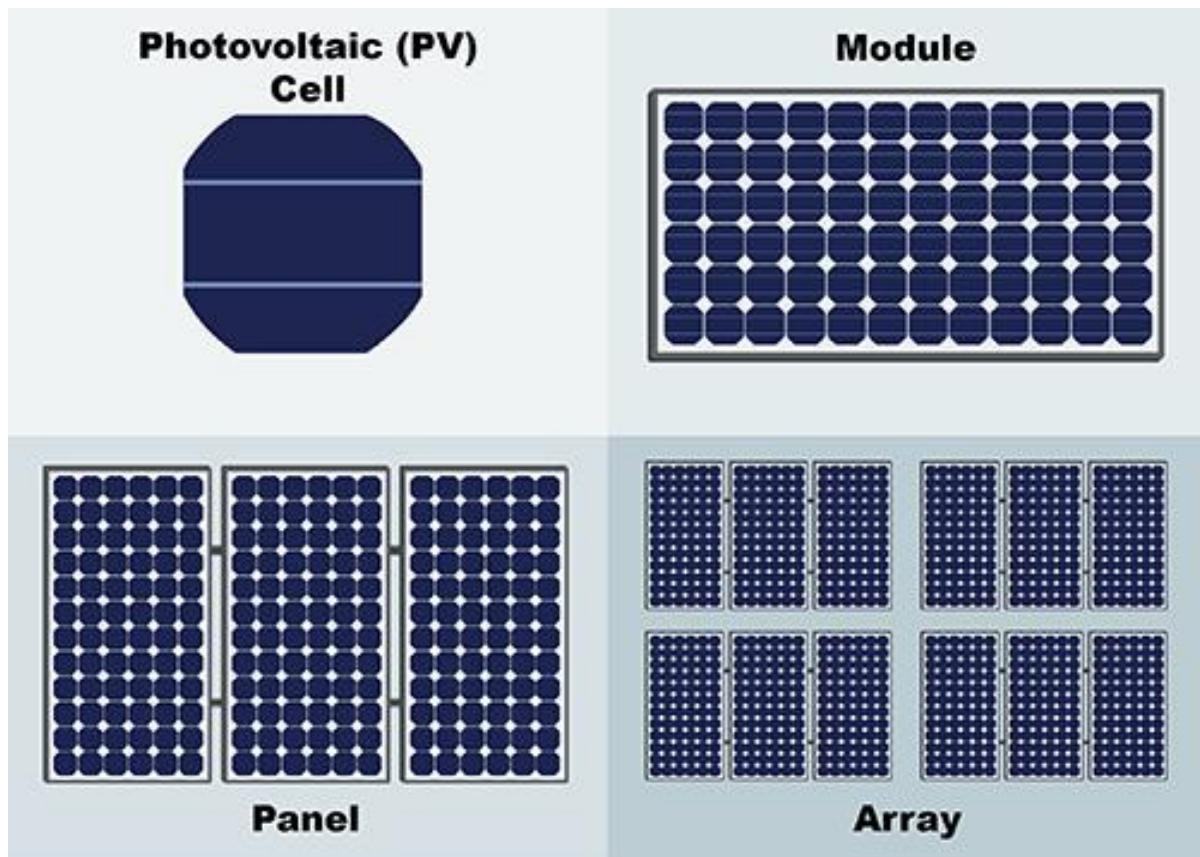
We offer solar panel mounting systems from Fischer, Schletter and K2 that allow us to mount the panels in a place that suits your requirements – whether that is on top of your existing roof tiles (on roof), flush with roof tiles (in roof) or on a flat roof or the ground



2.d.Solar PV Array

If photovoltaic solar panels are made up of individual photovoltaic cells connected together, then the **Solar Photovoltaic Array**, also known simply as a Solar Array is a system made up of a group of solar panels connected together. A photovoltaic array is therefore multiple solar panels electrically wired together to form a much larger PV installation (PV system) called an array, and in general the larger the total surface area of the array, the more solar electricity it will produce.

A complete photovoltaic system uses a photovoltaic array as the main source for the generation of the electrical power supply. The amount of solar power produced by a single photovoltaic panel or module is not enough for general use. Most manufacturers produce standard PV panels with an output voltage of 12V or 24V. By connecting many single PV panels in series (for a higher voltage requirement) and in parallel (for a higher current requirement) the PV array will produce the desired power output.



3.INVERTERS

3.a.Working Principle

A solar inverter can be defined as an electrical converter that changes the uneven DC (direct current) output of a solar panel into an AC (alternating current). This current can be used for different applications like in a viable electrical grid otherwise off-grid electrical network.

In a PV system, it is a dangerous BOS (balance of system) component that allows the utilization of normal AC powered apparatus. These inverters have some functions with PV arrays like tracking of utmost PowerPoint & protection of anti-islanding. If we are using a solar system for a home, the selection & installation of the inverter is important. So, an inverter is an essential device in the solar power system.



3.b.Types of Inverters

Solar inverters may be classified into three broad types:

- i. Stand-alone inverters, used in isolated systems where the inverter draws its DC energy from batteries charged by photovoltaic arrays. Many stand-alone inverters also incorporate integral battery chargers to replenish the battery from an AC source, when available. Normally these

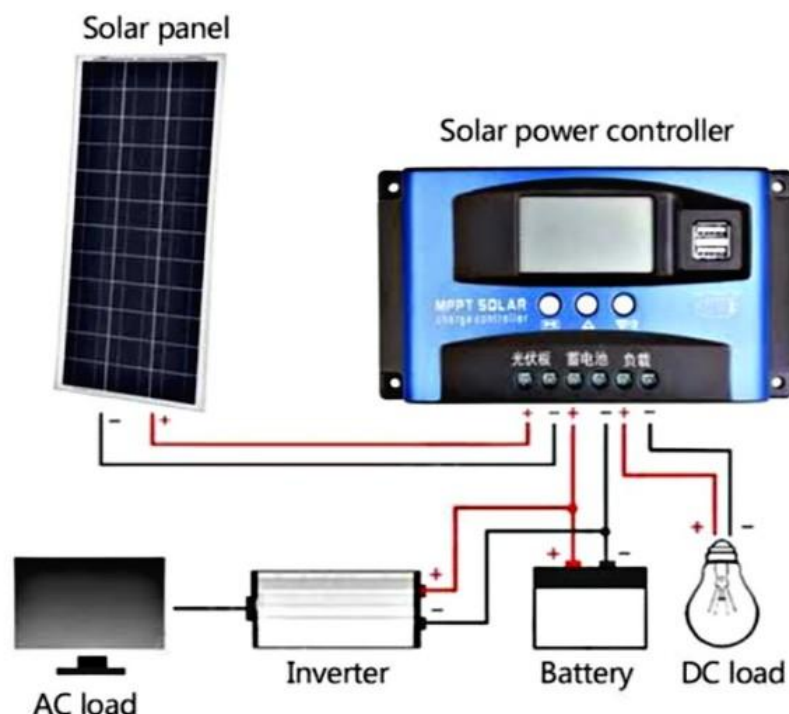
do not interface in any way with the utility grid, and as such, are not required to have anti-islanding protection.

- II. Grid-tie inverters, which match phase with a utility-supplied sine wave. Grid-tie inverters are designed to shut down automatically upon loss of utility supply, for safety reasons. They do not provide backup power during utility outages.
- III. Battery backup inverters, are special inverters which are designed to draw energy from a battery, manage the battery charge via an onboard charger, and export excess energy to the utility grid. These inverters are capable of supplying AC energy to selected loads during a utility outage, and are required to have anti-islanding protection.
- IV. Intelligent hybrid inverters, manage photovoltaic array, battery storage and utility grid, which are all coupled directly to the unit. These modern all-in-one systems are usually highly versatile and can be used for grid-tie, stand-alone or backup applications but their primary function is self-consumption with the use of storage.

4.CONTROLLERS

4.a.Functions of Controllers

The most essential charge controller basically controls the device voltage and opens the circuit, halting the charging, when the battery voltage ascends to a certain level. More charge controllers utilized a mechanical relay to open or shut the circuit, halting or beginning power heading off to the electric storage devices.



A solar charge controller is fundamentally a voltage or current controller to charge the battery and keep electric cells from overcharging. It directs the voltage and current hailing from the solar panels setting off to the electric cell. Generally, 12V boards/panels put out in the ballpark of 16 to 20V, so if there is no regulation the electric cells will damage from overcharging. Generally, electric storage devices require around 14 to 14.5V to get completely charged. The solar charge controllers are available in all features, costs, and sizes. The range of charge controllers is from 4.5A and up to 60 to 80A.

Generally, solar power systems utilize 12V of batteries. Solar panels can convey much more voltage than is obliged to charge the battery. The charge voltage

could be kept at the best level while the time needed to completely charge the electric storage devices is lessened. This permits the solar systems to work optimally constantly. By running higher voltage in the wires from the solar panels to the charge controller, power dissipation in the wires is diminished fundamentally.

The solar charge controllers can also control the reverse power flow. The charge controllers can distinguish when no power is originating from the solar panels and open the circuit separating the solar panels from the battery devices and halting the reverse current flow.

4.b.Types of Controller

There are three different types of solar charge controllers, they are:

- a. Simple 1 or 2 stage controls
- b. PWM (pulse width modulated)
- c. Maximum power point tracking (MPPT)

a. Simple 1 or 2 Controls:

It has shunt transistors to control the voltage in one or two steps. This controller basically just shorts the solar panel when a certain voltage is arrived at. Their main genuine fuel for keeping such a notorious reputation is their unwavering quality – they have so not many segments, there is very little to break.

b. PWM (Pulse Width Modulated):

This is the traditional type charge controller, for instance, anthrax, Blue Sky, and so on. These are essentially the industry standard now.

c. Maximum power point tracking (MPPT):

The MPPT solar charge controller is the sparkling star of today's solar systems. These controllers truly identify the best working voltage and amperage of the solar panel exhibit and match that with the electric cell bank. The outcome is extra 10-30% more power out of your sun oriented cluster versus a PWM controller. It is usually worth the speculation for any solar electric systems over 200 watts.

Features of Solar Charge Controller:

- Protects the battery (12V) from overcharging
- Reduces system maintenance and increases battery lifetime
- Auto charged indication
- Reliability is high
- 10amp to 40amp of charging current
- Monitors the reverse current flow

5.BATTERY

5.a.Purpose of Battery in PV

Batteries store and produce energy as needed. In PV systems, they capture surplus energy generated by your PV system to allow you to store energy for use later in the day. Like technologies such as fuel cells, a battery converts chemical energy to electrical energy. Rechargeable batteries also convert electrical energy into chemical energy. Depending upon your particular PV system, batteries may help you to use more of the energy collected by your PV system. Batteries can provide power when electrical loads require more power than the PV panels are generating. This can be due to the generation of less electricity due to adverse weather conditions, greater than normal power usage, or other anomalies with the PV power collection. Batteries also help establish the DC operating voltage for the required auxiliary components in the PV system. However, they can be expensive, and each system needs to be designed extremely well so that they are worth the added expense.

During the day:

- The PV system generates solar energy
- The system will check to see if all of the energy generation can be used to power your household
- Any surplus energy will be used to charge the battery
- If the battery is already charged, excess energy will be exported to the grid

At night or when there is low power generation:

- The PV system generates little to no solar energy
- Energy is obtained from the battery system
- After the battery is discharged, electricity can be obtained from the grid

5.b.Types of batteries

There are four main types of battery used in connection with storing electricity from solar power systems. Below is a summary of the various technologies currently commercially available and links to further information on each type.

1) Lead acid

Boring perhaps. Ugly and bulky definitely. But also dependable, tried and tested. Lead acid batteries have been taking Aussies off-grid for decades. But they are rapidly being eclipsed by other technologies with longer warranties and lower pricing as solar battery storage becomes more popular.

2) Lithium-ion

Lithium-ion (Li-ion) batteries are evolving in leaps and bounds as the electric car industry drives their development. Spearheaded by the brilliantly marketed Tesla Powerwall, lithium-ion batteries are looking to become the most popular choice for on-grid solar battery storage for the foreseeable future.

3) Flow

Flow batteries are a relatively new entrant to the battery storage marketplace (though their technology has been around for many years).

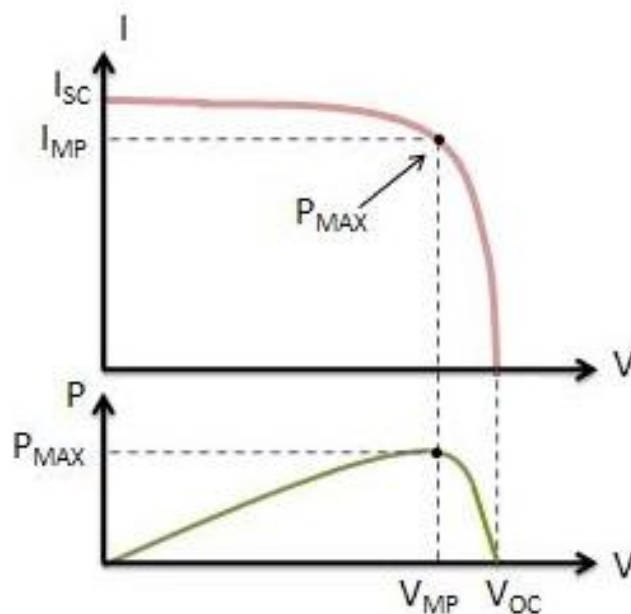
They are called flow batteries because they have a water based solution of zinc-bromide sloshing around inside them. At the moment only a few companies are producing flow batteries for the residential market, the most prominent of which is Redflow, an Australian-based flow battery company that outsources battery manufacturing to Thailand (previously North America). The ZCell is the smallest flow battery on the market

4) Sodium Nickel Chloride

Sodium nickel chloride technology is yet another competitor to the dominant lithium-ion storage technology. In Australia, GridEdge is producing their Quantum battery which, offers a range of environmental and safety benefits due to its unique battery chemistry.

6.SOLAR PV CHARACTERISTICS & PERFORMANCE

A Current (I) versus Voltage (V) Curve of a PV / Solar Module



shows the possible combinations of its current and voltage outputs. A typical I-V curve for a 12 V Module is shown in diagram.

The power in a DC electrical circuit is the product of the voltage and the current. Mathematically,

Power (P) in Watts (W) = The Current (I) in Amperes (A) X the Voltage (V) in Volts (V) i.e. $W = V \times A$

A Solar (PV) Cell or a Panel / Module produces its maximum

current when there is no resistance in the circuit, i.e. when there is a short circuit between its Positive and Negative terminals. This maximum current is known as the Short Circuit Current and is abbreviated as I_{sc} . When the Cell / Panel (Module) is shorted, the voltage in the circuit is zero.

Conversely, the maximum voltage occurs when there is a break in the circuit. This is called the Open Circuit Voltage (V_{oc}). Under this condition, the resistance is infinitely high and there is no current, since the circuit is incomplete. Typical value of the open-circuit voltage is located about 0.5 – 0.6 V for Crystalline Cells and 0.6 – 0.9 V for Amorphous Cells. These two extremes in load resistance, and the whole range of conditions in between them, are depicted on the I-V Curve. Current, expressed in Amps, is on the vertical Y-axis. Voltage, in Volts, is on the horizontal X-axis.

The power available from a photovoltaic device at any point along the curve is just the product of Current (I) in Amps (A) and Voltage (V) in Volts (V) at that point and is expressed in Watts. At the short circuit current point, the power output is zero, since the voltage is zero. At the open circuit voltage point, the power output is also zero, but this time it is because the current is zero.

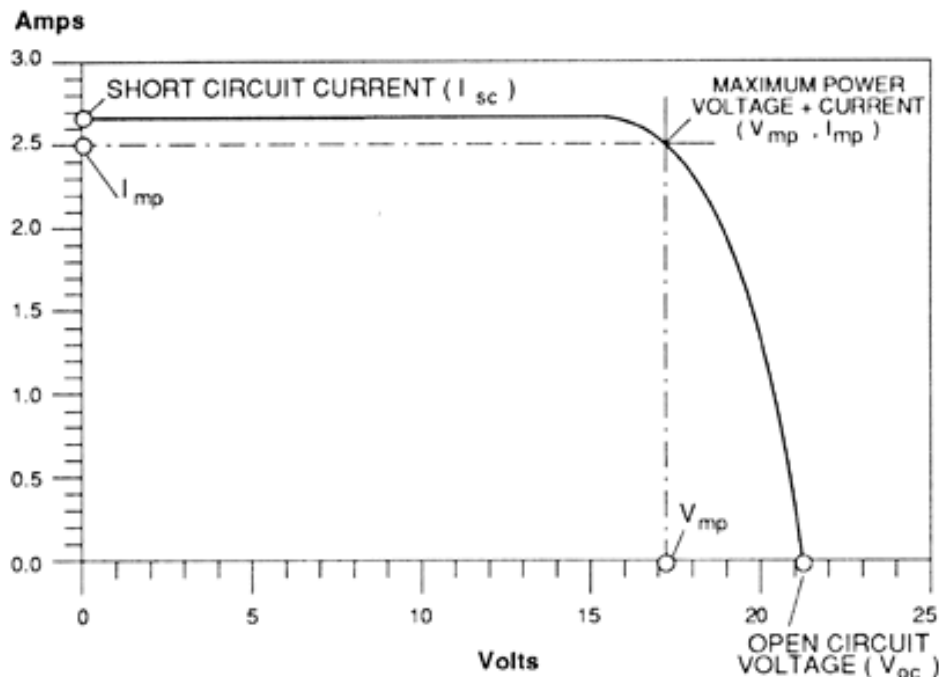
There is a point on the knee of the I-V Curve where the maximum power output is located and this point is called the Maximum Power Point (MPP). The voltage and current at this Maximum Power Point are designated as V_{mp} and I_{mp} .

The values of V_{mp} and I_{mp} can be estimated from V_{oc} and I_{sc} as follows: $V_{mp} = (0.75 \text{ – } 0.9) V_{oc}$ $I_{mp} = (0.85 \text{ – } 0.95) I_{sc}$

The rated power of the PV / Solar Module in Watts (P_{max}) is derived from the above values of voltage V_{mp} and current I_{mp} at this Maximum Power Point (MPP):

Rated power in Watts, $P_{max} = V_{mp} \times I_{mp}$

Example of I-V Curve and Ratings of a 12 V Solar (PV) Panel



The I-V Curve for a typical 12 Volt PV / Solar Panel is shown in the diagram.

This Maximum Power Point in the example curve given above is where V_{mp} is 17 Volts, and the current I_{mp} is 2.5 amps. Therefore, the rated or the maximum power W_{max} in watts is 17 Volts times 2.5 Amps, or 42.5 Watts.

The I-V curve is also used to compare the performance of PV / Solar Modules. The curve is, therefore, generated based on the performance under Standard Test Conditions (STC) of sunlight and device temperature of 25 °C. It assumes there is no shading on the device. Standard sunlight conditions on a clear day are assumed to be 1,000 Watts of solar energy per square meter (1000 W/m² or 1 kW/m²). This is sometimes called one sun, or a peak sun. Less than one sun will reduce the current output of the PV device by a proportional amount. For example, if only one-half sun (500 W/m²) is available, the amount of output current is roughly cut in half.

7.SOFTWARE-SOLAR PRO

The software calculates the I-V curve of solar modules accurately and quickly based on the electric characteristics of each manufacturer's product. The software calculates the amount of generated electricity based on the latitudes, longitudes, and the weather conditions of the installation site.



7.a.Report

solar Pro is used to create 3D models of residential, commercial flat-roof, ground-mounted, and single & dual-axis tracker PV systems. The shading effects of each object created in Solar Pro, including trees, buildings, and adjacent PV arrays, can be easily visualized on a minute-by-minute basis, 365 days of the year.

Solar Pro predicts hourly electricity generation using scientific, industry-standard mathematical models. IV Curve calculations are performed at the module level and take into account irradiation & temperature data, shading, and other detailed loss factors.

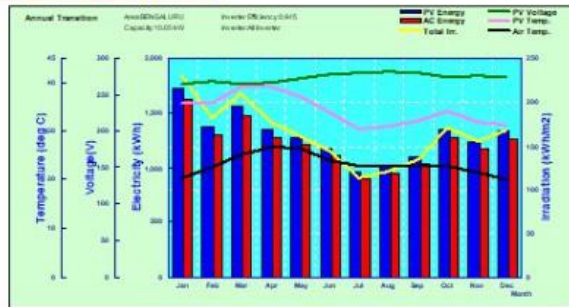
PV Generation System Simulation

This is aexample report for Bangalore.

This report has a energy graph,each month detailed report, economy simulation and PV data for complete 365 days.

PV Generation System Simulation

System Simulation

 Energy Graph

 Location and PV data

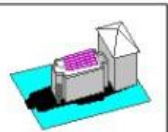
*Location

BENGALURU
INDIA
[Address]

*Title
[Words]

*PV System Information

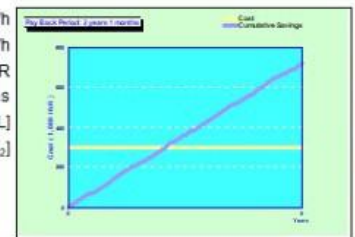
Capacity	10.05kW
System Setting	1 Inverter, 3 Parallel, 10 Series
Manufacturer	WINAI CO
Model	WSP-335MX

 12-Month Detailed Report

Term	AC Energy	Specific AC Energy	Load Energy	Eff. Reduction	Selling Price	Buying Price
Jan	8897	8897000	8897	0.00	16.315	16.315
Feb	1353.94	1353.94	0.00	13.095	13.095	0
Mar	1485.02	1477.76	0.00	14.850	14.850	0
Apr	1286.36	1286.00	0.00	12.864	12.864	0
May	1212.77	1205.67	0.00	12.128	12.128	0
Jun	1121.43	1115.99	0.00	11.214	11.214	0
Jul	912.23	907.77	0.00	9.122	9.122	0
Aug	962.27	955.75	0.00	9.623	9.623	0
Sep	1046.67	1041.15	0.00	10.467	10.467	0
Oct	1284.27	1277.99	0.00	12.843	12.843	0
Nov	1177.40	1171.15	0.00	11.774	11.774	0
Dec	1270.94	1266.46	0.00	12.709	12.709	0
Max Value	1353.94	1353.94	0.00	16.315	16.315	0
Max Yelm	Jan	Jan	Jan	Jan	Jan	Jan
Min Value	1225.03	1218.89	0.00	12.250	12.250	0
Min Yelm	14700.38	14662.72	0.00	147.004	147.004	0

 Economy Simulation

Annual AC Energy	14,700 kWh
Annual Load Energy	0 kWh
Electric Bill Reduction	147,004 INR
Pay Back Period	2 years 1 months
Crude Oil Reduction	3,778 [L]
CO ₂ Reduction	7,527 [kg-CO ₂]



*User Text

REFERENCE

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