SOLAR PHOTOVOLTAIC SYSTEM AND ITS DESIGN PRACTICES

Submitted in partial fulfillment of the requirements for the

Professional Training –I of

Bachelor of Engineering Degree in

Electrical and Electronics Engineering

By

M.SHIVA(39140704)

DEPARTMENT OF ELECTRICAL AND ELECTRONICS

SCHOOL OF ELECTRICAL AND ELECTRONICS

SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY

JEPPIAAR NAGAR, RAJIV GANDHI SALAI,

CHENNAI – 600119. TAMILNADU.

OCTOBER - 2021

SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY

(Established under Section 3 of UGC Act, 1956)

Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai – 600119

SCHOOL OF ELECTRICAL AND ELECTRONICS

BONAFIDE CERTIFICATE

This is to certify that this Professional Training Report is the Bonafide work of **M.SHIVA(39140704)** who underwent the professional training in **"SOLAR PHOTOVOLTAIC SYSTEM AND ITS DESIGN PRACTICES "** from 21 JULY 2021 to 05 AUGUST 2021.

Internal Guide

Head of the Department

Dr. SIVA CHIDAMBARANATHAN M.E., Ph.D.,

Submitted for Viva voce Examination heldon

Internal Examiner **External Examiner**

ACKNOWLEDGEMENT

The satisfaction and elation that accompany the successful completion of any task would be incomplete without the mention of the people who have made it possible. It is our great privilege to express our gratitude and respect to all those who have guided me during the course of my Professional Training.

First and foremost, we would express our sincere gratitude to our beloved Founder Chancellor **Col. Dr. JEPPIAAR, M.A., B.L., Ph.D.,** and Chancellor **Dr. Mariazeena Johnson, B.E., M.B.A., M.Phil., Ph.D.,** I extend my sincere thanks to our President
Dr. Marie Johnson, B.E., M.B.A., M.Phil., Ph.D., and for providing me the necessary facilities for the completion of the professional training. I also acknowledge our Vice Chancellor **Dr. T. Sasipraba, M.E., Ph.D**, and the Pro Vice Chancellor **Dr. E.Logashanmugam, M.E ,Ph.D,** the Pro Vice Chancellor **Dr.Wilson Aruni Ph.D., FAMPV,** for their constant support and endorsement.

I would like to express our gratitude to our Registrar **Dr. S. S. Rao, MBA,Ph.D.** and Controller of Examinations **Dr. Igni Sabasti Prabu M.E., Ph.D.,** for their valuablesupport offered to complete my professional training successfully.

I like to express our gratitude to **Dr. V.Sivachidambaranathan M.E.,Ph.D.,** Head of the Department of Electrical and Electronics Engineering, Sathyabama Institute of Science and Technology for having been a constant source of support and encouragement for the completion of the professional training.

I would also like to express our sincere thanks to our internal guide who guided me in the preparation of the report.

Also, I thank the **Almighty** and my **Parents** for supporting me in the completion of the professional.

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.

VATIO®

Certificate

OF INDUSTRY INTERNSHIP

This is to certify that

M SHIVA

Studying **3rd Year,B.E, EEE** in **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY**

has successfully completed the Industry Internship Programme at VATIO Energy India Pvt Ltd, Chennai through Online from 21st July to 05th August 2021 in the area of
"Solar Photovoltaic system & its Design Practices"

Best wishes from VATIO Energy for future endeavors !

Raj-gw.

G.Rajaganesan, Director – Technical
VATIO Energy India Pvt Ltd.

Vatio Energy India Pvt. Ltd. Chennai

05th August 2021
Date

Table of contents

SI No.	Title	Page No
	Introduction	8
1	Solar energy	8
1.1	What is Solar energy	8
1.2	Why we are going for solar energy	9
2	Solar pv system	11
2.1	Working Principle of Solar PV	11
2.2	Solar PV Technology Basics	12
2.3	Solar Cell Types	15
2.4	Solar pv array	16
3	Inverters	17
3.1	Working Principle	17
3.2	Types of Inverters	18
4	Controllers	20
4.1	Functions of Controllers	20
4.2	Types of Controllers	21
5	Battery	22
5.1	Purpose of Battery in PV	22
5.2	Types of batteries	22
5.3	Solar pv characteristics and performance	23
6	Solar photovoltaic assessment	25
6.1	Tools	26
6.2	Solar panel installation	27
7	ON Grid solar pv system	27

7.1	Working of On-Grid Solar PV System	28
7.1	Types of On-Grid Solar PV System	28
8	OFF Grid solar pv system	29
9	Software solar pro	30
10	Report	30
11	Reference	32

INTRODUCTION

Solar photovoltaic system:

Photovoltaics offer consumers the ability to generate electricity in a clean, quiet and reliable way. Photovoltaic systems are comprised of photovoltaic cells, devices that convert light energy directly into electricity. Because the source of light is usually the sun, they are often called solar cells. The word photovoltaic comes from “photo,” meaning light, and “voltaic,” which refers to producing electricity. Therefore, the photovoltaic process is “producing electricity directly from sunlight.”

Photovoltaics are often referred to as PV. PV systems are being installed by Texans who already have grid-supplied electricity but want to begin to live more independently or who are concerned about the environment. For some applications where small amounts of electricity are required, like emergency call boxes, PV systems are often cost justified even when grid electricity is not very far away.

When applications require larger amounts of electricity and are located away from existing power lines, photovoltaic systems SECO FACT SHEET NO. 11 can in many cases offer the least expensive, most viable option. In use today on street lights, gate openers and other low power tasks, photovoltaics are gaining popularity in Texas and around the world as their price declines and efficiency increases.

HOW IT WORKS:
PV cells convert sunlight directly into electricity without creating any air or water pollution. PV cells aremade of at least two layers of semiconductor material. One layer has a positive charge, the other negative. When light enters the cell, some of the photons from the light are absorbed by the semiconductor atoms, freeing electrons from the cell’s negative layer to flow through an external circuit and back into the positive layer.

This flow of electrons produces electric current. To increase their utility, dozens of individual PV cells are interconnected together in a sealed, weatherproof package called a module. When two modules are wired together in series, their voltage is doubled while the current stays constant. When two modules are wired in parallel, their current is doubled while the voltage stays constant.

To achieve the desired voltage and current, modules are wired in series and parallel into what is called a PV array. The flexibility of the modular PV system allows designers to create solar power systems that can meet a wide variety of electrical needs, no matter how large or small.

1.SOLAR ENERGY

1.1.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.

1.2.Why we are going for solar energy?

SOLAR ENERGY VERSUS WIND ENERGY

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 pronetomakinglotsofnoise.

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 industria l 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.

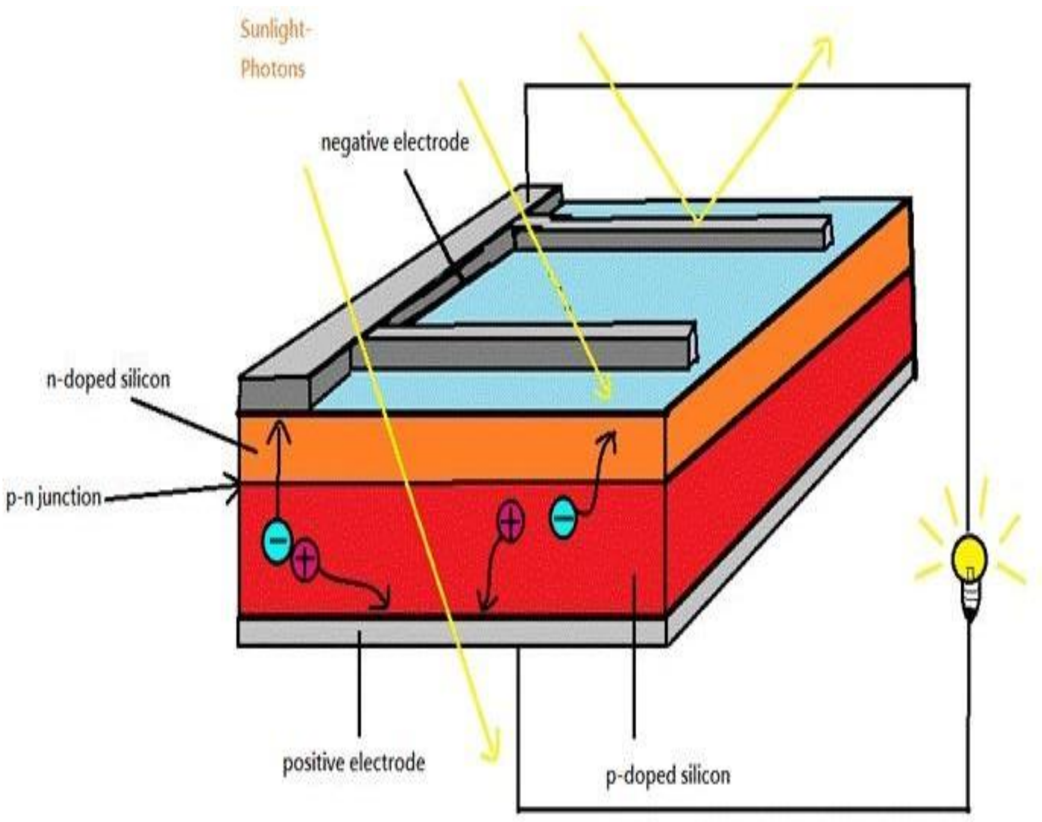
2.SOLAR PV SYSTEM

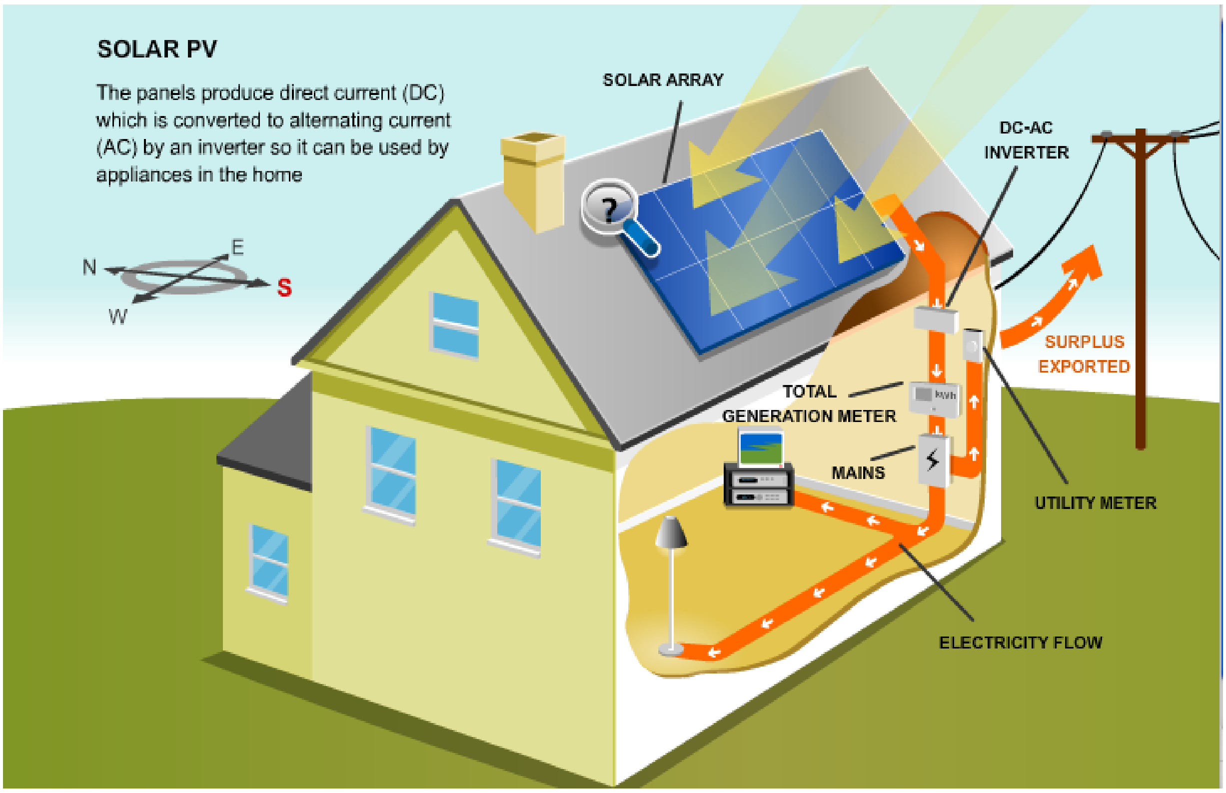
2.1.Working Principle of Solar PV

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 hit 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.





2.2.Solar PV Technology Basics

Solar cells, also called photovoltaic cells, convert sunlight directly into electricity.

.

Photovoltaics (often shortened as PV) gets its name from the process of converting light (photons) to electricity (voltage), which is called
the photovoltaic effect. This phenomenon was first exploited in 1954 by scientists at Bell Laboratories who created a working solar cell made from silicon that generated an electric current when exposed to sunlight. Solar cells were soon being used to power space satellites and smaller items such as calculators and watches. Today, electricity from solar cells has become cost competitive in many regions and photovoltaic systems are being deployed at large scales to help power the electric grid.

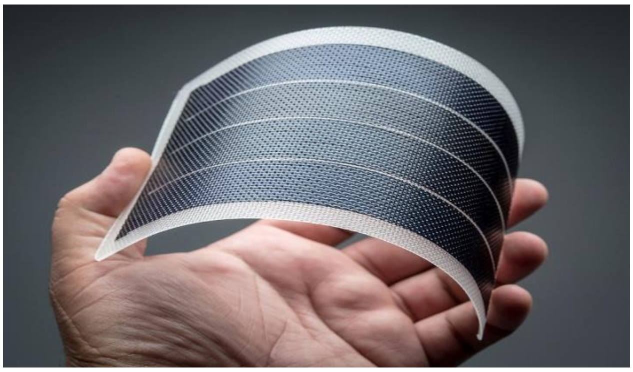
Silicon Solar Cells

The vast majority of today's solar cells are made from silicon and offer both reasonable prices and good efficiency (the rate at which the solar cell converts sunlight into electricity). These cells are usually assembled into larger modules that can be installed on the roofs of residential or commercial buildings or deployed on ground-mounted racks to create huge, utility-scale systems.

Thin-Film Solar Cells

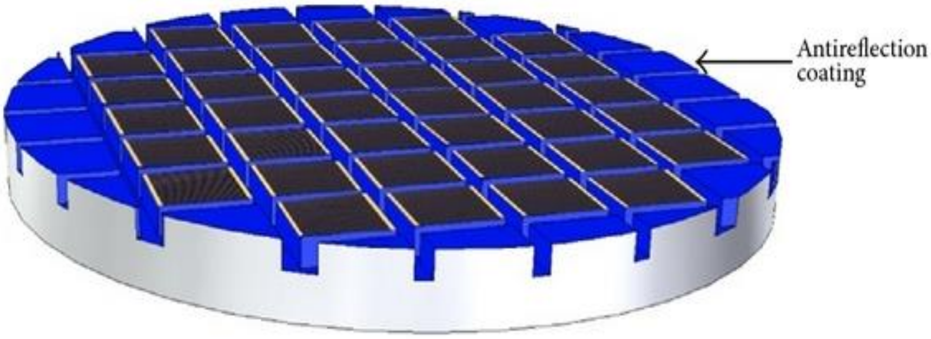
Another commonly used photovoltaic technology is known as thin-film solar cells because they are made from very thin layers of semiconductor material, such as cadmium telluride or copper indium gallium diselenide. The thickness of these cell layers is only a few micrometers-that is, several millionths of a meter.

Thin-film solar cells can be flexible and lightweight, making them ideal for portable applications—such as in a soldier's backpack—or for use in other products like windows that generate electricity from the sun. Some types of thin-film solar cells also benefit from manufacturing techniques that require less energy and are easier to scale-up than the manufacturing techniques required by silicon solar cells.



III-V Solar Cells

A third type of photovoltaic technology is named after the elements that compose them. III-V solar cells are mainly constructed from elements in Group III—e.g., gallium and indium—and Group V—e.g., arsenic and antimony—of the periodic table. These solar cells are generally much more expensive to manufacture than other technologies. But they convert sunlight into electricity at much higher efficiencies. Because of this, these solar cells are often used on satellites, unmanned aerial vehicles, and other applications that require a high ratio of power-to-weight.



Next-Generation Solar Cells

Solar cell researchers at NREL and elsewhere are also pursuing many new photovoltaic technologies—such as solar cells made from organic
materials, quantum dots, and hybrid organic-inorganic materials (also known as perovskites). These next-generation technologies may offer lower costs, greater ease of manufacture, or other benefits. Further research will see if these promises can be realized.

Reliability and Grid Integration Research

Photovoltaic research is more than just making a high-efficiency, low-cost solar cell. Homeowners and businesses must be confident that the solar panels they install will not degrade in performance and will continue to reliably generate electricity for many years. Utilities and government regulators want to know how to add solar PV systems to the electric grid without destabilizing the careful balancing act between electricity supply and demand.

Materials scientists, economic analysts, electrical engineers, and many others at NREL are working to address these concerns and ensure solar photovoltaics are a clean and reliable source of energy.

2.3.Solar Cell Types

A solar cell (also called photovoltaic cell or photoelectric cell) is a solid state electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage or resistance, vary when exposed to light.

The following are the different types of solar cells.

- Amorphous Silicon solar cell (a-Si)
- Bio-hybrid solar cell
- Cadmium telluride solar cell (Cd-Te)
- Concentrated PV cell (CVP and HCVP)
- Copper indium gallium selenide solar cells (CI(G)S)
- Crystalline silicon solar cell (c-Si)
- Float-zone silicon
- Dye-sensitized solar cell (DSSC)
- Gallium arsenide germanium solar cell (GaAs)
- Hybrid solar cell
- Luminescent solar concentrator cell (LSC)
- Micromorph (tandem-cell using a-Si/μc-Si)
- Monocrystalline solar cell (mono-Si)

- Multi-junction solar cell (MJ)
- Nanocrystal solar cell
- Organic solar cell (OPV)
- Perovskite solar cell
- Photo-electrochemical cell (PEC)
- Plasmonic solar cell
- Polycrystalline solar cell (multi-Si)
- Quantum dot solar cell
- Solid-state solar cell
- Thin-film sola Solar Cell Types r cell (TFSC)
- Wafer solar cell, or wafer-based solar cell crystalline

2.4.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 manufactures 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

3.1.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 c 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.

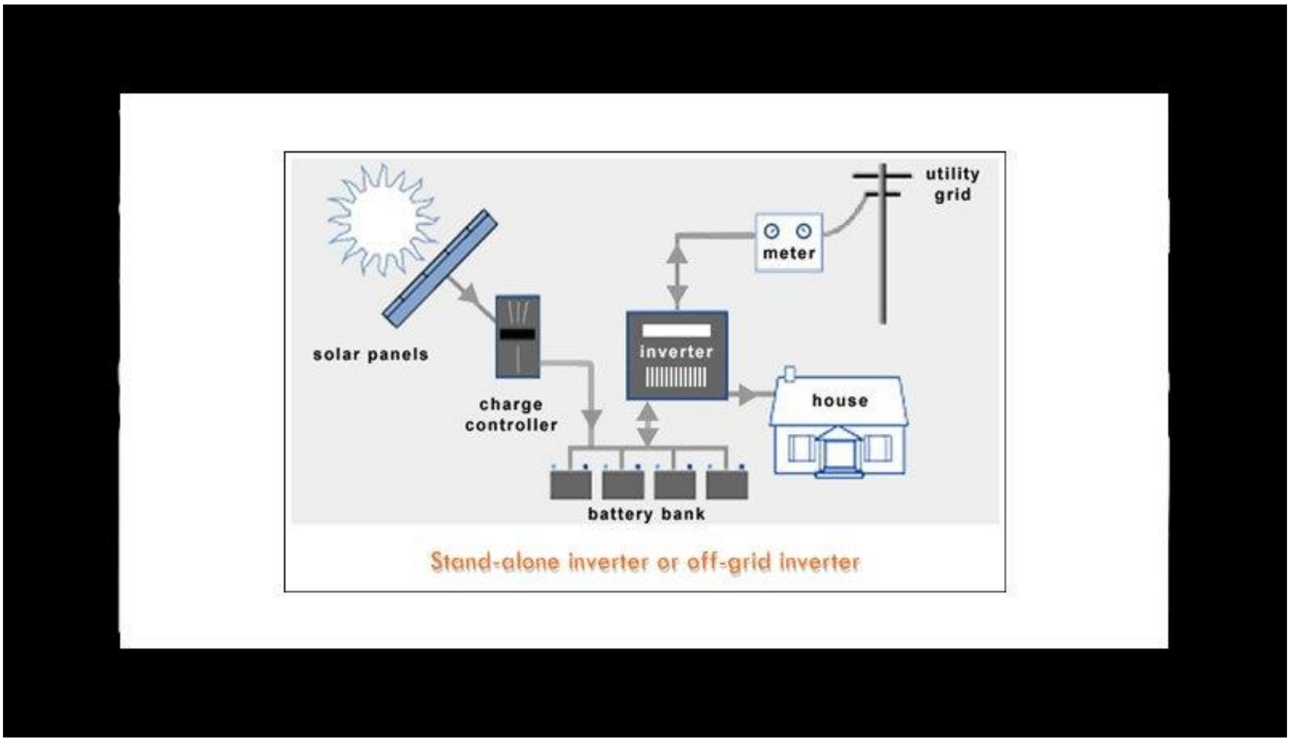
If we are using a solar system for a home, the selection & installation of the inverter is important. So, an inverter is an essential device in the solar power system(Current). This current can be used for different applications like in a viable electrical grid otherwise off-grid electrical network.

3.2.Types of Inverters

Solar inverters may be classified into different types:

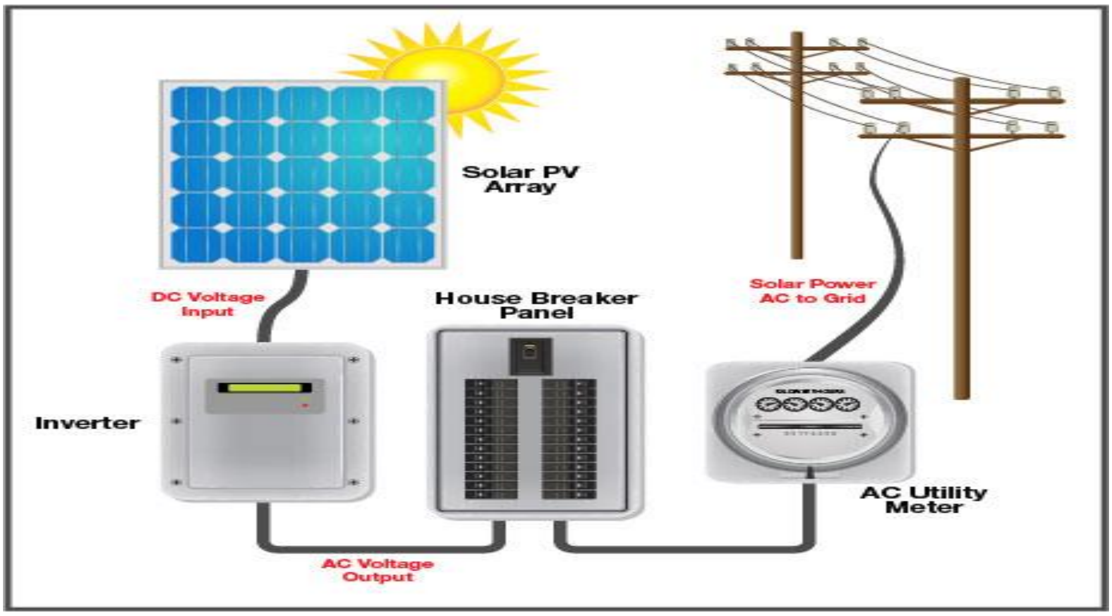
Stand-alone inverters:

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.



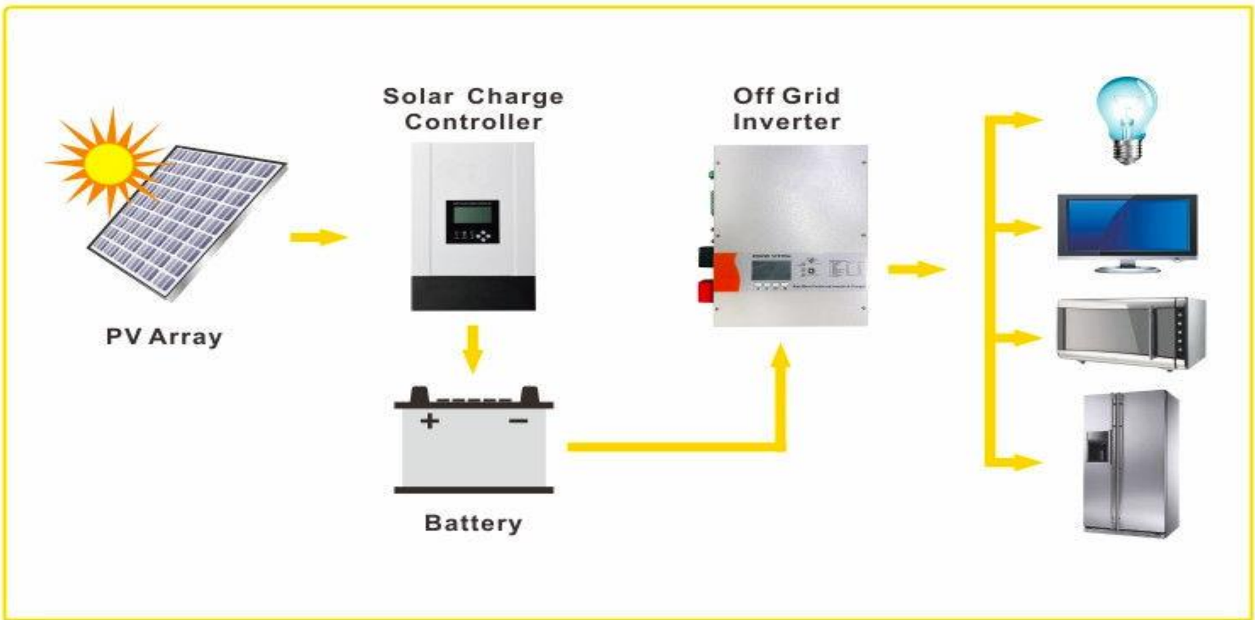
Grid-tie inverters:

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.



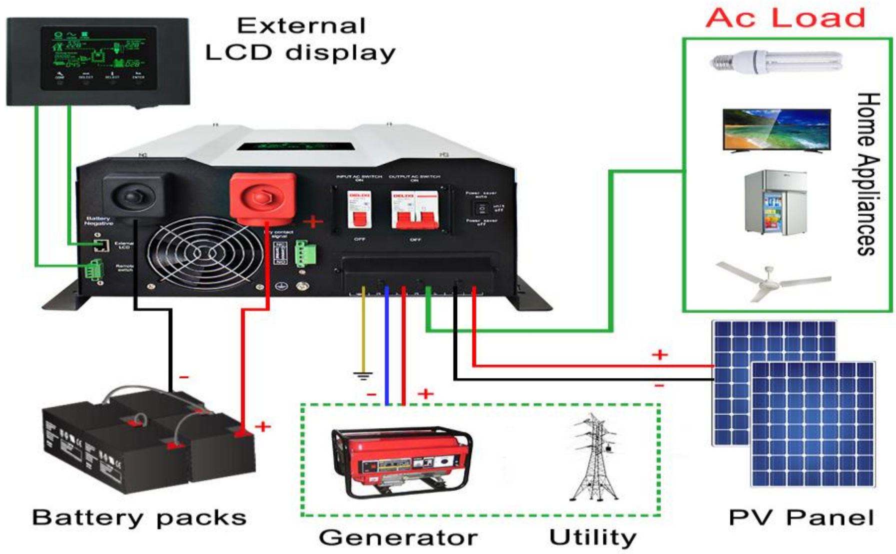
Battery Backup Inverters

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.



Intelligent Hybrid Inverters:

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.

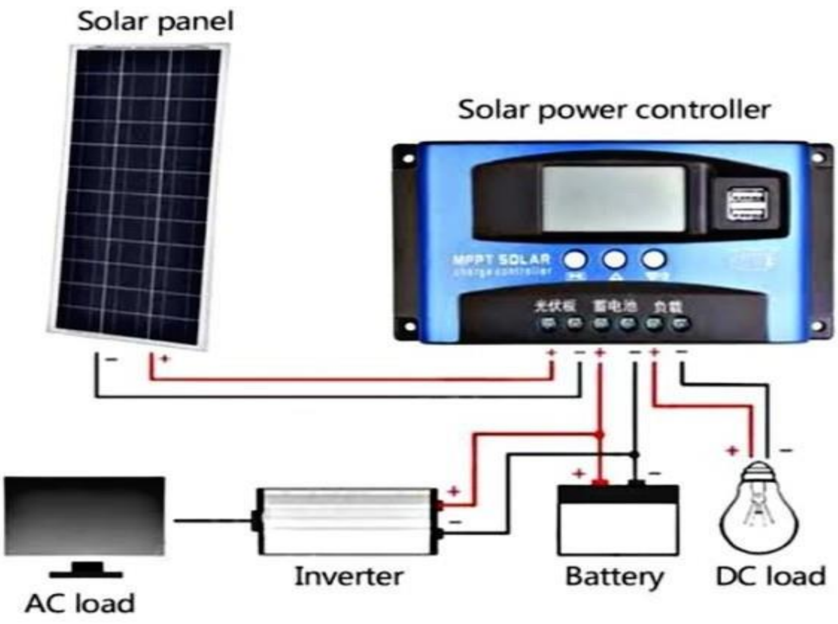


4.CONTROLLERS

4.1.Functions of Controllers

The most essential charge controller basically controls the device voltage and opens the circuit, halting the charging, when the battery voltage ascents 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.

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.

4.2.Types of Controller

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

1.Simple 1 or 2 stage controls
2.PWM (pulse width modulated)
3.Maximum power point tracking (MPPT)

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.

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.

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.

5.BATTERY

5.1.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

5.2.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 prici

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 Power wall, lithium-ion batteries are looking to become the most popular choice for on-grid solar battery storage for the foreseeable future.

3) Flow

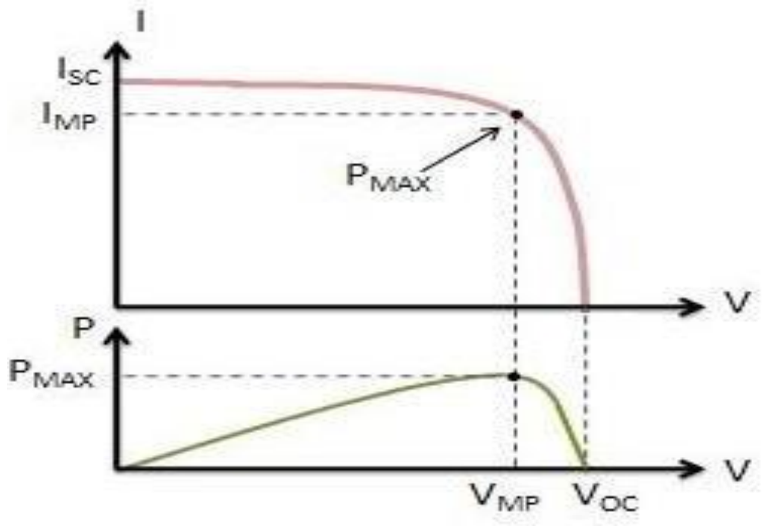
Flow batteries are a relatively new entrant to the battery storage marketplace (though their technology has been around for many years).

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, Grid Edge is producing their Quantum battery which, offers a range of environmental and safety benefits due to its unique battery chemistry.

5.3.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 X 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 Isc. 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 (Voc). 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 â€“
0.6 V for Crystalline Cells and 0.6 â€“ 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.

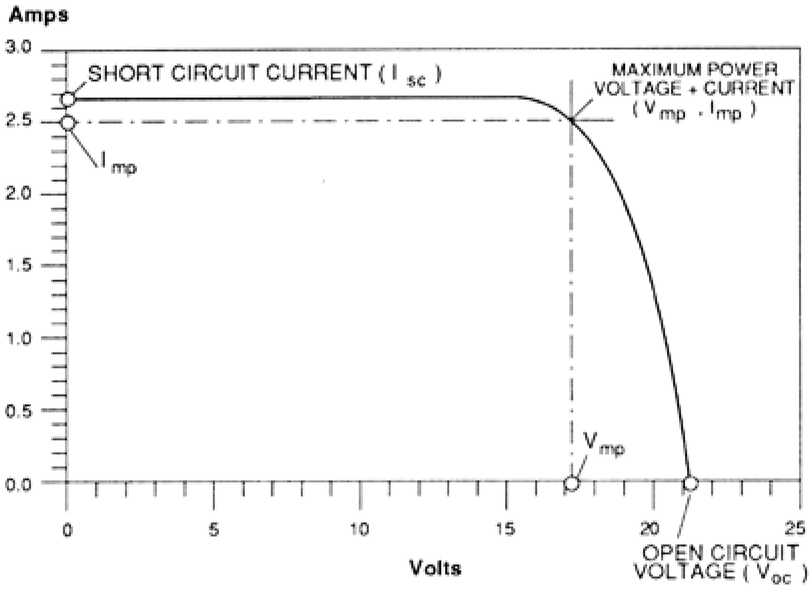
There is a point on the knee of the I-V Curve where the maximum power output is located and this point is called the Maximum Power Point (MPP). The voltage and current at this Maximum Power Point are designated as Vmp and Imp.

The values of Vmp and Imp can be estimated from Voc and Isc as follows: Vmp = (0.75 â€“ 0.9) Voc Imp = (0.85 â€“ 0.95) Isc

The rated power of the PV / Solar Module in Watts (Pmax) is derived from the above values of voltage Vmp and current Imp at this Maximum Power Point (MPP):

Rated power in Watts, Pmax = Vmp x Imp

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 diagram.

This Maximum Power Point in the example curve given above is where Vmp is 17 Volts, and the current Imp is 2.5 amps. Therefore, the rated or the maximum power Wmax 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 Â°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.

6.SOLAR PHOTOVOLTAIC SITE ASSESSMENT

An important consideration when installing a solar photovoltaic (PV) array for residential, commercial, or agricultural operations is determining the suitability of the site. A roof-top location for a residential application may have fewer options due to limited space (roof size), type of roofing material (such as a sloped shingle, or a flat roof), the orientation (south, east, or west), and roof-mounted structures such as vent pipe, chimney, heating & cooling units.

A location with open space may utilize a ground-mount system or pole-mount system. Determining the physical location of a solar PV array is a critical step to optimize energy output performance of the system. The ideal location is where solar modules are exposed to full sunshine from sun up to sun down without worry about shade cast on the modules from trees, power poles, guide wires, vent pipes, or nearby buildings, or the changing location of the sun.

In the Northern Hemisphere, solar PV arrays are oriented to the south toward the Equator. Over the course of a calendar year, the sun's altitude (height) in the sky changes. For example, during the month of June, the sun reaches its highest point in the sky on June 21 at 12:00 noon (summer solstice), and the sun is at its lowest point in the sky on December 21 at 12:00 noon (winter solstice).

The solar industry uses the phrase "solar azimuth angle" which is the sun's horizontal position and is measured in degrees east or west of true south (180 degrees). For example, if the sun is located 35 degrees west of true south, the solar azimuth angle is 215 degrees (180 + 35 = 215). The sun's vertical position in the sky is referred to as the "altitude angle" and is measured in degrees above the horizon. At sunup or sundown, the altitude angle would equal 0 degrees.

At 90 degrees altitude, the sun would be directly overhead. When the sun is located at 180 degrees (true south), the sun is at its highest altitude angle of the day. This is referred to as "solar noon."

6.1.Tools:

There are a number tools used to conduct a solar site assessment.The tool used to measure solar irradiance (sunlight intensity) is a pyranometer.

Tools used are:
- Solar pathfinder
- Compass
- Measuring tape
- Camera
- Angle measurement equipment
- Notebook

6.2.Solar panel installation

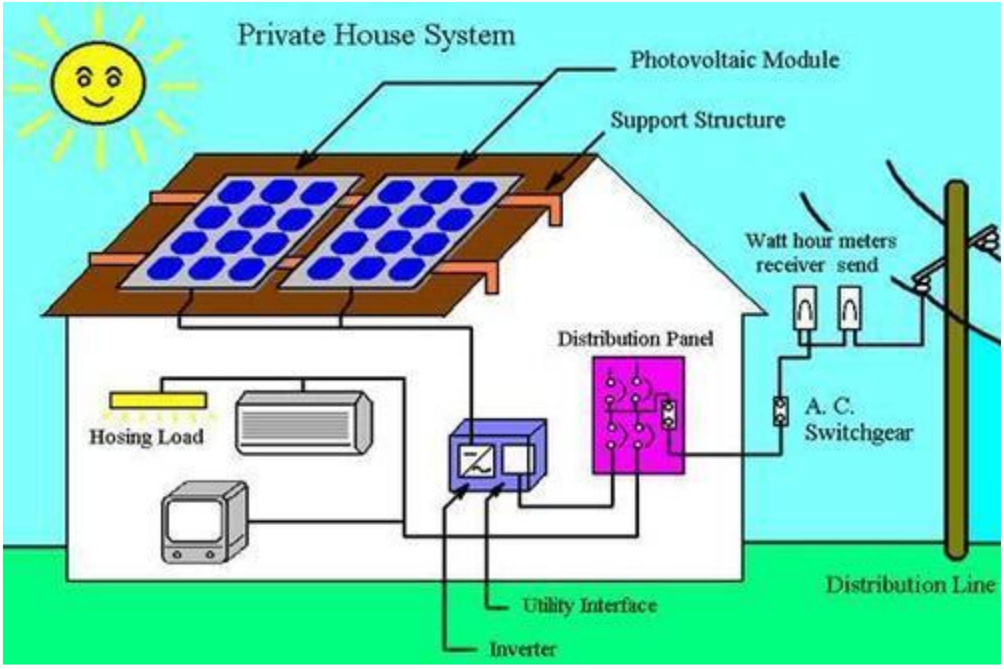
Steps of solar Home roof installation:

- Evaluate your options
- Load calculation and energy audit
- Grid-Connected vs Off-Grid vs Hybrid
- Estimate your budget
- Choose your solar developer
- Site Survey
- Receive your proposal
- Documentation and permits
- Installation
- Warranty and maintenance

7.ON GRID SOLAR PV SYSTEM

The On-grid system is connected with utility grid (like BESCOM in Bangalore) and this system would work only if the grid is available. In case of a power cut, the system will not work and hence the On-grid system is also termed as a Grid-tied system. Grid is required since the inverter needs to be provided a reference voltage and the inverter needs to sync with the grid in order to export energy back into the grid.

On grid systems make sense for locations with no daytime power cut or with less than 2 hrs of daytime power cut. This type of system is apt for reducing your electricity bills since it is cheaper than a battery based system and there is no recurring cost of replacement of components.



7.1. Working of On-Grid Solar PV System:

Once the solar generation starts, the generated energy is first consumed by the loads. Once the load requirement is satisfied, the remaining energy will be exported to the grid. Grid by itself acts as a virtual battery taking in all the excess energy that has been exported. This is known as banking of energy.

During the night, when there is no solar, the loads can import the banked energy. Similarly, when there is less generation from solar due to cloudy conditions, the required energy is imported from the grid. At the end of every billing cycle, the export and import billing will be calculated and this net will be calculated with the help of a Bi-directional meter.

Working of a Bi-directional meter

Difference between the traditional Unidirectional meter and the Bi-directional meter is that the unidirectional meter only displays the total energy imported from the grid. However, Bi-directional meter records 3 readings – the total amount of energy Exported (in kWh), total amount of energy Imported, and Net energy difference of the export and import.

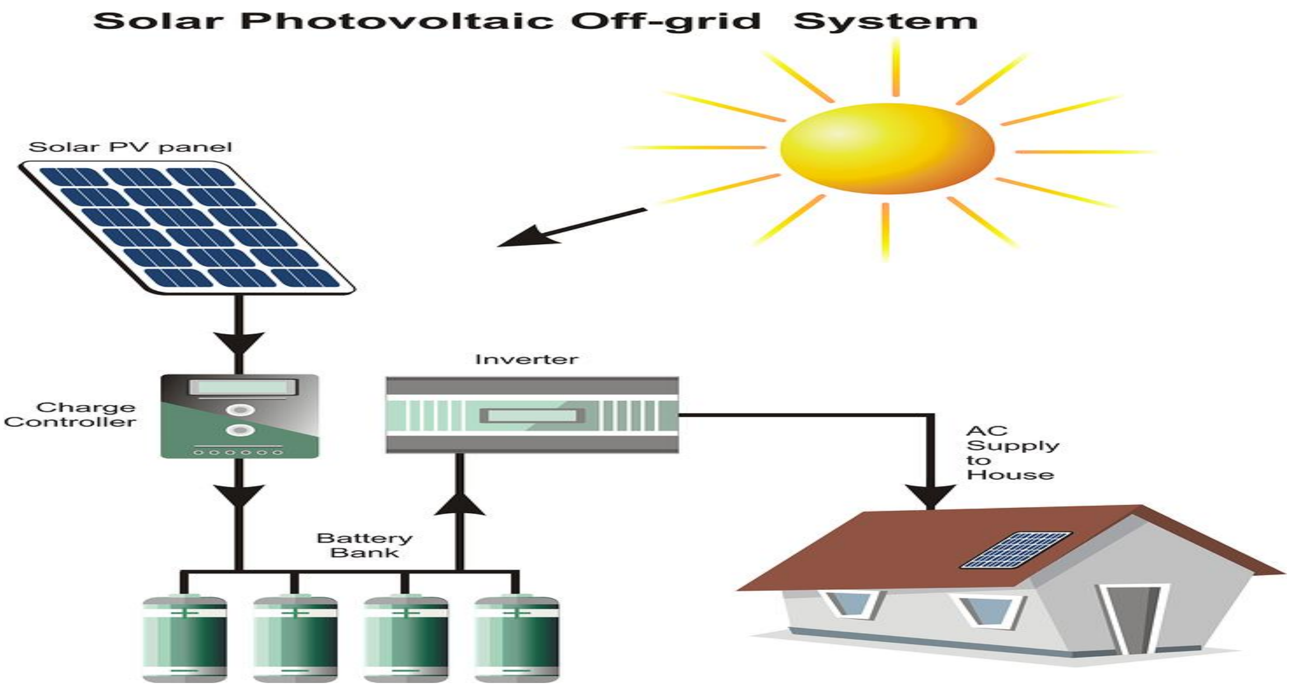
7.2. Types of On-Grid Solar PV systems

Solar technology in rooftop sector has improved drastically over the past few years and has catered to the growing demands of the discerning public. There are many types of rooftops and each one of them has varying conditions like different roofs, different orientations, shadow issues, etc. Within on-grid solar PV systems, there are mainly three different types systems:

- String Inverter
- Micro Inverter
- Power Optimizers

8.OFF GRID SOLAR PV SYSTEM

- An Off-Grid Solar Photovoltaic (PV) System is a solar power generation system which is independent of the Utility Grid and is its own self-sustaining system.
- An Off-Grid Solar PV System stores power generated by the Solar PV Panels locally, in batteries. The power required for consumption by the loads is the drawn from these charged batteries
- This type of system is suitable for locations where there is no Utility Grid connectivity or areas where Power Cuts are extremely frequent. An Off-Grid Solar PV System can replace diesel generators in these situations.



9.SOFTWARE-SOLAR PRO

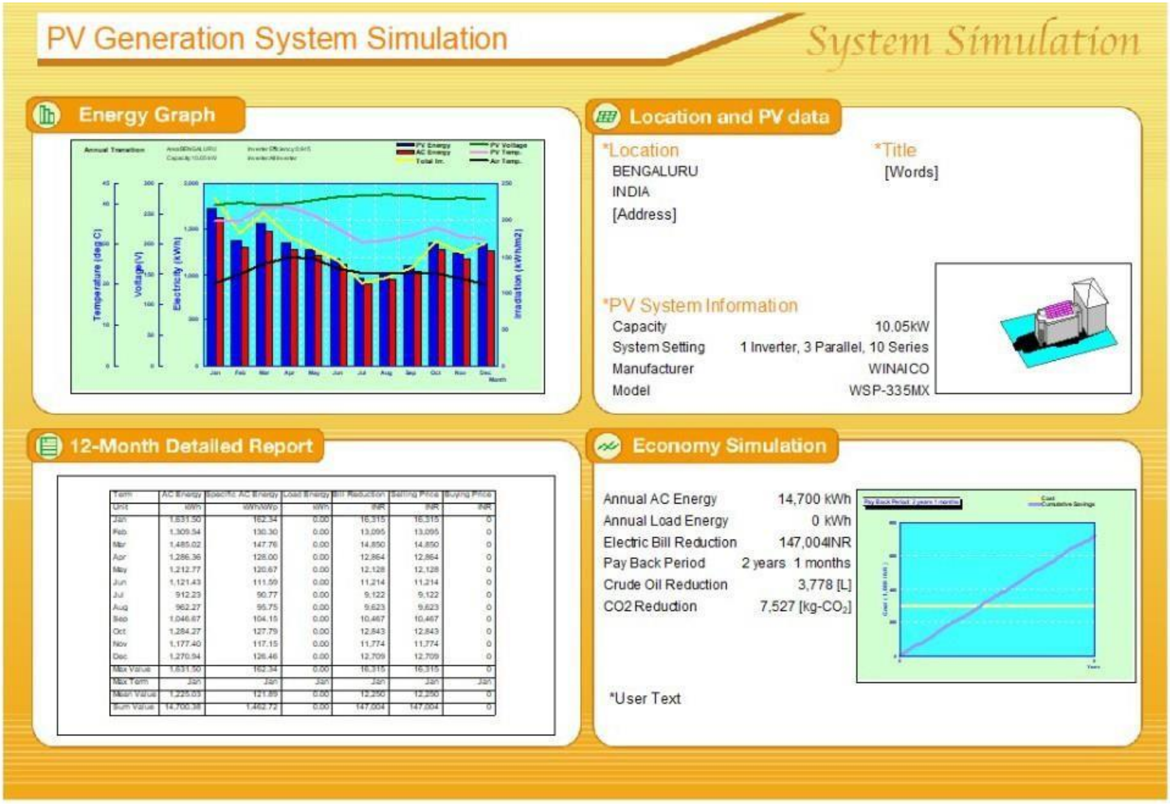
he software calculates the i-v curve of solar modules accurately and quickly based on the electric characteristics of eachmanufacturer's product. The software calculates the amount of generated electricity based on the latitudes, longitudes, and the weather conditions of the installation site.

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



REFERNCE

http://pvinsights.com/Knowledge/Principle.php
https://www.cleanmax.com/solar-update/how-solar-energy-compares-to-other-renewable-sources-of-energy.php
https://en.m.wikipedia.org/wiki/List_of_types_of_solar_cells
https://en.m.wikipedia.org/wiki/Solar_inverter
https://www.solarpowerworldonline.com/2015/07/what charge-controllers-function/
https://www.fuelcellstore.com/blog-section/battery-energy-storage-for-the-pv-system
https://www.e-education.psu.edu/ae868/node/518
https://www.alternative-energy-tutorials.com/solar-power/pv-array.html
https://www.lapsys.co.jp/english/products/pro.html