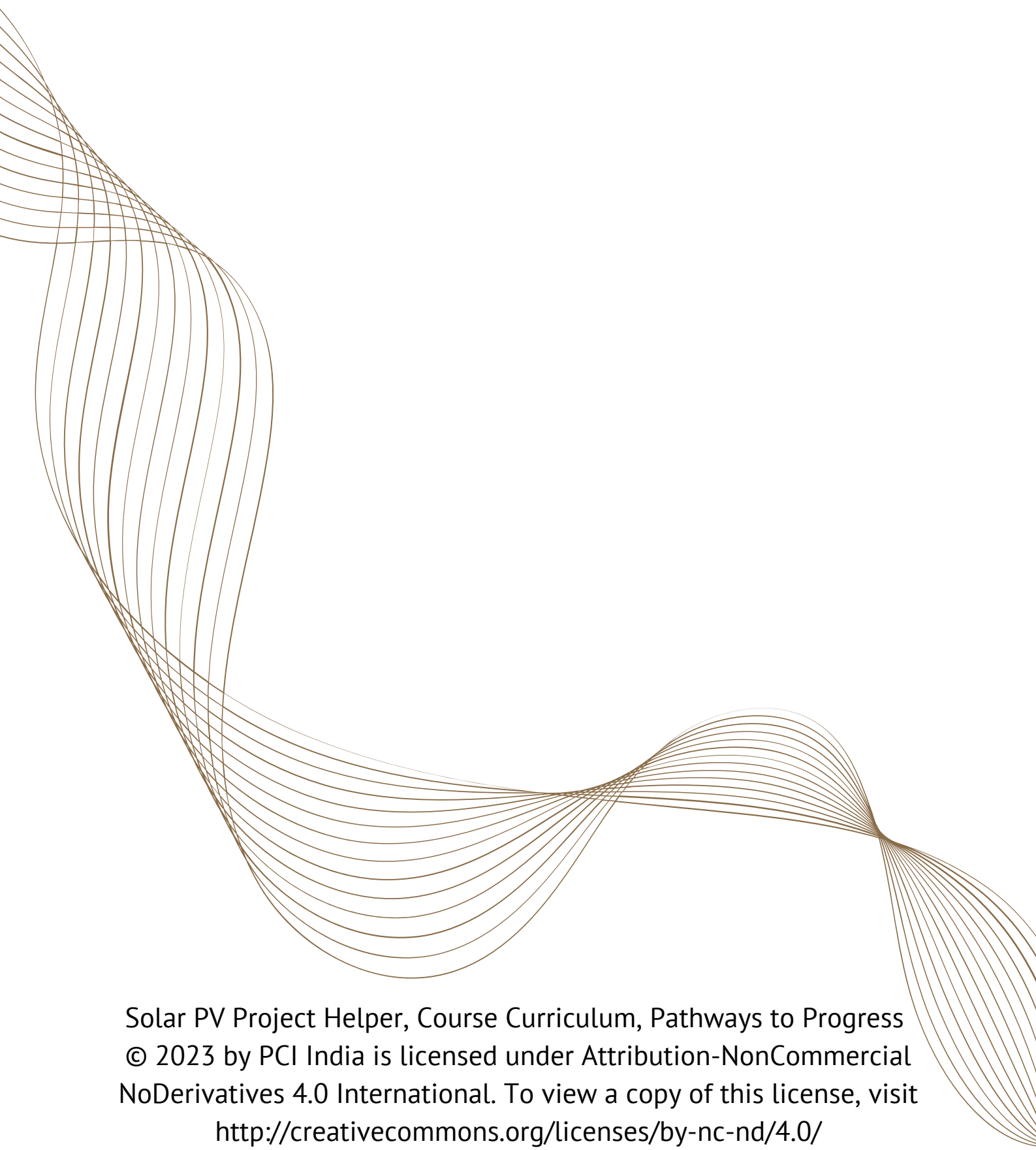
2023

SOLAR PV PROJECT HELPER

SECTOR: GREEN JOBS

QP CODE: SGJ/Q0111

COURSE CURRICULUM: PATHWAYS TO PROGRESS



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CHAPTER 1: INTRODUCTION TO SOLAR PV SECTOR IN INDIA

LEARNING OBJECTIVES

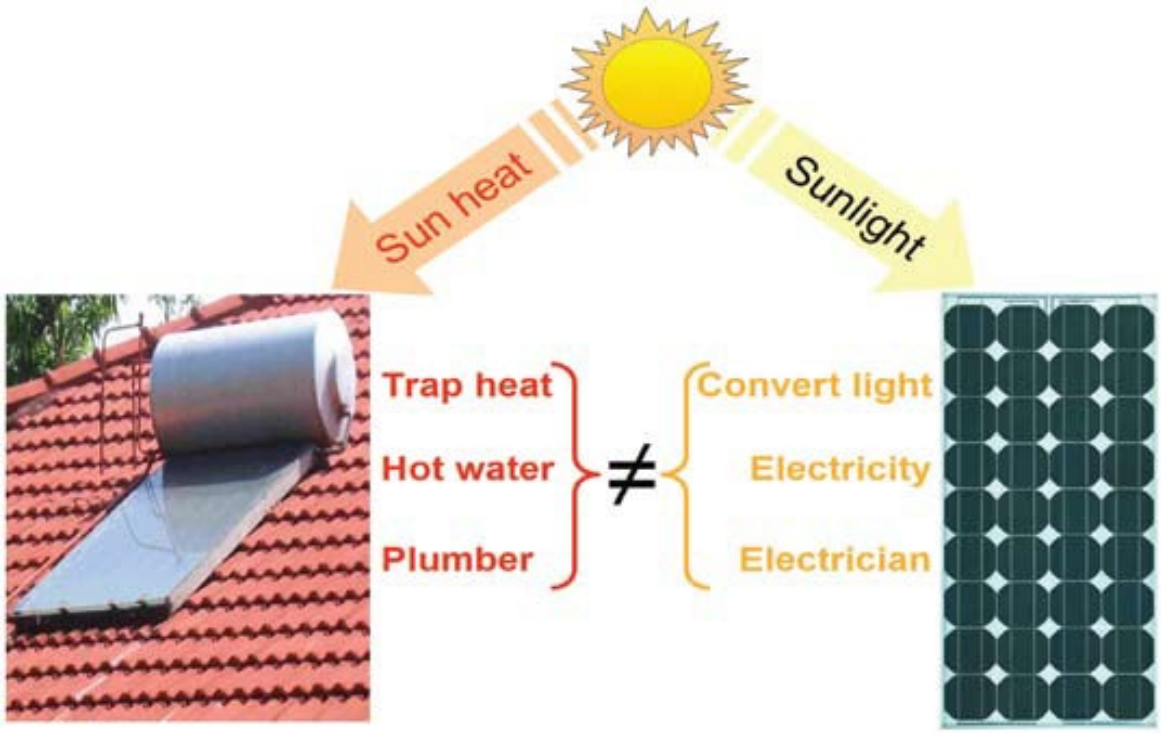
- Explain the role of Solar PV Project helper, its importance in the sector and the advantages of doing the course.
- Discuss the basic aspects of solar energy and power generation.
- Discuss the broader overview of solar PV technology and sector in India.
- Explain the types of solar PV Power plants including rooftop and ground mounted PV Power Plants and their working principles.
- Identify various tools used in solar power plants.
- Discuss the precautions to be followed while using electrical and mechanical components.
- Explain the importance of reading and interpreting signs, no and/or cautions at project site.

HISTORY OF SOLAR PV

Solar energy has been used in various ways since the 7th century BC. The history of solar energy is an interesting story. The sun's rays were amplified and used to create fire. In the third century B.C. the Greeks and Romans used 'burning mirrors' to light torches for religious purposes. It has been said that in the 2nd century B.C. Archimedes used the reflective properties of brass to set fire to Roman ships attacking Syracuse. By the 6th century A.D. sunrooms on houses became popular. Justinian Code initiated 'sun rights' to ensure individual access to the sun.

INTRODUCTION TO SOLAR SYSTEM

The sun delivers its energy to us in two main forms: heat and light. There are two main ypes of solar power systems, namely, solar thermal systems that trap heat to warm up water, and solar PV systems that convert sunlight directly into electricity as shown in below figure.



THE DIFFERENCE BETWEEN SOLAR THERMAL AND SOLAR PV SYSTEMS

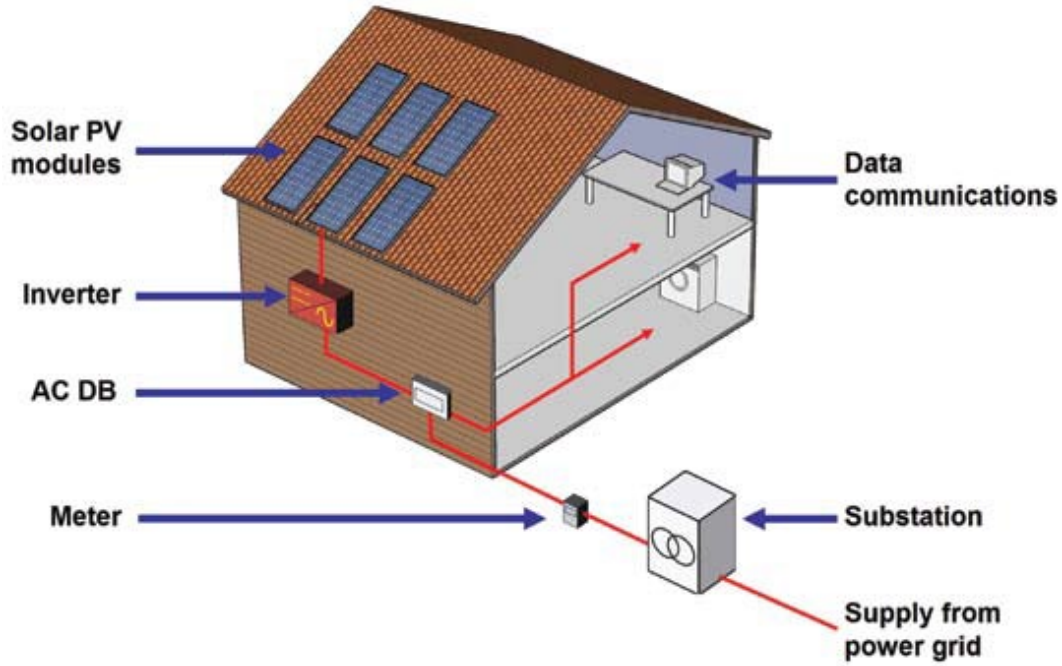
When the PV modules are exposed to sunlight, they generate direct current ("DC") electricity. An inverter then converts the DC into alternating current ("AC") electricity, so that it can feed into one of the building's AC distribution boards ("ACDB") without affecting the quality of power supply.

TYPES OF SOLAR PV SYSTEM

Solar PV systems can be classified based on the end-use application of the technology. There are two main types of solar PV systems: grid-connected (or grid-tied) and off-grid (or stand-alone) solar PV systems.

The main application of solar PV in Singapore is grid-connected, as Singapore's main island is well covered by the national power grid. Most solar PV systems are installed on buildings or mounted on the ground if land is not a constraint. For buildings, they are either mounted on the roof or integrated into the building. The latter is also known as Building Integrated Photovoltaics ("BIPV"). With BIPV, the PV module usually displaces another building component, e.g., window glass or roof/wall cladding, thereby serving a dual purpose and offsetting some costs.

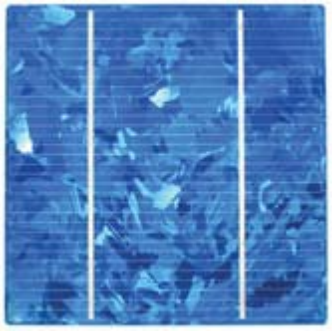
The configuration of a grid-connected solar PV system is shown in below figure.



SOLAR PV TECHNOLOGY

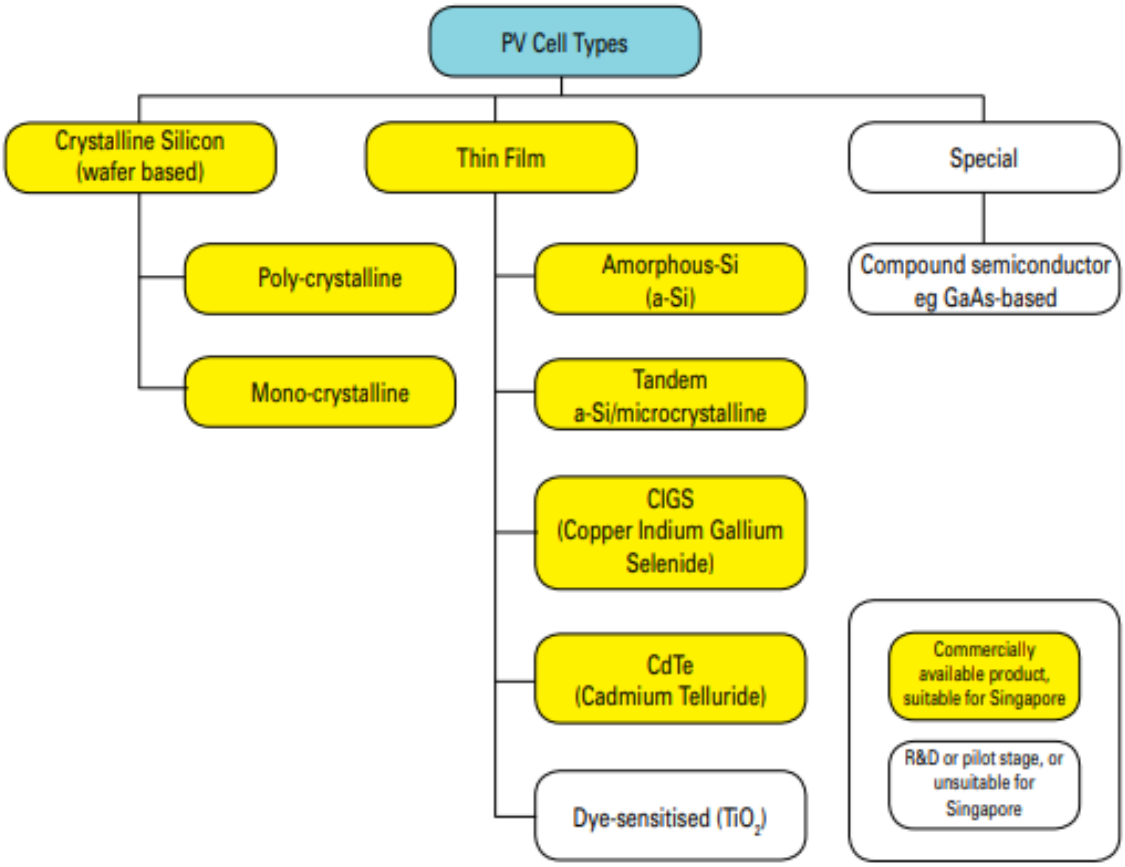
This section gives a brief description of the solar PV technology and the common technical terms used. A solar PV system is powered by many crystalline or thin film PV modules. Individual PV cells are interconnected to form a PV module. This takes the form of a panel for easy installation.

Mono-Crystalline Silicon PV Cell



Poly-Crystalline Silicon PV Cell

PV cells are made of light-sensitive semiconductor materials that use photons to dislodge electrons to drive an electric current. There are two broad categories of technology used for PV cells, namely, crystalline silicon, as shown in above Figure which accounts for the majority of PV cell production; and thin film, which is newer and growing in popularity. The "family tree" in below Figure gives an overview of these technologies available today and below Figure illustrates some of these technologies.



Mono-crystalline silicon

Poly-crystalline silicon

Flexible amorphous thin film

CIGS thin film

CRYSTALLINE SILICON AND THIN FILM TECHNOLOGIES

Crystalline Silicon and Thin Film Technologies Crystalline cells are made from ultra-pure silicon raw material such as those used in semiconductor chips. They use silicon wafers that are typically

150-200 microns (one fifth of a millimeter) thick. Thin film is made by depositing layers of semiconductor material barely 0.3 to 2 micrometers thick onto glass or stainless-steel substrates. As the semiconductor layers are so thin, the costs of raw material are much lower than the capital equipment and processing costs.

Apart from aesthetic differences, the most obvious difference amongst PV cell technologies is in its conversion efficiency, as summarized in Table 1. For example, a thin film amorphous silicon PV array will need close to twice the space of a crystalline silicon PV array because its module efficiency is halved, for the same nominal capacity under Standard Test Conditions1 (STC) rating.

Technology	Module Efficiency
Mono-crystalline Silicon	12.5-15%
Poly-crystalline Silicon	11-14%
Copper Indium Gallium Selenide (CIGS)	10-13%
Cadmium Telluride (CdTe)	9-12%
Amorphous Silicon (a-Si)	5-7%

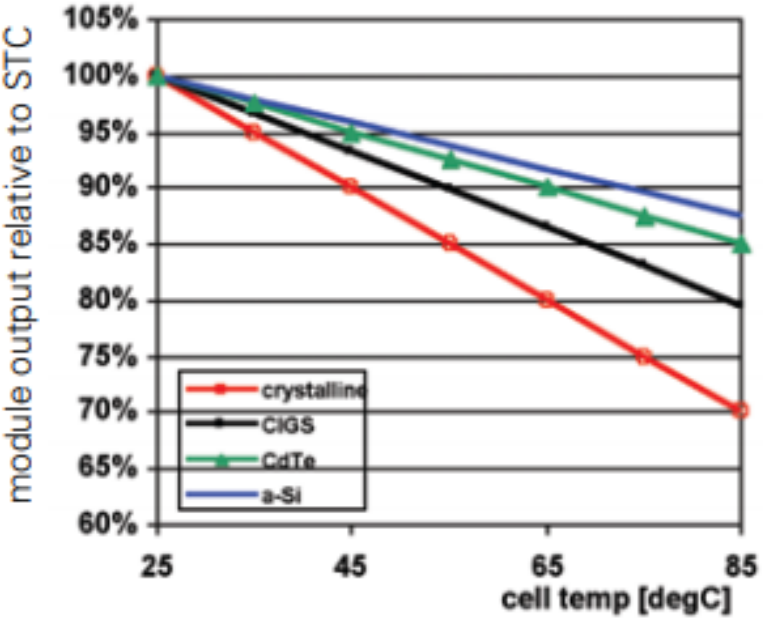
For crystalline silicon PV modules, the module efficiency is lower compared to the sum of the component cell efficiency due to the presence of gaps between the cells and the border around the circuit i.e., wasted space that does not generate any power hence lower total efficiency.
Another important differentiator in solar PV performance, especially in hot climates, is the temperature coefficient of power. PV cell performance declines as cell temperature rises.

For example, in bright sunlight, cell temperatures in Singapore can reach over 70°C, whereas PV modules are rated at a cell temperature of 25°C. The loss in power output at 70°C is therefore measured as (70 - 25) x temperature coefficient.

Most thin film technologies have a lower negative temperature coefficient compared to crystalline technologies. In other words, they tend to lose less of their rated capacity as temperature rises. Hence, under Singapore's climatic condition, thin film technologies will generate 5-10% more electricity per year.

A PV module data sheet should specify the temperature coefficient. See below Table 2 and chart in below Figure.

Technology	Temperature Coefficient [%/°C]
Crystalline silicon	-0.4 to -0.5
CIGS	-0.32 to -0.36
CdTe	-0.25
a-Si	-0.21



The PV modules are next connected in series into a PV string as shown in below figure. A PV array as shown in below Figure is formed by the parallel aggregation of PV strings.

PV String

PV Array

TECHNICAL INFORMATION

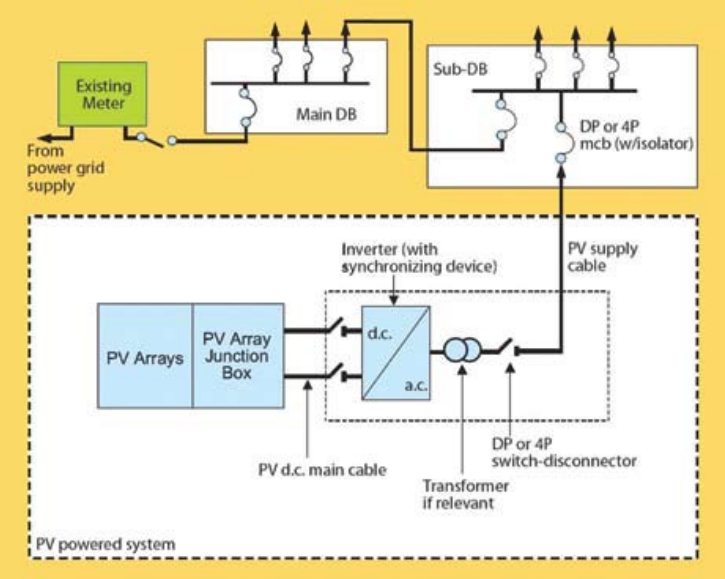
Single-core, double isolated sheathed cables that can withstand the environmental conditions and minimize the risk of earth faults and short circuits are used to interconnect the PV strings and arrays. The cable connections are protected in enclosures known as junction box that provides the necessary connectors as shown in below Figure.

Electricity produced by the solar PV installation is in the form of DC. The output of the PV installation is connected through the DC main cables to the DC terminals of the PV inverter where electricity is converted from DC into AC.

After conversion, the AC current of the PV inverter is connected through PV supply cable to the building's electrical installation (AC distribution board). Below Figure shows a typical PV inverter connected to the electrical installation of a building. Note that the actual configuration of the PV inverter may vary across different systems.

Just like any electrical installation in a building, earthing is an important safety requirement for solar PV system. Arrangement must be made for proper connection of the solar PV system to the consumer's electrical installation earthing system.
In locations susceptible to lightning strikes, a lightning protection system must be provided, and all the exposed metallic structures of the solar PV system must be bound to the lightning earthing system.

It is the responsibility of the consumers to have their solar PV systems maintained regularly to ensure safe operation of their solar PV systems and electrical installations. See below Figure for a diagram showing the solar PV system forming part of a consumer's electrical installation.



ROLE OF SOLAR PV PROJECT HELPER, ITS IMPORTANCE IN THE SECTOR AND THE ADVANTAGES OF DOING THE COURSE.

Solar energy has a substantially reduced impact on the environment compared to fossil fuels. Its greenhouse gas emissions are inconsequential as the technology does not require any fuel combustion. Also, although concentrating solar thermal plants (CSP) are comparatively inefficient in their water usage depending on the type of technology being used, the right technology significantly increases efficiency while photovoltaic (PV) solar cells do not require any water when generating electricity.

Video: Solar Industry Opportunities - https://www.youtube.com/watch?v=HPwKOK99PUQ

SOLAR ENERGY

You must have seen wet clothes being kept in the sun to dry; do you know what energy is being used here? It is the heat energy from the sun that makes the clothes dry. The energy radiated from the sun can be used in many forms on Earth. The energy produced by the sun and received by Earth in one hour is strong enough to meet global energy needs for almost a year. Solar energy exists in two forms; humans can utilize heat and light, and both. Solar power can also cause chemical reactions and generate electricity. Harnessing and using Solar energy are some of the significant ways of achieving a clean future. As the green market is growing in many countries, Solar power's share is also becoming a big part of sustainable development.

If you have been asked to write a short note on solar energy or need solar energy information in English, this article is for you. Here we will give you a solar energy definition and equip you with solar energy project information.

TYPES OF SOLAR PANELS

Solar energy can be converted into usable energy, and there are many ways of doing it to get heat, electricity, hot water, and even cooling buildings and industrial complexes. Solar panels are equipment that can absorb the Sun's rays and generate heat or electricity with it. The most common types of solar panels fit into three broad categories: monocrystalline, thin-film, and polycrystalline. These solar panels are different from each other in the way they are made, the cost involved in making them, their performances, appearance, and the kind of installation they are best suited for. Each of these panels has unique features and capabilities. Solar cells have semiconducting material that converts light into electricity. Silicon is used widely as the semiconducting material in solar panels.

Based on the types of installation you require; you can choose the best fit from these three explained below:

1. **Monocrystalline and Polycrystalline Solar Panels:** The Monocrystalline and Polycrystalline Solar panels have solar panels made from silicon wafers. The wafers are assembled into rows and columns in both panels to form a rectangle. They are then covered with a glass sheet and framed together. The difference between these two panels lies in the composition of silicon used in each of them. To make a monocrystalline panel, a single pure silicon crystal is used. For a polycrystalline panel, fragments of silicon crystals are used that are melted together to form a mould and then cut into wafers.

2. **Thin Film Solar Panels:** The thin-film panels are made up of different materials and not just silicon. CdTe or Cadmium telluride is the most common material used in making thin-film solar panels. Layers of CdTe are placed between transparent conducting panels. These layers help capture sunlight. A top layer of glass protects the panels. Thin-film panels could also be made from amorphous Si (a-Si) which are non-crystalline wafers sitting on top of glass, metal, or plastic. Another popular material used in thin-film solar panels is CIGS (Copper Indium Gallium Selenide).

USES OF SOLAR ENERGY

The use of solar energy greatly reduces long-term utility expenses like gas, electricity, etc. They are renewable energy sources that have applications in the following sectors:

Residential Application

The residential applications comprise solar water heaters for heating water. This is achieved by installing a photovoltaic cell on the roof of the house which collects the solar energy to warm water. Solar energy is also used to generate electricity in residential complexes. During the daytime, solar energy is captured in batteries and used to supply power through the day and night. These uses of solar energy cut down energy expenditures greatly.

Industrial Applications

The thermal energy from the Sun supplies power to warehouses, offices, and industries. Even radio and TV stations are being powered through solar energy. In aircraft, solar energy provides power to warning lights, and lighthouses also use solar energy.

Remote Applications

Remotely situated places like schools, hospitals, buildings, and clinics can also benefit from the power generated by solar energy. Desalination plants also use solar energy instead of electricity.

Transportation

Public transportation means like light-rails, buses, and trolleys use solar energy.

Pool Heating

During the cold season, solar energy is used to heat swimming pools.

ADVANTAGES AND DISADVANTAGES OF SOLAR ENERGY USAGE

Solar energy notes are not complete without talking about its miscellaneous advantages and disadvantages.

ADVANTAGES OF SOLAR ENERGY SYSTEMS

1. **A Renewable Source of Energy:** There is no way we can run out of solar energy. Solar energy can be applied around the world in many areas. Sunlight will be available to us for 5 billion years, as per the scientists.

2. **Reduction in Electricity Consumption and Bills:** Since some of your energy needs will be met by solar energy, the amount of electricity you consume from other sources would decrease, which in turn reduces your electricity bills.
3. **Low Maintenance Costs:** All you need to do to maintain a solar system is to keep them clean. Most solar equipment from reliable manufacturers has 20 to 25 years of warranty. There is no wear and tear on a solar system since there are no moving parts involved in its working.
4. **Employment**: It creates jobs as you employ solar panel manufacturers and installers, thereby helping the economy.
5. **Eco-friendly Solutions:** Solar systems are eco-friendly as there is no green gas emitted from them after installation.

DISADVANTAGES OF SOLAR ENERGY SYSTEMS

1. **High Initial Cost:** The cost of purchasing a solar energy system is quite high initially. The various costs involved are the solar panel cost, batteries, inverters, wiring, and installation.
2. **They are Dependent on the Weather:** On a cloudy or rainy day, it is still possible to collect solar energy, but its efficiency takes a hit. Since solar systems depend on sunlight for their power, less sunlight can bring down a solar system's performance.
3. **Storing Solar Energy is Expensive:** If solar energy systems are not used up right away, they need huge batteries to be stored. These batteries are used in off the solar grid systems and must be charged throughout the day to use them at night. This is an expensive solution to make solar energy available during the night too.
4. **Needs a Lot of Space:** Depending on the level of electricity you want to produce, solar panels would increase in number. These panels take a lot of space, and some roofs might not even fit in all the solar panels you require.

SOLAR ENERGY PROJECT INFORMATION

There are many DIY solar projects that school students, as well as engineering students, can try on their own. Some ideas for solar energy projects are listed below:

- Battery charger by using solar power.
- Solar charging station.
- USB charger using solar technology.
- Scare mosquitoes with solar energy.
- Solar lamp made with cardboard.

WHAT EXACTLY IS SOLAR ENERGY?

Solar energy is one of the renewable energies and is described as the transformation of energy present in the sun. Most of the sunlight that enters the earth's atmosphere comes in the form of visible light and infrared radiation. Plants utilize it to turn it into sugar and starches, a process known as photosynthesis. This energy is converted into electricity using solar cell panels.

BENEFITS AND DRAWBACKS OF SOLAR ENERGY

The following are some of the benefits of solar energy:

- **Clean**: It is regarded as the cleanest kind of energy since it emits no carbon dioxide, unlike fossil fuels, which is one of the causes of global warming.
- **Renewable**: As long as the sun persists, there is an abundant supply of energy on Earth.
- **Reliable**: Because the energy can be stored in the batteries, there is no concern about unreliability.
- Reduction in Utility bills since it is easily captured, free energy exists.

Solar Energy has the following drawbacks:

- During the winter and on overcast days, productivity is poor.
- Installation and the initial cost of supplies are both costly.
- More space is being consumed.

SOLAR ENERGY TYPES

Solar energy is categorized into two types based on the manner of conversion and the sort of energy it produces**. Passive and active** solar energy are modes of conversion, as are solar thermal energy, photovoltaic solar power, and concentrating solar power.

- Passive solar energy is the capture of the sun's energy without the need for mechanical means.
- Active solar energy collects, stores, and distributes energy using mechanical devices.
- Solar thermal energy is the energy produced by turning solar energy into heat.

SOLAR ENERGY INITIATIVE

Solar energy - one of the simplest scientific experiments that you may prepare for your school fair science project is the experiment on the efficiency of the solar heating functioning model. This functional model is quick, easy, and extremely enlightening.

The outcome may differ if the project is carried out outside owing to wind and weather conditions, hence it is advised that the experiment be carried out indoors.

Use reflectors to concentrate solar radiation in one tiny area to gather and store heat energy in this solar heater project. The efficiency of solar energy will be demonstrated in this experiment.

SOLAR ENERGY'S IMPORTANT APPLICATIONS

Solar energy is a renewable, limitless, and cost-effective source of energy. Solar devices are classified into two types: active and passive. Pollution may be minimized to some extent by using solar energy. One of the purest and clean kinds of energy. Heating, interior and outdoor lighting, transportation, and other uses are examples. Some of the other applications are as follows:

- Solar energy applications in India
- Solar energy is used to charge batteries
- Cooking with solar energy Houses with solar energy

SOLAR ENERGY APPLICATIONS IN INDIA

India is one of the most populous countries in the world, and because solar energy is environmentally benign, it is ideal. It doesn't emit any carbon dioxide. It is an unlimited energy source, making it a great substitute for nonrenewable resources. This energy may be used in rural regions for a variety of applications such as cooking, drying, electricity generation, and so on. Because electricity generation in India is expensive, solar energy is the most cost-effective option.

1. **Solar Cooking Energy:** It is simple to cook with solar energy. Cooking in a solar oven instead of a standard oven will save you money on your power bill. To cook in a solar box, you'll need a thermometer, an aluminum foil-lined box, pan duct tape, a cooking bag, and Styrofoam insulation.

2. **Industrial Solar Energy:** Because of the utilization of heavy gear and equipment, industries need greater quantities of power. Solar energy may be used to provide power. It is also used to protect pipelines against corrosion. Solar energy will help you keep your electricity expenditures under control.

3. **Battery Charging using Solar Energy**: Batteries used to play video games, for example, can be charged during the day as a backup in case of power outages. You may also charge the reserve battery bank in the sunshine throughout the day and use it at night to conserve power.

4. **Water Heater from the Sun**: To replace traditional water heaters, there are two types of solar water heaters: active solar hot water systems and passive hot water systems.

5. **Solar Panel:** Solar panels are mostly used to generate power from solar energy. The photons that impact the solar cell lose electrons from their atoms, and the entire may be changed into an electrical circuit with the right attachment of conductors on the positive and negative sides of a cell. The movement of electrons across the circuit aids in the generation of electricity. A solar panel is made up of many solar cells, and many panels can be combined to form a solar array. Let us learn about the functions of solar panels and their practical use in real life in this session.

SOLAR PANEL APPLICATIONS

Solar panels are utilized in a variety of sectors depending on the need and need. The following are some of the applications for solar panels:

- Solar panels may be utilized to provide power for the dairy industry's sterilizing, pressurization, concentration, drying, and boiler feedwater processes.
- Solar panels can supply warmth for procedures such as sterilization, pasteurization, bleaching, and cooking in the case of tinned food.
- Textile: The textile sector is heavily reliant on the widespread usage of solar panels for the effective use of solar energy. These are employed in processes such as bleaching, dyeing, drying, degreasing, pressing, and so on.
- Paper: Heat is required for many operations in this sector, and solar panels are used to generate heat for activities such as drying, boiler feed water, bleaching, and so on.
- Solar panels are employed in the chemical industry to generate heat, which is utilized in the manufacturing of soaps, synthetic rubber, processing heat, preheating water, and so on.

- Beverages: We may envision solar panels being used extensively in the beverage industry for procedures such as washing, sterilizing, and pasteurization.
- Solar panels are utilized in the timber industry in operations such as drying, thermos-diffusion beams, pre-heating water, and pulp preparation.
- Plastics: Solar panels are used to create heat for usage in processes such as preparation, distillation, separation, extension, drying, blending, and so on.

TAKE ADVANTAGE OF THE SOLAR POWER BENEFITS

Apart from the obvious financial benefits, there are other pertinent reasons why you should convert to using solar power instead of fossil fuels.

1. **Solar Power Is Good for the Environment:** The most known fact about solar energy is that it represents a clean, green source of energy. Solar power is a great way to reduce your carbon footprint. There's nothing about solar power that pollutes mother nature. Solar power doesn't release any greenhouse gasses, and except for needing a source of clean water to function, it uses no other resources. Hence, it's safe and environmentally friendly. Yet, people are still in doubt because solar energy is good.

   Solar power is self-sufficient and installing solar panels on your roof is a safe and easy path to contribute to a sustainable future. Starting on your home is a great way to show you care about the environment.

2. **Solar Electricity Makes Your Home Go Off-the-Grid:** The decrease in the cost of solar panels serves as a great example of why there should be an increase in the use of solar energy. Traditional electricity relies heavily on fossil fuels such as coal and natural gas. Not only are they bad for the environment, but they are also limited resources. This translates into a volatile market, in which energy prices alter throughout the day.

   Solar electricity boosts your electricity independence! By investing in a 4kW solar system, which is the most common domestic size, you can easily protect yourself against unpredictable increases in utility prices and enjoy cheap electricity throughout the entire day – the sun will never increase its rates and it gives you energy security. Once you have solar panels up on your roof, you've technically reached an energy-independent status. Solar battery storage systems can also help store electricity for nighttime and rainy days.

3. **Solar Power Can Use Underutilized Land:** You may continue to wonder why solar power. With the increasing need of solar energy, it's become easily accessible to most of

us. Across countries, there are vast land that are far away from big cities or capitals and are not used for anything at all.

With solar power, we can make use of the land and subsequently generate great value; solar energy provides a source of power for everyone. In this way, we don't need to use high priced land that might be better suited for other applications.

You might have heard of solar farms – panels used to harvest solar energy in large numbers. This highlights perfectly how solar power makes use of underutilized land. For instance, a 45-acre solar farm has been recently built in the UK, and it's able to power 2,500 homes.

4. **Solar Power Causes Less Electricity Loss:** Electricity needs to be transported from big power plants to end-consumers via extensive networks. Long distance transmissions equal power losses. Ever wondered what are solar panels used for? They're on your roof to get energy from the sun. Rooftop solar power is helpful in increasing electricity efficiency, considering the short distance. Your energy becomes domestic and as a result you're in control of your own bills and energy usage. Furthermore, the best solar panels are durable, thus chances of service interruption are reduced.

5. **Solar Power Improves Grid Security:** When there are many of us switching to solar power, we are less likely to experience blackouts or brownouts. Every household in the UK that have solar cells installed, functions as a small power plant. This, in turn, provides us with a greater electricity grid security, especially in terms of natural or human-caused disasters. With the help of solar panel grants, you can also be paid to export electricity back to the grid.

6. **Solar Power Creates Jobs and Economic Growth:** Our national economy can be helped by solar power. The more people who opt for solar, the more needs will be for companies to install solar panels. This creates additional jobs for skilled workers, and consequently keeps the economy growing. In 2015, for instance, the UK become the second-largest solar employer, with 35,000 people, and the continent's largest solar photovoltaic (PV) panel installation market.

7. **Solar Power Is a Free Source of Energy:** The sun provides us with more energy than we could ever use, and no one can monopolize the sunlight. Your solar power system will start saving money from the moment it's turned on; however, the advantages of solar power are best visible in the long-term. The longer you have your solar power system,

the more you enjoy the benefits of solar technology and support the environment. Aside from solar electricity, solar energy has a second application. We often associate solar energy with electricity, which is acquired through PV panels, but it's also possible to use the energy generated by the sun for heating purposes. This process is accomplished by deploying solar thermal systems that simply convert the sunlight into heating solutions. The acceptance of solar technology is at hand, and we can start by increasing our use of solar panels.

THE FOLLOWING PRECAUTIONS SHOULD BE TAKEN WHILE USING ELECTRICITY:

- Never touch/handle any electrical appliance with wet hands. A wet body can act as a good conductor of electricity. In the case of any leakage, the person with wet body/hands will get a severe shock.
- Never try to pull away from a person who has contacted a live wire. Electricity is a very convenient and useful form of energy. However, if proper precautions are not taken, electricity can be very hazardous Magnets and Magnetic Effect of Current.
- Wiring. All wires used in electrical circuits should be covered with a good insulator. So, always use good quality electrical wires.
- Joints in wires. All wires /electrical joints should be properly covered with insulation tape.
- Electrical connections. All electric connections at switches, plugs. sockets and junctions must be tight. Fuses and switches must be connected in the live wires.
- Repairs or replacement. Defective switches, sockets, or wires should be replaced immediately. Whenever any repair or replacement of any electrical component is required, put on rubber gloves, and rubber shoes, or stand on a dry wooden stand. Before starting repairs, the main switch should be switched off. The testers, screwdrivers, pincers, and other repairing tools should have proper insulation on them.
- Fuse. Each circuit should have a fuse of the proper rating. Fuses should be one should never try to pull away from a person who has contacted a live wire connected to the live wire.
- Earthing. All electrical appliances must be properly earthed. By proper earthing, the danger of any accidental shock can be reduced.
- Dealing with accidents. In case of any short-circuiting, or any accidental contact of a person with a live wire, do as follows: immediately switch off the main switch. provide him or her support of some non-conducting material such as rubber sheet, or wood.

CHAPTER 2: ASSIST IN INSTALLATION AND MAINTENANCE OF SOLAR PV POWER PLANT

LEARNING OBJECTIVES

- Identify various components and tools of solar PV power plants.
- Explain how to assist in survey of the site for installation of solar power plant.
- Discuss to make foundations for module mounting structures and other components under supervision.
- Explain how to assist in measurement and recording of readings from various equipment.
- Discuss how to carry out cleaning of modules as per schedule and standard procedure and remove any shadowing objects.
- Explain to assist in replacing defective modules.
- Discuss how to assist in repair and replacement of broken foundations for modules, combiner boxes, inverters and transformers, etc.
- Explain to clean the work area after completing the installation and maintenance activity.
- Explain to remove all the tools, consumables used from the work area and dispose of any waste materials in accordance with safe working practices.
- Explain how to identify processes where material and resources utilization can be optimized.

IDENTIFY KEY COMPONENTS AND TOOLS OF SOLAR PV POWER PLANTS

Do you want to cash in on the benefits of solar energy? Purchase the right solar equipment and better yet, let experts install those components for you. Solar energy equipment comprises all the components of a solar system. Installation of all the solar equipment components enables the harnessing of the sun's energy and its conversion into electricity.

To fulfil the power demands of your home or office, you must know everything about the key solar equipment components: solar panels, solar inverters, mounting structures, a net meter, and solar accessories.

1. **Solar Panels:** If you are planning a switch to solar energy, you already know the benefits of using a solar panel, but do you know how it works?

   Here is a brief synopsis: The ultimate requirement — solar panels are responsible for harnessing electricity from sunlight. Each solar panel comprises individual solar cells that capture the sun's rays. Every cell has silicon semiconductors, boron (positive charge), and phosphorus (negative charge). On the other hand, sunlight comprises innumerable particles of energy called photons that capture the sun's rays. The process is termed the photovoltaic effect, and the panels are also called photovoltaic solar panels.

The wonders that they are, solar panels are of many kinds. Here's a very brief guide on the best solar panels you can choose from.

- Monocrystalline solar panels: Energy-efficient, heat-resistant, and dark-colored – these solar panels are based on half-cut cell technology. They're ideal for installation in areas with partial shadow issues or space limitations.
- Polycrystalline solar panels: More affordable than monocrystalline, these are blue-colored panels with medium efficiency.
- Passivated Emitter and Rear Contact cells (PERC) solar panels: These are the most efficient solar panels that require less space and provide the highest energy retention.
- Thin-film solar panels: Lightweight, flexible, easy-to-install solar panels – they can adhere to any solid surface like glass, metal, or plastic. Their cost is less compared to other panels.

2. Mounting Structures: Solar panels won't produce optimal results if not installed in the right way. A solar panel stand, or mounting structure plays a very crucial role when it comes to mounting the solar panels.

Following are the five different types of mounting structures you can choose from

- Ground mounts: These are made from aluminum racking supported by galvanized steel. They are ideal for open space applications like solar farms. Ground mounted racks are attached to the ground via footings or concrete pillars. No roof penetration is needed, and they have a risk-free installation.
- Roof-mounted racks: This solar equipment is a stand that is adjustable to fit the rooftops and hold the weight of the solar panels. The installation cost is low too.
- Floaters: When you install solar panels on water, they are mounted on interconnected plastic rafts that serve as floating platforms on the water's surface.

- Tracking system mounted racks: Suitable for solar water pumping and tracking systems, they're of two types – One-axis and Two-axis. The one-axis mount measures the sun's motion. The two-axis mount employs PV concentration systems to track the sun's daily and seasonal path.
- Top-of-pole mounted racks: They anchor the PV solar panels on poles, and their design prevents particle accumulation on the solar panel.
- Side-of-pole mounted racks: These are variants of pole mounts with support placed on the side of the pole. They are better options for places with remote solar lighting systems.

3. Solar Inverters: Now that you know about the panels and their mounting, the next most important solar energy equipment is the solar inverter. Your solar panels produce a direct current charge, while you require an alternating current in your house. The inverter is that solar equipment that converts and regulates the energy produced by solar panels. Precisely, a solar inverter converts direct current into alternating current.

You can select from the major types of inverters for your solar power systems:

- Central inverters: Less expensive and more commonly used, these are suitable for solar systems with large solar access. This equipment of solar energy is installed indoors. A central inverter can convert the power produced by all the solar panels linked together.
- Micro Inverters: These are popular for household purposes. They are suitable for areas where a part of the solar panel system stays temporarily blocked from sunlight. They are placed behind every individual solar panel, allowing monitoring, and analyzing of each module's energy production levels. They are expensive but grant a higher level of information access.
- Battery-based inverters: These can be grid-interactive (on-grid) or stand-alone (off-grid). They reduce grid power consumption and provide you with a continuous power supply. They are affordable and easy to maintain.

4. Energy Meter or Bi-directional Meter: You can record the energy production via solar panels through an energy meter. Discom mandates replacing an energy meter with a bi-directional net meter in the residential solar system.

What is a bi-directional meter? As the name suggests, this net meter can send electricity units to the grid and import electricity from the grid as well. Since a net meter records, the power generated and the power consumed, you pay the amount for the net units you consume.

5. Solar Accessories: Besides the major solar equipment components, a solar panel system also requires:

- AC cables
- DC cables
- AC combiner box
- DC combiner box
- Earthing strips
- Lightning arrester
- Conduit pipes for routing cables
- MC_4 connectors
- Electrical connection components
- Working safely with solar PV system

To get the most from solar panels, you need to point them in the direction that captures the most sun. But there are several variables in figuring out the best direction. This page is designed to help you find the best placement for your solar panels in your situation.

This advice applies to any type of panel that gets energy from the sun; photovoltaic, solar hot water, etc. We assume that the panel is fixed or has a tilt that can be adjusted seasonally. (Panels that track the movement of the sun throughout the day can receive 10% (in winter) to 40% (in summer) more energy than fixed panels. This page doesn't discuss tracking panels.)

Solar panels should always face true south if you are in the northern hemisphere, or true north if you are in the southern hemisphere. True north is not the same as magnetic north. If you are using a compass to orient your panels, you need to correct for the difference, which varies from place to place. Search the web for "magnetic declination" to find the correction for your location.

The next question is, at what angle from horizontal should the panels be tilted? Books and articles on solar energy often give the advice that the tilt should be equal to your latitude, plus 15 degrees in winter, or minus 15 degrees in summer. It turns out that you can do better than this - about 4% better.

Fixed or Adjustable?

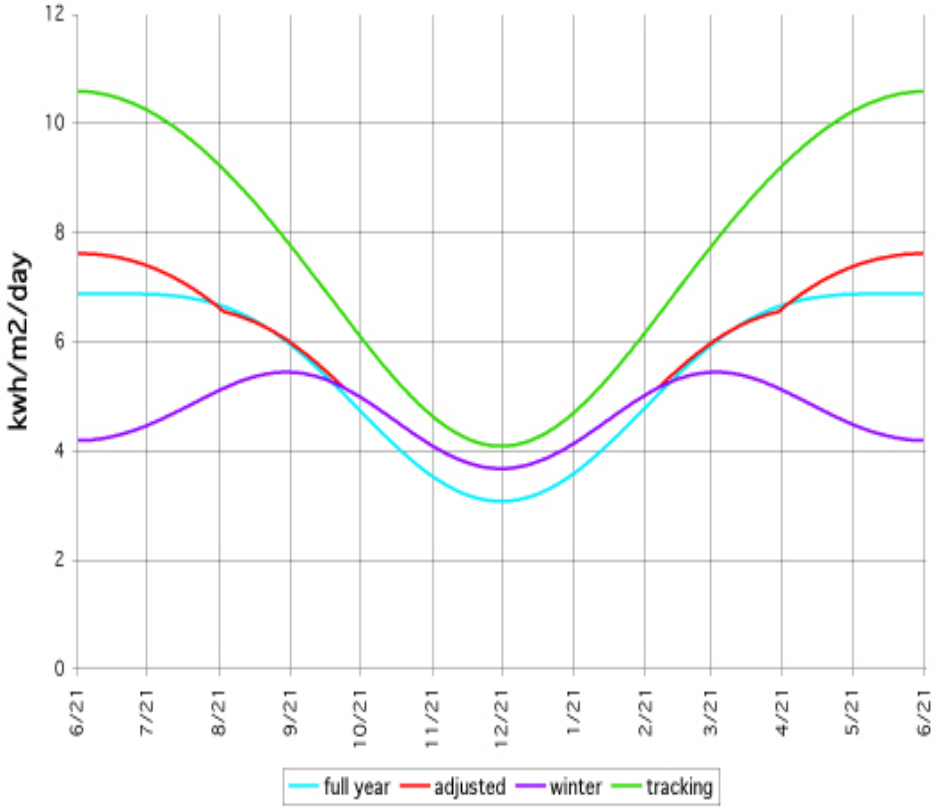
It is simplest to mount your solar panels at a fixed tilt and just leave them there. But because the sun is higher in the summer and lower in the winter, you can capture more energy during the whole year by adjusting the tilt of the panels according to the season. The following table shows the effect of adjusting the angle, using a system at 40° latitude as an example. (The comparison

would be a little different for different latitudes.) Each option is compared with the energy received by the best possible tracker that always keeps the panel pointed directly at the sun.

	Fixed	Adj. 2 seasons	Adj. 4 seasons	2-axis tracker
% of optimum	71.1%	75.2%	75.7%	100%

In short, adjusting the tilt twice a year gives you a meaningful boost in energy. Adjusting four times a year produces only a little more but could be important if you need to optimize production in spring and fall. You can jump to the section on the best fixed tilt angle, or skip to the sections on two-season or four-season adjusting.

The graph below shows the effect of adjusting the tilt. The turquoise line shows the amount of solar energy you would get each day if the panel is fixed at the full year angle. The red line shows how much you would get by adjusting the tilt four times a year as described below. For comparison, the green line shows the energy you would get from two-axis tracking, which always points the panel directly at the sun. (The violet line is the solar energy per day if the panel is fixed at the winter angle, discussed below.) These figures are calculated for 40° latitude.



Fixed Tilt

If your solar panels will have a fixed tilt angle, and you want to get the most energy over the whole year, then this section is for you. A fixed angle is convenient but note that there are some disadvantages. As mentioned above, you'll get less power than if you adjusted the angle. Also, if you live where there is snow, adjusting the panels to a steeper angle in winter makes it more likely that they will shed snow. A panel covered in snow produces little or no power.
Use one of these formulas to find the best angle from the horizontal at which the panel should be tilted:

If your latitude is below 25°, use the latitude times 0.87.
If your latitude is between 25° and 50°, use the latitude, times 0.76, plus 3.1 degrees.
If your latitude is above 50°, see Other Situations below.

Safety is a full-time job and everyone working with PV systems is responsible for it. To work safely with a PV system, one must have:

- Good work habits.
- A clean and orderly work area.
- Proper equipment and training in its use.
- An awareness of potential hazards and how to avoid them.
- Periodic review of safety procedures; and
- Instruction in cardio-pulmonary resuscitation (CPR) and basic first aid.

Prior to any installation or maintenance work of PV system it is necessary to:

- Identify all the possible risks.
- Determine the work practices that will be undertaken to remove the risk, or to minimize the risk if it cannot be removed altogether; and
- Communicate to other colleagues working in that site about these risks and how they will be removed or minimized.
- Potential Risks from solar PV systems

PV MODULES

PV modules generate electricity if light falls on them. Attempting to cover them, using a blanket or cardboard for example, is not a safe practice. Light could still reach the PV module, or the cover may come off. In many PV systems, the PV array is more than 120V DC. This voltage level is dangerous, and any installation or maintenance work must be undertaken with extreme care.

PV modules generally have aluminum frames and are mounted on metal array frames, which are often located on metal roofs. All these metal objects can become very hot during the day and touching these could causes burns on the skin, wear gloves and suitable clothing.

Operation & Maintenance (O&M) is one of the most critical ways to ensure that the solar power system gives the best possible generation. Maintain the plant infrastructure and equipment, with the goal of improving the equipment's life by preventing excess depreciation and impairment. This enables the solar power plant to produce the maximum amount of energy throughout its operational life, perfectly aligning the interests of developers, clients, and the investors.

Combining our experience in plant maintenance and advanced diagnostics the O&M staff, using a remote monitoring system, ensures the plant functions smoothly, thereby continuously generating solar power.

General checks

As a solar plant is installed, engineers prepare a schedule for preventive maintenance. This includes, but is not limited to, adjustments, cleaning, lubrication, repairs, replacements, and the extension of equipment life. At least twice a year, O&M personnel conduct a general inspection of the installation-site.

During this inspection, technicians:

- Ensure roof drainage is adequate, roof drains are not clogged and confirm that there are no signs of water pooling near the array.
- Ensure roof penetrations (if any) are watertight.
- Check for ground erosion near the footings of a ground mount system.
- Confirm electrical enclosures are only accessible to authorized personnel.
- Check for corrosion on the outside of enclosures and the racking system.
- Check for cleanliness throughout the site to ensure that there is no debris in the inverter pad area or elsewhere.
- Check for loose hanging wires in the array.

- Check for signs of animal infestation under the array.

Specific checks

Apart from the basic checks, some specific checks happen as part of the preventive maintenance.

- **Modules:** Modules need the maximum amount of preventive maintenance, and cleaning activities are majorly concentrated around them.
- **Frequency of cleaning:** In normal conditions, where there isn't too much dust or dirt, cleaning is carried out on a fortnightly basis. However, in dusty areas such as Rajasthan, the cleaning frequency is increased to once a week.
- **Water Quality:** The cleaning of the modules is done keeping in mind the TDS (total dissolved solids) levels, water specifications and certain wiping details. In India, the TDS level of the water needs to be at least below 250 parts per million (ppm). The chlorine (less than 250 ppm) and calcium (less than 250 ppm) level of the water, as well as the electrical conductivity, is kept in mind while carrying out the cleaning. Water quality is tested after every six months to ensure that set standards are maintained.
- **Quality of cleaning equipment:** Brushes without hard bristles (say fiber brushes) should be used for cleaning. A low-quality brush, like one with metal bristles, could negatively impact the glass surface of the modules. In some cases where hard substances like bird droppings have gotten stuck on the module, engineers use detergent to clean the surface. However, the detergent is not highly concentrated and has very high-water content.
- **Innovation in Cleaning:** Technicians are currently in the process of developing automated cleaning systems. In the sprinkle-type cleaning system, nozzles will be placed on the module itself, and it will automatically start the system using remote monitoring, pressurize the water, and pour it over modules. It would be particularly useful when it is hard to install a water source at the site. However, this would be a costlier way to clean when compared to deploying someone at the site.
- **Post wash care:** Post extensive cleaning, modules are wiped off properly to ensure no stain is left to avoid affecting the generation capacity. Engineers decide for Ultra Poly Vinyl Chloride (UPVC) conduit pipes to ensure water supply. After the system returns to steady-state temperature (i.e., there is no remaining impact from the cooling effect of wash water), the current produced is noted along with weather conditions including temperature, irradiance etc. This maintenance work is recorded in the logbook, and the production of the clean system to the previous production values is compared.
- **Inverter:** Most German-make inverter manufacturers recommend servicing it on a quarterly basis. The ventilation is provided via a filter, and this filter needs to be

frequently cleaned. Therefore, usage of high-quality filters is advantageous. As part of preventive activities, our engineers check the voltage of the string inverter and record it in the periodic logbook. This gives an understanding of voltage fluctuations if any.

- **MC4 Cabling Connector:** Under preventive measures, we ensure that there is no gap between the male and female connector pipes. Any gap, irrespective of the size, could cause a fire and damage the modules. Separately, off-takers can install a "check" meter of equal or higher accuracy with reference to the main meter to cross-check the production level monthly. All readings must be, equal, with a 2-3% correction allowance.
- **Transformer:** For transformers at the site with installed capacity in megawatts, parameters such as the operating temperature, OTI (oil temperature), WTI (winding temperature), and oil level are monitored daily. If there is any internal disturbance in the transformer, it reflects in these parameters which are monitored at least three times in a day (at 11 AM, 02 PM and 04 PM as solar power is generated at its peak during these slots). The transformer must be cleaned thoroughly once in six months. Organization conducts IR test and cable yearly to check the transformer performance.
- **Protection from external elements:** To ensure that the plant is working smoothly (i.e., without any shutdown), the same has to be sealed properly. Else, rats and other rodents can enter, and get electrocuted. This, in turn, can cause a short circuit, and affect the entire plant. Many people are not aware that even high-pressure water can damage the modules. If the water stream is too strong, our team will place the outlet at a farther distance.
- **Remote monitoring:** A solar power plant constantly needs to be monitored to detect breakdowns and optimize its operation. The same function could be performed either on-site or remotely wherein we retrieve all the data either from the inverter or from communicating equipment (probes, meters etc.).

Monitoring the solar PV panels consistently is the cornerstone of the O&M of a solar power plant. It includes inspection, supervision, sending signals and messages, and receiving signals from the environment about irradiation. Clients expect the solar power plants to achieve high levels of power generation. Hence, we have developed capabilities that include state-of-the-art plant supervision technology, end-to-end solar power plant maintenance execution (from modules to substations) and superior performance engineering expertise.

INSTALLATION OF SOLAR PV SYSTEM

Solar power is energy from the sun and is a form of renewable energy. It will never be exhausted and can be used again and again at free of cost. A simple example of the Sun's power can be seen by using a magnifying glass to focus the Sun's rays on a piece of paper which burns it easily.

There are many ways of harnessing solar energy. The most commonly available technologies are:

Solar Photovoltaic (PV) Systems

Solar Hot Water Systems

Concentrated Solar Power (CSP)

Passive Solar Design

INSTALLATIONS AND OPTIMIZE THE ROUTE PLAN SOLAR PHOTOVOLTAIC (PV) SYSTEMS:

Solar PV systems directly convert sunlight into electricity. There are two types of solar PV systems exists. Standalone or off-grid PV systems and grid connected or on-grid PV systems. Standalone systems are generally smaller in size and distributed.

Examples of Standalone PV systems: solar water pumping system, street lighting, rural micro grid and solar home system

SITE LEVEL PRE-REQUISITES FOR SOLAR PANEL INSTALLATION

Examples of grid connected PV systems: Rooftop distributed systems and MW scale project.

Grid connected PV systems can be small distributed systems installed in building rooftops or ground and connected at 230V or 440V grid. Large utility scale PV projects are generally connected to grid substation at a voltage level of 11KV or higher.

SOLAR HOT WATER SYSTEMS:

Solar hot water is one of the most common applications to use solar energy. Solar energy is used to heat water through a "flat plate solar collector" or "evacuated tube collector". Solar collectors should not be confused with solar modules which produce electricity.

BATTERY HAZARDS

Standalone PV systems contain batteries. A large percentage of the batteries are the lead- acid type and the sulphury acid which is hazardous. Chemical burns will occur if the acid contacts an unprotected part of the body - eyes are particularly vulnerable. Anytime you are working around lead-acid batteries you should wear non-absorbent gloves, protective eyewear, and apron.

Even though the total voltage of battery banks in photovoltaic systems may be low, there can be lethal levels of electrical power present.

Never smoke or have open flames or sparks around batteries. As the batteries charge, explosive hydrogen gas is produced. Always make sure battery banks are adequately vented and that a No Smoking sign is posted in a highly visible place.

When measuring the short-circuit current of either the modules or the entire array, be careful not to short circuit the battery bank. An explosion can result. To prevent this, open the battery disconnect switch between the short circuit and the batteries.

Never allow tools to fall onto the terminals or connections. Never allow the construction or use of shelves above the batteries, as objects can fall off the shelves onto the batteries. Battery banks must always be adequately vented.

If the battery bank does not have a disconnect switch, be very careful when removing a wire from right at the batteries. If the batteries are charging, and the hydrogen gas being given off has not been properly vented, it can be ignited by the spark, resulting in an explosion. Make sure the battery enclosure is properly vented.

Batteries are generally heavy. Proper care must be taken when handling and carrying the batteries. Appropriate lifting device should be used while installing the batteries and to shift the batteries from one place to another.

INVERTERS

Inverters are generally heavy. Care should be taken when carrying an inverter and installing an inverter, particularly if it is to be mounted in a high location. The output of the inverter is 230V or 415V AC, which is potentially a deadly voltage.

Insects, snakes, and other vermin: Spiders, wasps, and other insects often move in and inhabit junction boxes in PV systems. Some wasp build nest in the array framing. Rattlesnake uses the shades provide by the array and fire ants are commonly found under arrays or near battery storage boxes. Always be prepared for the unexpected when you open the junction box. Look carefully before you crawl under the array. It may sound funny, but fire ants or black widow spiders (let alone rattlesnake) can cause painful injury.

SAFETY EQUIPMENT

Following is a list of recommended safety equipment that you should have available. Check these items against a site safety plan and check to make sure all equipment is in working order before beginning a job.

PERSONAL SAFETY RESOURCES

- A work partner (never work alone!)
- An understanding of safety practices, equipment, and emergency procedures
- Safety checklists
- Safety helmets & eye protection
- Battery safety accessories
- Appropriate safety harnesses, if working on elevated sites
- Proper measuring equipment: electrical and dimensional
- Tape and use wire nuts or cable connectors on end of cables

SITE SAFETY RESOURCES

- First-aid kit
- Fire extinguisher
- Appropriate ladders
- Appropriate lifting equipment
- Safety goggles, apron, gloves
- Use suitable labels on all equipment's, wiring, etc.
- Remove all jewelry that might encounter electrical components.
- Do not wear loose clothing or have loose hair.

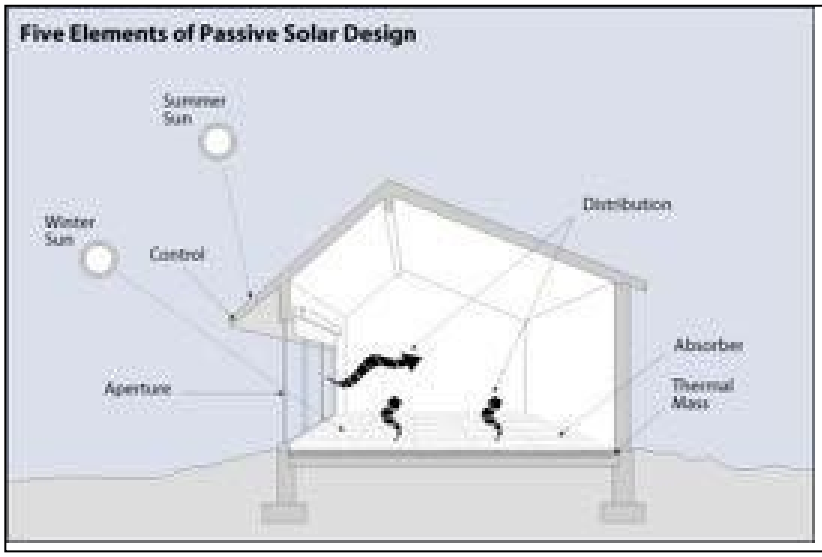
CONCENTRATED SOLAR POWER (CSP)

CSP is a centralized form of solar thermal power that uses sunlight to make steam and then uses this steam to supply heat or drive a turbine to make electricity. CSP uses large mirrors to concentrate the Sun's rays towards a central point which is normally transparent tube carrying water. This concentrated energy is used to boil water and create steam, which can be directly used for heating/ cooking, or to drive a steam turbine and create electricity. In order that the concentrators work effectively throughout the day, tracking systems are used to track the concentrators.

Parabolic Dish | Parabolic Trough | Power Tower

PASSIVE SOLAR DESIGN

Passive solar design refers to designing a building to utilize the sun's energy as intelligently as possible. Techniques will vary significantly throughout the world; however, the central idea is to keep the sun's rays out of the house in the summer and to trap the sun's rays inside the house during winter.



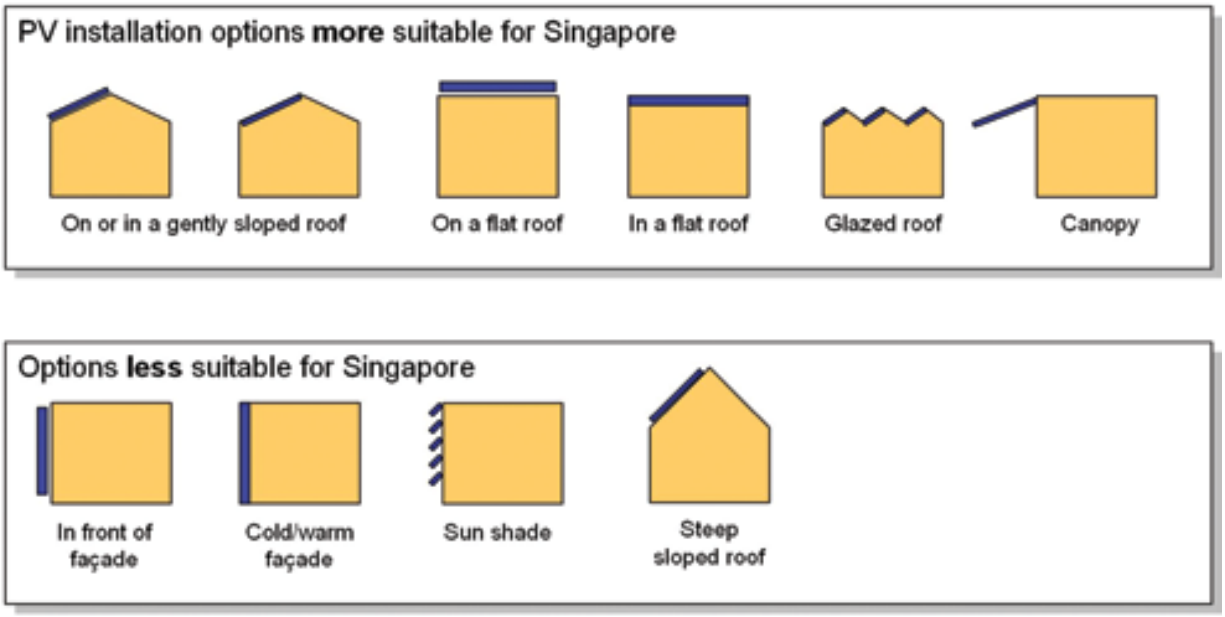
- Lower energy needs
- Cool in summer
- Warm in winter
- Orientation
- Window sizes
- Insulation
- Site specific

SOLAR PV SYSTEMS ON A BUILDING

There are many examples overseas where PV modules are mounted on the roof and integrated into building façades. They work particularly well in Europe and North America, as south-facing façades in these regions are well exposed to the sun.

We must consider that the sun passes almost directly overhead. This is because we are located near the Equator, and the path of the sun follows the Equator, with seasonal variations of up to 23.50 to the north or south. Therefore, there are optimal positions to locate the PV modules that have to be taken into consideration. Refer to Appendix A for examples of solar PV systems on buildings in Singapore.

To maximize electricity production for use in Singapore, the best location for the PV modules to be installed is right on top of a building, facing the sky. The possible installation options are shown in below Figure.



WHERE TO INSTALL PV MODULES ON A BUILDING

Vertical façades and steeply sloped roofs tend to suffer a big loss in the ability to generate electricity in exchange for higher public visibility. With the PV modules facing the sky, it is possible to improve the yield by installing PV modules on trackers to follow the sun from east to west during the day (single-axis trackers), and from north to south during seasonal changes (dual-axis trackers).

However, trackers can only improve system performance under direct sunshine, and they give no advantage in diffused sunlight conditions, such as on cloudy or hazy days.

The downside of having flat-mounted PV modules is that they tend to get dirty from rainwater and dust. See below Figure. It is therefore better to mount the PV modules at an incline (10-150 for framed modules, or as little as 3-50 for unframed modules), to allow rainwater to properly drain off.

AVOID SHADING PV MODULES

PV modules should be free from shade. Shading of any single cell of a crystalline silicon PV module will drastically reduce the output of the entire PV module. Thin film PV modules are more tolerant to partial shading than crystalline silicon PV modules. Typical culprits include shadows cast by tall trees and neighboring buildings.

Besides mounting PV modules on the rooftop, customized PV modules can be integrated into the building façade in a creative, aesthetically pleasing manner. They can be mounted on any part of the rooftop or external walls that is well exposed to sunlight e.g., skylights, cladding, windows, and external shading devices.

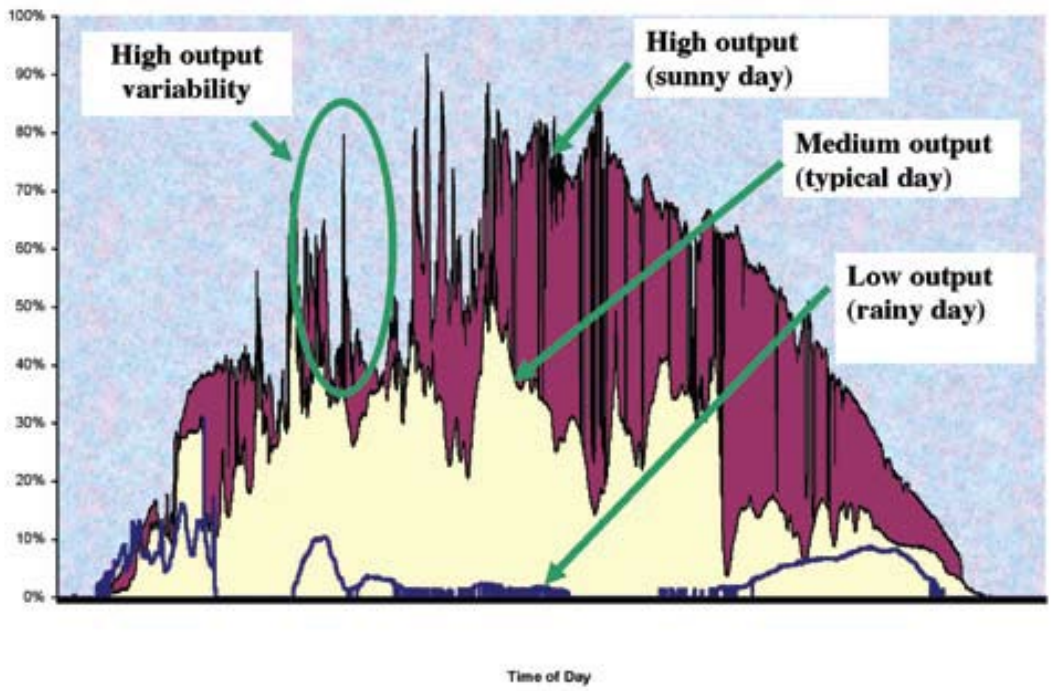
They can also be integrated into external structures such as façades and canopies, as shown in below Figure, respectively.

BIPV modules integrated into a façade

BIPV modules integrated into a skylight canopy.

SOLAR PV OUTPUT PROFILE

Solar PV only produces electricity when sunlight is available. The output of a solar PV system varies with its rated output, temperature, weather conditions, and time of the day. The power output profile of the PV installation as shown in below Figure, at a selected test site in Singapore collected over a period from 2002-2004, in terms of its capacity factor2 , shows a high variation of solar PV output.



SOLAR PV YIELD

The amount of electricity you can generate from a solar PV system depends not only on the availability of sunshine but also on the technology you choose to install. For example, a typical 10-kW rooftop solar PV system in Singapore would produce about 11,000 to 12,500 kWh annually using crystalline PV modules, and 12,000 to 14,500 kWh annually with amorphous silicon thin film PV modules.

COST OF A SOLAR PV SYSTEM

The cost of your solar PV system will depend on many factors: system configuration, equipment options, labor cost and financing cost. Prices also vary depending on factors such as whether your home is new, and whether the PV modules are integrated into the roof or mounted on the roof. The cost also depends on the system size or rating, and the amount of electricity it produces.

Generally, solar PV systems entail high capital costs. With solar power, you can save on the purchase of electricity from the grid. But even with these savings, it will take a long time to recover the capital cost of the solar PV installation. The operating costs for solar PV installations are negligible, but the annual maintenance cost beyond the warranty period may amount to 0.5% to 1% of the capital cost of the installation.

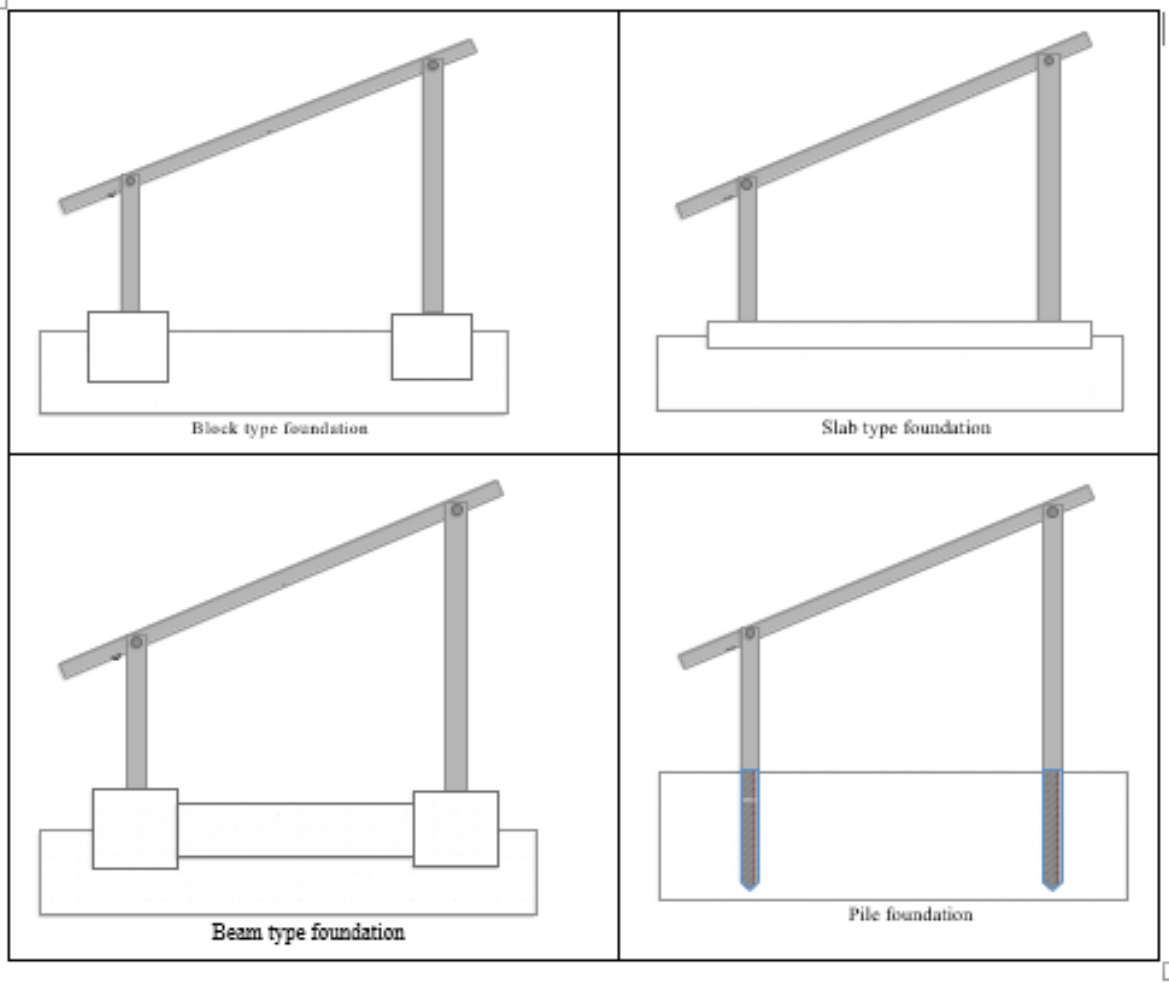
FOUNDATION AND STRUCTURAL ALIGNMENT

The most critical element of foundation and structure installation is alignment. The points where the mounting structure is to meet the foundation must be level, and any mounting bolts must be spaced correctly. It is critical that careful measurements be made both for spacing and for flatness. The orientation of the foundation must face true south.

- Determining and marking the north-south direction with the help of a compass
- Aligning the locations for foundation for mounting structure

TYPE OF FOUNDATIONS FOR MOUNTING STRUCTURE

Foundation for array mounting structure may be different for different sites, type and load bearing capacity of soil, wind velocity, waterlogging possibility, and type of mounting structure. Conceptual drawing of foundation type generally used to hold PV array structure are presented below:



Example of block type foundation

Example of array installed on a RCC roof of the control room.

Example of slab foundation

Example of beam type foundation

Example of pile foundation

ARRAY INSTALLATION AND WIRING

Once the mounting structure is in place, modules are place on to it and fixed properly. Modules pre-wired with MC_4 connector before fixing to the structure. Modules are connected in series and parallel as per design. It is necessary to draw the module.

Tools and connectors required for PV module wiring

BATTERY INSTALLATION

It is essential to check the following before installation of batteries:

- Review battery safety procedures
- Do not mount the batteries directly on a concrete floor. Mount onto wooden or other non-conducting rails.
- Make sure the batteries are fully charged, and that the electrolyte level is at manufacturer's recommended level.
- Check all cell voltages and write down on a status sheet for later comparison.

- Handle batteries with extreme care, and use tools carefully. The greatest danger will occur if wires are hastily connected, or if tools are dropped onto the bare battery terminals.
- All connections should be "walked through" a few times, perhaps with another installer present to confirm before actual wiring is done.
- Make sure to place a sign at the batteries warning unauthorized personnel about the dangers.

BATTERY WIRING:

Like solar modules, batteries are connected in series and parallel to achieve required voltage and capacity. To operate at a higher voltage, batteries are connected in series. Examples of wiring of battery bank at different voltage configurations and capacity are shown below.

Twenty-four 2V batteries are connected in series and to get 48V battery bank.

CONTROL CENTRE PRE-WIRING

- Understand and follow the schematic diagram of the system wiring.
- Assemble all controls, disconnect switches, alarms and meters and load centers as pre-planned.
- Make sure there is the required safe space between any boxes and walls or pipes or other equipment.
- Check that all connections are secure and clean, that all wiring is color coded or marked for correct polarity and that all wire lugs are fastened tight to their wires.

- Before connecting the inverter, make sure the polarity is correct. Most inverters can be damaged if connected with the wrong polarity.
- Label all main switches so that an uninformed person with the operation guide can safely and easily disconnect the system in an emergency.

POWER DISTRIBUTION SYSTEM

Three basic configurations could be applied for distribution of power in solar microgrid systems. Applicability and techno-economic feasibility of these configurations depend on system capacity, configuration, equipment type and distribution of loads.

- DC distribution system;
- AC single phase distribution system;
- AC three phase distribution system;

Recommended conductor size for different configurations is presented in the next pages. Maximum cable route length of copper cable with different cross-section area for 12V DC power distribution system considering 2% voltage drop.

Maximum cable route distance (m) with different cross section area of cable with 2% voltage drop							
Current (A)	1.5mm²	2.5mm²	4mm²	6mm²	10mm²	16mm²	25mm²
1	10	16	26	39	66	105	164
2	5	8	13	20	33	52	82

3	3	5	9	13	22	35	55
4	2	4	7	10	16	26	41
5	2	3	5	8	13	21	33
6	2	3	4	7	11	17	27
7	1	2	4	6	9	15	23
8	1	2	3	5	8	13	20
9	1	2	3	4	7	12	18
10	1	2	3	4	7	10	16

Maximum cable route length of copper cable with different cross-section area for 24V DC power distribution system considering 2% voltage drop.

Cable route distance (m) with different cross section area of cable with 2% voltage drop							
Current (A)	1.5mm²	2.5mm²	4mm²	6mm²	10mm²	16mm²	25mm²
1	20	33	52	79	131	210	328
2	10	16	26	39	66	105	164
3	7	11	17	26	44	70	109
4	5	8	13	20	33	52	82
5	4	7	10	16	26	42	66
6	3	5	9	13	22	35	55
7	3	5	7	11	19	30	47
8	2	4	7	10	16	26	41
9	2	4	6	9	15	23	36
10	2	3	5	8	13	21	33

Maximum cable route length of copper cable with different cross-section area for 48V DC power distribution system considering 2% voltage drop.

Cable route distance (m) with different cross section area of cable with 2% voltage drop							
Current (A)	1.5mm²	2.5mm²	4mm²	6mm²	10mm²	16mm²	25mm²
1	39	66	105	157	262	420	656
2	20	33	52	79	131	210	328
3	13	22	35	52	87	140	219
4	10	16	26	39	66	105	164

5	8	13	21	31	52	84	131
6	7	11	17	26	44	70	109
7	6	9	15	22	37	60	94
8	5	8	13	20	33	52	82
9	4	7	12	17	29	47	73
10	4	7	10	16	26	42	66

Maximum cable route length of aluminums cable with different cross- section area for 230V AC power distribution system considering 2% voltage drop.

Cable route distance (m) with different cross section area of cable with 2% voltage drop						
Current (A)	1.5mm²	2.5mm²	4mm²	6mm²	10mm²	16mm²
1.0	1.5	117	195	313	469	782
2.0	1.5	59	98	156	235	391
3.0	1.5	39	65	104	156	261
4	1.5	29	49	78	117	195
5.0	1.5	23	39	63	94	156
6.0	1.5	20	33	52	78	130
7.0	1.5	17	28	45	67	112
8	1.5	15	24	39	59	98
9.0	1.5	13	22	35	52	87
10.0	1.5	12	20	31	47	78

DEPENDENCIES ON PV SYSTEM TYPE, SITE, AND ENVIRONMENTAL CONDITION

If micro-inverters are not used, the PV system will have both AC and DC components. The DC system determines system power capacity and energy production, whereas the inverter and the AC system has the greatest impact on system reliability. There can be several single points of failure in the AC system—for example, the central inverter, or the generator step-up (GSU) transformer. Central-inverter considerations are discussed in the next section.

O&M measures and cost depend on the wire management system employed. Preventive maintenance entails making sure wires are secure and protected. Corrective maintenance entails finding and repairing ground faults, such as wire scaping against a module frame; and

arc-faults that may be caused by a broken wire or loose connection. Wire management may be classified in three categories: open air; direct bury; or conduit/cable tray.

Module-to-module and module-to-combiner wires are often in open air. These are most subject to damage, but it is easy to locate their problems and repair them.

Direct bury of conductors is a lower first cost than installing conduit and pulling conductors. Failure risk of direct-bury conductors is usually low, and failures are typically caused by rodents chewing on them. Proper compaction of the soil is a best practice for reducing this problem. However, if the direct-bury conductor fails, it may be difficult to locate the fault, and the conductor must be dug up to find and fix the problem. This can be very expensive. Not only does the conductor need to be dug up, but there is likely other buried infrastructure in the vicinity, making the dig-up process very slow. Direct bury is chosen in many cases, driven by capital-cost considerations.

O&M will be minimal for conductors in conduit or lay-in trays, which are designed as an integral part of the rack and wiring system.

Maintenance must be provided to ensure that the wire management system continues to protect the wires from physical damage. O&M problems will be exacerbated if:
Wires, plastic wire ties, or grommets/bushings are exposed to sunlight. Even products listed for direct ultraviolet (UV) exposure will show degradation over the long life of a PV system and require eventual replacement.

Movement or rubbing against modules, rack parts, or other wires due to wind or thermal expansion/contraction are allowed. This will require more frequent inspection, testing, and replacement. Movement of ballasted rack systems on a roof can cause damage to conduit or wires, and even ground -mounted parts can experience movement over a long period of time. A design that accommodates such movement and thermal expansion/contraction will require less corrective maintenance.

Wire ties pinch wires too tightly. This will eventually deform the insulation. Faults may occur anywhere that wires are held tightly between metal parts.

Wires are pulled too tight or do not have strain relief. This will require more frequent maintenance. Wires exposed where there is weight from accumulated ice, or where module leads do not come in the right length for the installation, will require frequent testing and repair.

Exposure to animals, such as squirrels, requires measures to deny the animals access to the wiring and to repair any sections where the insulation has been chewed. Large bundles of wires do not allow wires at the center of the bundle to cool as they would in open air, leading to early degradation of the insulation and potential fault.

GSU transformers are common in utility-scale PV plants, and the failure risk has been low historically. In the past, transformers were overbuilt and have a reputation for being very reliable. However, as design engineers now have access to computer-aided design (CAD) tools, they are able to meet requirements without overdesigning. If the GSU fails, it can idle the plant for months. GSUs are very expensive and have a very long lead time. Also, they are large and heavy, and the logistics associated with delivery are complicated. Delivery of GSUs may include a crane and require special permits for transport on roads and interstates.

2 The risk of GSU transformer failure may be mitigated during the design phase by dividing the plant into multiple arrays, each with its own GSU transformer. It is critical to follow the manufacturer's recommendations for a preventive maintenance program. It may also be possible to work with local utilities to pool resources for better access to replacement units. At the minimum, the responsible party should have a fully formed reaction plan in place. Some operators keep a spare GSU on-site to reduce down-time associated with this critical component.

Central, String, DC-Optimized, or Micro-Inverter Configuration O&M depends on the topology of the inverter system: micro-inverters on each module, string inverters on series strings of modules, DC-optimized inverters that combine elements of both topologies, and larger central inverters. The cost per watt of capacity is much higher for a micro- inverter and string inverter than it is for a central inverter. The different types of inverters have different failure and replacement profiles and different effects on production.

Inverter reliability continues to increase for all types of inverters, with 10-year warranties now commonly available and 20-year extended warranties/service plans also gaining prevalence. However, a sound O&M plan should account for inverter failure because it is one of the most frequent causes of PV system performance loss (EPRI 2010). The best preventive maintenance for the inverters would be to perform the manufacturer's required maintenance—to include, but not limit to, re-torquing current-carrying conductor fasteners (screw lugs on terminal blocks) and thermal imaging of electrical connections and components. Inverter air filters will take in grass and dust during mowing, high winds, or dusty conditions, and the O&M plan should establish a timeframe when the grass-cutting is done and schedule a preventive filter swap/cleaning to follow such dusty conditions. A technician will be dispatched faster to service

a central inverter (see Appendix C for corrective maintenance choices for both string and central inverters), whereas failures of micro-inverters, and to a lesser extent string inverters, can be delayed until a scheduled visit because their impact on the performance of a large plant is incremental.

CHAPTER 3: ASSIST IN INSTALLATION AND MAINTENANCE OF OFF GRID SOLAR SYSTEMS

LEARNING OBJECTIVES

- Explain to assist in survey of the site for installation of solar modules and solar pump.
- Explain how to visually inspect for physical defects of equipment.
- Explain how to mount and fix the structures and modules on the foundations under supervision.
- Explain how to assist in laying of cables and pipes under supervision.
- Discuss to assist in installation and regular maintenance.
- Explain to make proper foundation under supervision.
- Discuss to assist in erection of the pole under supervision.
- Discuss to assist in installation and regular maintenance of streetlights.
- Discuss to visually inspect all components including batteries, solar modules, cables of small solar systems.
- Explain to assist in installation and regular maintenance of solar modules, lights, fan, etc.
- Discuss to assist in cleaning of PV module, including Dry/ Wet/ and robotic cleaning.
- Discuss to clean the work area after completing the installation.

GRID-CONNECTED SOLAR PV SYSTEM CONFIGURATION

A building has two parallel power supplies, one from the solar PV system and the other from the power grid. The combined power supply feeds all the loads connected to the main ACDB. The ratio of solar PV supply to power grid supply varies, depending on the size of the solar PV system. Whenever the solar PV supply exceeds the building's demand, excess electricity will be exported into the grid. When there is no sunlight to generate PV electricity at night, the power grid will supply all the building's demand.

A grid-connected system can be an effective way to reduce your dependence on utility power, increase renewable energy production, and improve the environment.

OFF-GRID SOLAR PV SYSTEMS

Off-grid solar PV systems are applicable for areas without power grid. Currently, such solar PV systems are usually installed at isolated sites where the power grid is far away, such as rural areas or offshore islands. But they may also be installed within the city in situations where it is inconvenient or too costly to tap electricity from the power grid. For example, in Singapore, several URA parking sign lights are powered by off-grid solar PV systems.

An off-grid solar PV system needs deep cycle rechargeable batteries such as lead-acid, nickel-cadmium, or lithium-ion batteries to store electricity for use under conditions where there is little or no output from the solar PV system, such as during the night, as shown in below figure.

Therefore, on an overall basis, solar PV-derived electricity is still much more expensive than that from the power grid. However, the cost of solar PV has historically been falling by about 4% a year, and if this continues, solar PV may be competitive within the next 10 years. For incentives on solar PV system, please refer to Appendix D.

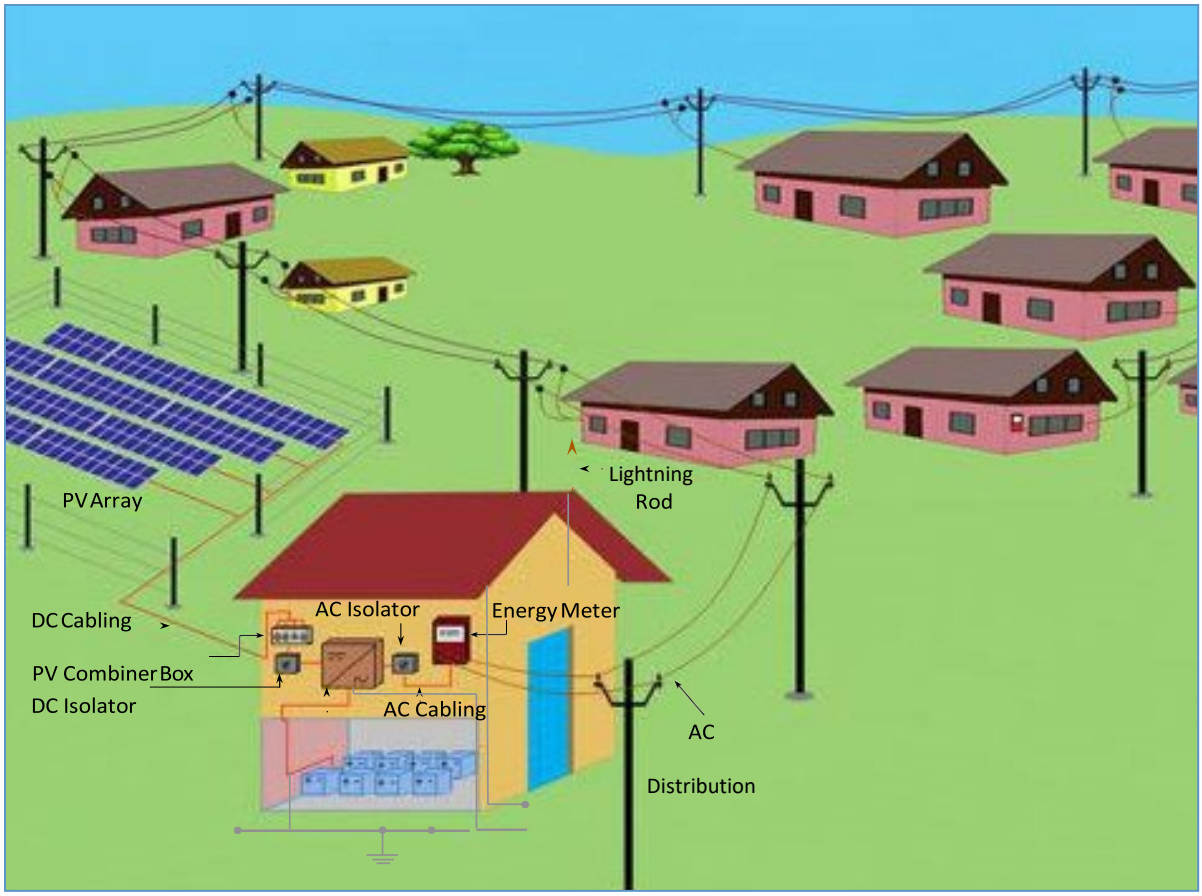
WHAT IS A SOLAR MICROGRID SYSTEM?

A solar microgrid is a small-scale solar powered grid that can operate independently to supply energy for limited number of consumers in a village or a hamlet. A solar microgrid generally consist of a solar PV array, a battery bank, charge controller or control system, inverter (in case of AC supply), cables for power distribution and safety devices.

Size of a microgrid system depends on the number of consumers and corresponding energy demands. Capacity of a microgrid system can be as small as 100W to supply basic lighting load for few adjacent households or even more than 100kW to supply residential and commercial load in a village.

The IEC62257 Part 9-1:2008: Micro power systems technical specifications covers low- voltage AC, three-phase or single-phase, with rated capacity of the power plant at the electrical output less than, or equal to, 100kVA.The voltage levels covered under this IEC technical specification are:

- Low Voltage (LV) AC systems at voltage level of 120-240V single phase /208-415V three phase at 50Hz or 60Hz
- Extra low voltage IELV) DC systems less than 120V DC



A conceptual schematic of solar microgrid system

COMPONENTS OF A SOLAR MICROGRID SYSTEM PV MODULE – VARIATIONS ON SIZE/WATTAGES

PV modules are the device that captures the Sun's energy and converts it into electricity. There are a wide variety of modules available today which differ in the type of silicon used, the manufacturing process, and the product quality. The vast majorities of commercially available PV modules are made from silicon and differentiate into the three main varieties: mono-crystalline, polycrystalline and thin-film solar cells. The different types of PV module vary significantly by cost, efficiency, and appearance. The choice is highly dependent on the application; however, the most important thing is to ensure that they are compliant to the relevant codes and standards as will be discussed.

Rated Capacity at STC (Wp)	Isc	Imp	Voc	Vmp	Length (mm)	Width (mm)	Weight (kg)
50Wp	3.04	2.8	21.77	17.89	608	666	4.6
100Wp	6.11	5.57	21.84	17.99	1152	666	8
200Wp	8.1	7.48	32.65	26.74	1486	982	15.5
250Wp	8.71	8.18	37.55	30.58	1639	982	17.45
300Wp	8.74	8.05	45.1	37.28	1956	992	27

PV Modules

Storage

Inverter & Electronics

Charge Controller

Solar Array Mounting System

Cables & Connectors

BATTERY STORAGE – TYPE AND CLASSIFICATIONS

In a standalone PV system, battery storage is required if electrical loads are required to operate at nighttime, or during extended periods of cloudy or overcast weather when the PV array by itself cannot supply enough power. The primary functions of a storage battery in a PV system are:

- Energy Storage Capacity and Autonomy
- Voltage and Current Stabilization
- Supply Surge Currents

The number of days the battery storage capacity is available to operate the electrical loads directly from the battery, without any energy input from the PV array is called days of "autonomy" in a standalone PV system. For common, less critical PV applications, autonomy periods are typically designed for between two and six days. For critical applications involving essential loads or public safety autonomy periods may be greater than ten days.

In general, electrical storage batteries are broadly classified as Primary and Secondary Batteries. Primary batteries are not used in PV systems because they cannot be recharged. A secondary battery can store and deliver electrical energy and can also be recharged by passing a current through it in an opposite direction to the discharge current.

		
Flooded Electrolyte LA battery	VRLA battery	Lithium-Ion battery

The batteries that are commercially available and viable for use in photovoltaic system include:

- Flooded Lead Acid Batteries
- Valve Regulated Lead Acid (VRLA) Batteries
- Nickel Cadmium (NiCd)
- Nickel metal Hydride (NiMH)
- Lithium Ion (Li-ion)

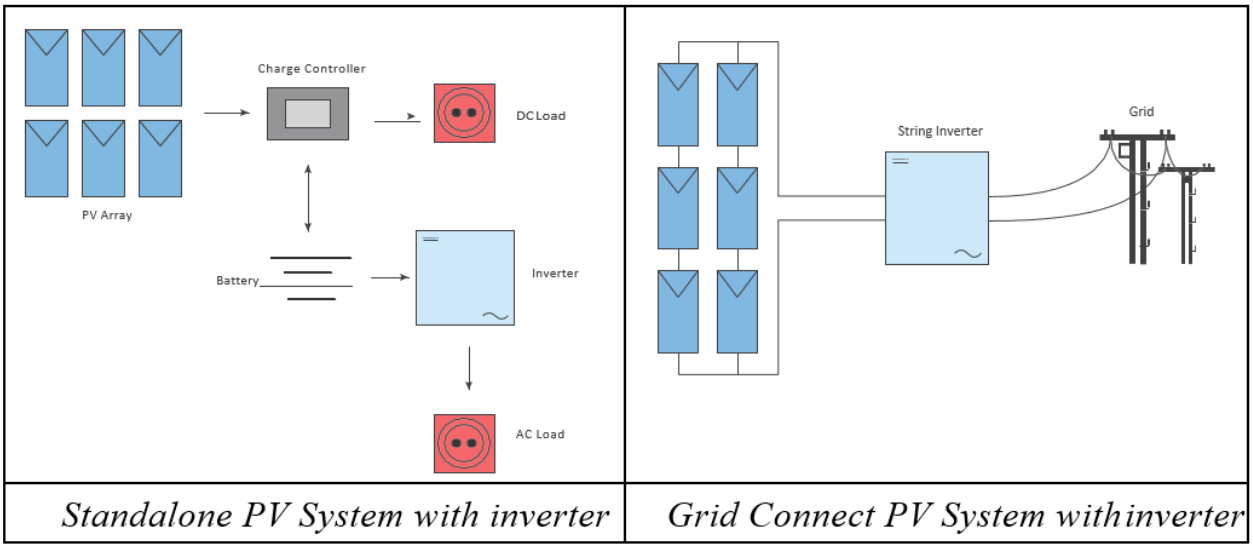
There are several types of lead-acid batteries manufactured. The following sections describe the types of lead-acid batteries commonly used in PV systems.

1. **Flooded Lead-Acid Batteries:** Flooded lead-acid batteries are the most common lead-acid batteries. They contain vents which allow the resulting hydrogen gas from electrolysis escape. As a result, the electrolyte level will fall over a period, and must be monitored and topped up with water, preferably demineralized water. The hydrogen gas produced is highly flammable. Care must be taken to ensure that there is adequate ventilation above and around flooded batteries.

2. **Valve Regulated Lead-Acid (VRLA):** Valve regulated lead acid (VRLA) batteries are also known as captive electrolyte batteries and as the name implies, the electrolyte is immobilized in some manner and the battery is sealed under normal operating conditions. Under excessive overcharge, the normally sealed vents open under gas pressure through a pressure regulating mechanism. Electrolyte cannot be replenished in these battery designs; therefore, they are intolerant of excessive overcharge. VRLA batteries are available in two different technologies: Absorbed Glass Mat (AGM) and Gelled Electrolyte.

3. **Lithium-Ion Batteries:** Lithium ion batteries are an emerging technology and have a number of advantages over other batteries, especially lead acid batteries. They are generally smaller and lighter for the same capacity, are faster at charging, and are less susceptible to degradation due to charging and discharging. However, lithium-ion batteries have a very high up-front cost, and they can be sensitive to extreme temperature and voltages.

4. **Inverters & other electronic equipment:** The photovoltaic array and battery produce DC current and voltage. The purpose of an inverter is to convert the DC electricity into a form suitable for AC electrical appliances and/or exportable to the AC grid. The typical low voltage (LV) supply into a domestic dwelling or small commercial building will be either 230V AC single phase or 415V AC three phases. Higher voltages may be supplied to larger commercial buildings which will then have transformers for stepping down to 230V or 415V.



Standalone PV System with inverter | *Grid Connect PV System with inverter*

Stand-alone inverters, or off-grid inverters, are very different from grid-connected inverters. Stand-alone inverters do not include the same MPPT function as grid-connected inverters because in stand-alone systems, the PV array is not usually connected to the inverter but is wired through a system controller to the batteries as shown in Figure above.

The inverter in a stand-alone power system takes its power from the batteries to supply the AC circuit(s). The system controller (voltage regulator) itself can be a MPPT. The advantage of the MPPT controller is to optimize the battery charging. This function has no impact on whether the inverter itself will supply power to any AC circuits. Stand-alone inverters are typically voltage-specific, i.e. they are manufactured to operate from a specific nominal battery voltage e.g. 12V, 24V, 48V or 120V DC.

In a grid-connected PV system, the PV array is directly connected to the grid-connected inverter. The grid-connected inverter is the device which delivers the solar power to the AC power grid. The PV array is configured so that it operates within specific range of DC voltages to suit the grid-connected inverter's specifications. The inverter will convert the solar DC power to an AC sine wave that matches the AC supply in voltage and frequency to which it is connected.

Grid-connected inverters cannot independently produce a grid equivalent AC sine wave: the inverter must see and reference the grid to be able to operate. If the AC grid is not present, the inverter will simply not function.

Battery charge regulation and control of the energy produced by the PV array is a critical function in PV systems. The most important functions of battery charge regulators and system controls are listed below.

- Prevent Battery Overcharge
- Prevent Battery Over discharge.
- Provide Load Control Functions
- Provide Status Information to System Users/Operators
- Interface and Control Backup
- Energy Sources
- Divert PV Energy to an Auxiliary Load
- Serve as a Wiring Centre

BALANCE OF SYSTEMS EQUIPMENT

In addition to the PV modules, battery, inverter, and charge controller there are other components required in a solar PV microgrid system; these components are referred to as Balance of Systems (BoS) equipment. BoS equipment includes:

- **Solar Array Mounting System:** The equipment used to safely secure the PV modules to the mounting surface or ground.
- **Cabling**: Both DC and AC cabling is required to connect components.
- **Array Junction Box**: This may or may not be required depending on the PV array; it is used to combine the different array strings.
- **Protection and Disconnect Switches**: These components ensure the safety of the system.
- **Lightning Protection**: May or may not be required (depending on criteria in IEC62305-2/IEC 62305-3) to protect the system from lighting strikes.
- **Metering**: Measures the quantity of electricity generated by solar or quantity of electricity consumed by a customer.
- **System Monitoring**: Shows the system owner exactly how much electricity their system is producing and can be helpful in detecting a problem within the system.
- **Signage**: PV systems installed requires various signs to ensure safety.

HOW SOLAR SYSTEM WORKS?

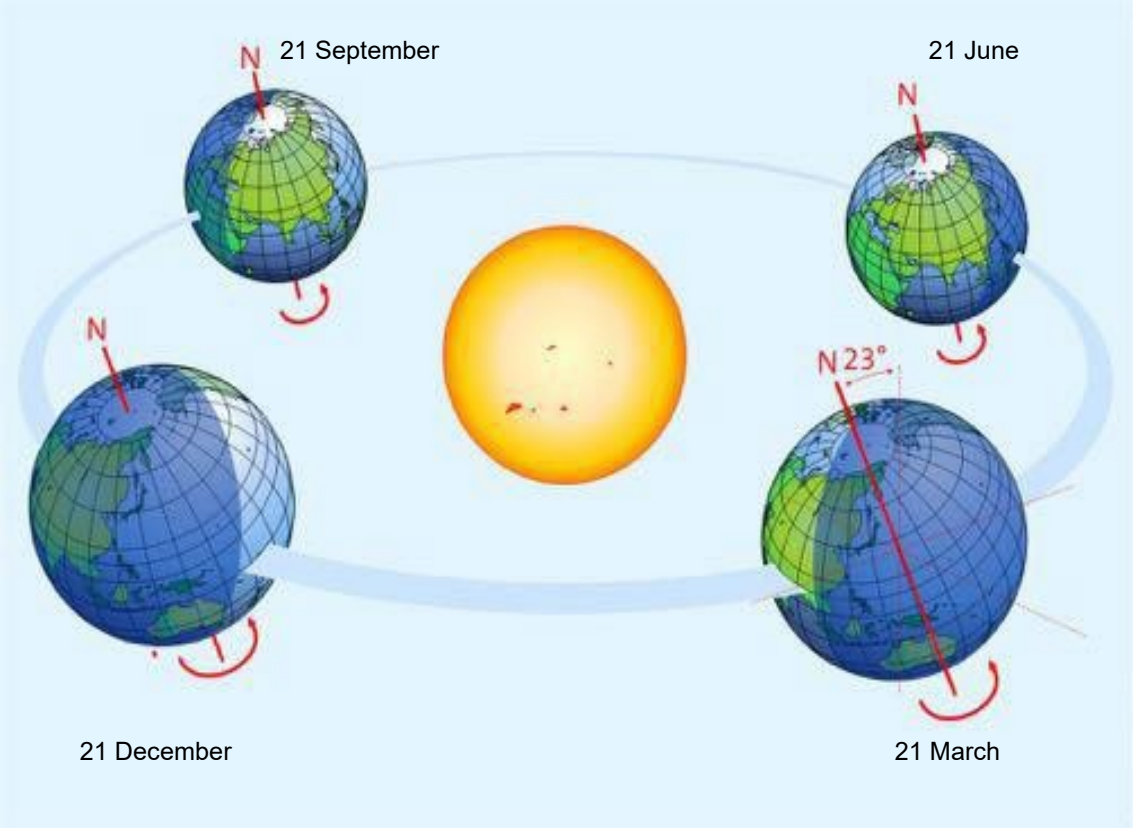
A PV module's performance is directly related to the amount of sunlight it receives. If a PV module is shaded, even partially, its performance will be very poor. PV modules should never be

installed in a location, where they will be shaded all the time as they will produce little to no power and prolonged shading can damage the module. On overcast days as well as on sunny days, PV modules will not perform because the clouds reduce the amount of sunlight hitting the modules.

The solar panel converts sunlight into direct current ("DC") electricity. This DC electricity is used to charge a battery through a charge controller. The inverter converts that "DC" power from the solar panel or battery into alternating current or "AC" power. AC power output from inverter can be used to operate light, fan, TV, computer etc. It is also possible to operate DC loads like DC lights, DC pump, computer, mobile charger, etc. directly from the solar panel or battery.

MOVEMENT OF SUN ACROSS THE SKY

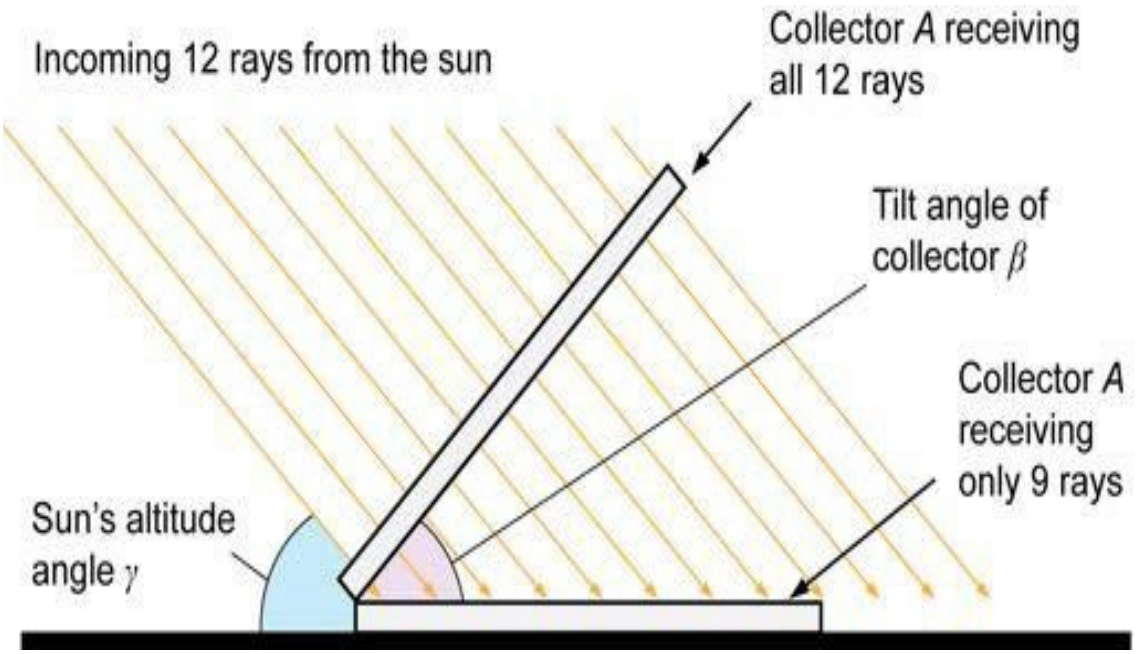
On 21st June the Sun reaches highest position in the northern hemisphere sky and on the 21st of December the Sun position is lowest in the sky. In the summer season the days are long, and the Sun is high in the sky. The days during summer are longer than the days during the winter season.



Seasonal variation of solar radiation due to earth's movement

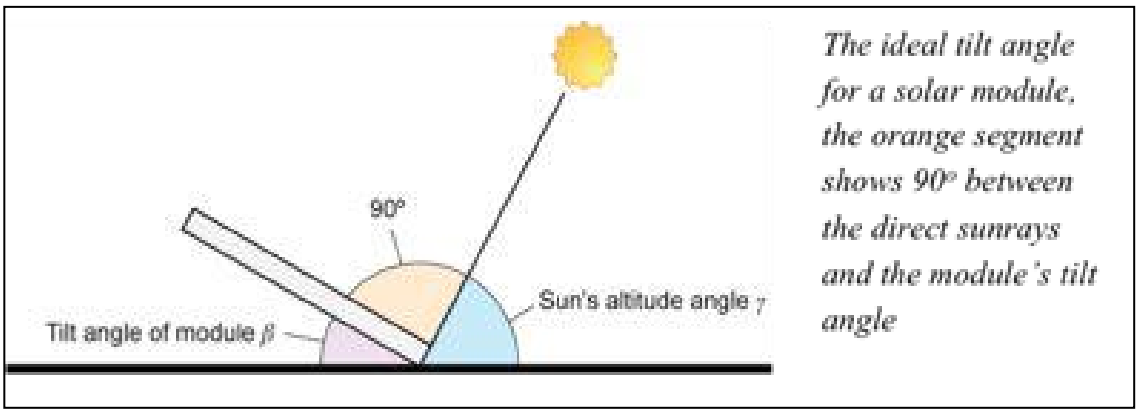
GEOMETRIC EFFECT

The direction that a solar panel faces is referred to as its orientation. The orientation of the solar array is very important as it affects the amount of sunlight hitting the array and hence the amount of power the array will produce. The orientation generally includes the direction the solar module is facing (i.e., due south) and the tilt angle which is the angle between the base of the solar panel and the horizontal. The amount of sunlight hitting the array also varies with the time of day because of the sun's movement across the sky.



TILT ANGLES

Solar modules should be installed so that as much radiation as possible is collected. Ideally the solar modules should be tilted at an angle to the horizontal (β°) as shown, facing true south (if installed in the northern hemisphere such that there is 90 degrees between the sun (at solar noon) and the solar module. To have a module face directly towards the sun always would require a solar tracking frame to be installed. This can be expensive, so it is not common practice for most PV applications.



The ideal tilt angle for a solar module, the orange segment shows 90° between the direct sunrays and the module's tilt angle

To have a module face directly towards the sun always would require a solar tracking frame to be installed. This can be expensive, so it is not common practice for most PV applications.

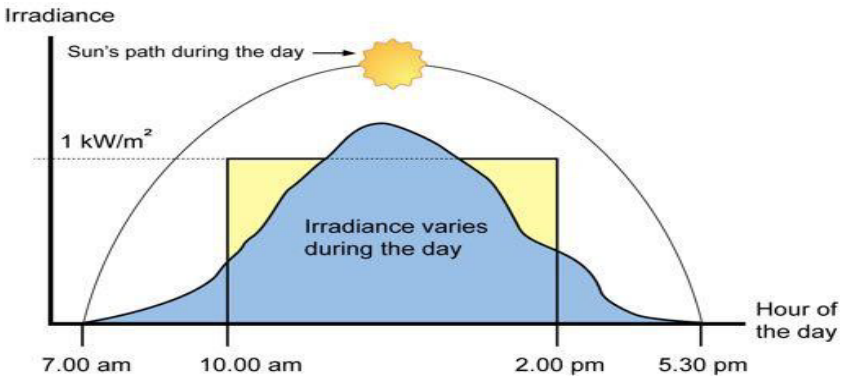
Modules mounted on a fixed structure should be tilted up from the horizontal. The correct tilt angle varies with the times of year the system is used, and the latitude of the site.

The tilt should be within 10 degrees of the listed angle. For example, a system used throughout the year at a latitude of 25° can have a tilt angle of 15° to 35° without a noticeable decrease in annual performance.

PEAK SUN HOUR

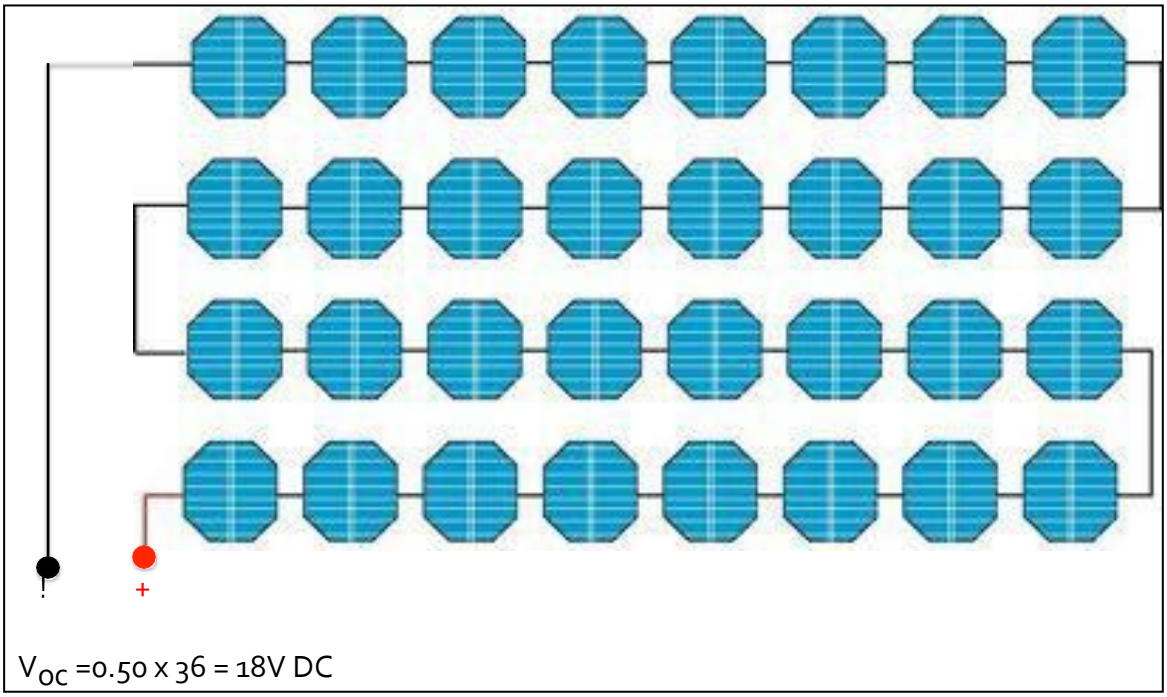
In solar PV system design practice, the average daily solar insolation in units of kWh/m2/day is referred to as "peak sun hours". Since the peak solar radiation is 1kW/m2, the number of peak sun hours is numerically identical to the average daily solar insolation. For example, a location that receives 5kWh/m2 per day can be said to have received 5hours of sun per day at 1kW/m2. This helps to calculate energy generation from a PV power plant as PV modules are rated at an input rating of 1kW/m2.

- Solar energy available in each location is expressed as kWh/m2/day. This is commonly referred as Peak Sun Hours (PSH).
- For example, if solar radiation for a particular location is 5kWh/m2/day then PSH for that location will be 5 hours.
- Now, if you install 1kW solar panel on that location, it will produce 1kW **x** 5h = 5kWh energy per day without considering any losses.



OPERATIONS OF A PV MODULE

A typical silicon solar cell produces only about 0.5 volt. A solar module is basic building block of any solar system where multiple cells are connected in series. Usually, 36 solar cells are connected to give a voltage of about 17V, which is enough to charge 12V battery. Similarly, a 72 cells module produces about 34V, which can be used to charge a 24V battery.



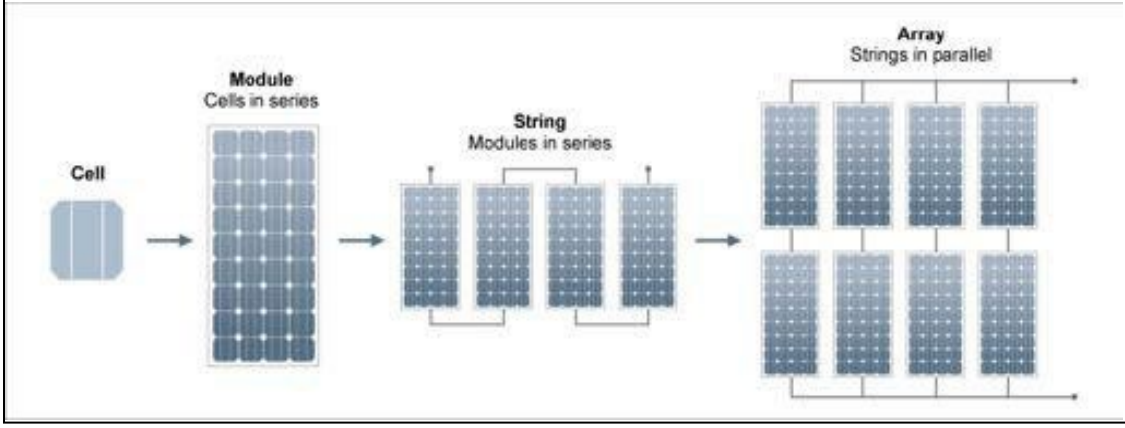
Cells are connected in series to make a PV module.

In many applications the power available from one module is inadequate for the load. Individual modules can be connected in series, parallel, or both to increase either output voltage or current. This also increases the output power. When several modules are connected in series, it is called a PV string. Voltage of a string is addition of voltages of individual module. If 10 modules of 34V are connected to make one string, voltage of the string will be 340V.

When modules or PV strings are connected in parallel, the current increases. For example, three modules which produce 34V and 5A, connected in parallel, will produce 34V and 15A. If three PV strings of 340V are connected in parallel, will produce 340V and 15A.

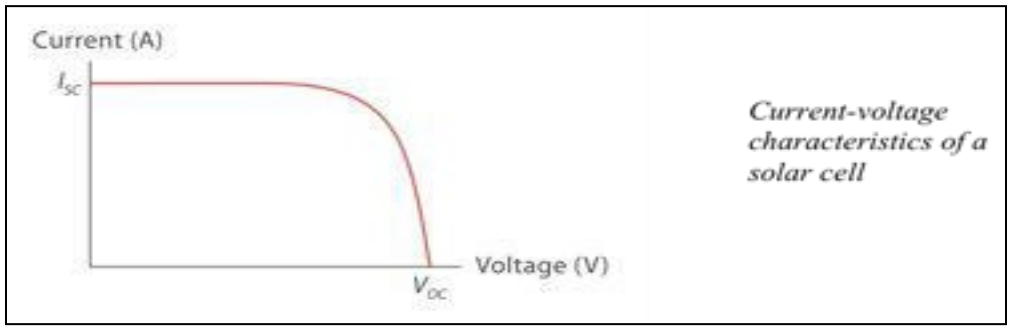
The collective of multiple strings connected in parallel for greater power is called PV Array.

- A typical silicon solar cell produces only about 0.5 volt.
- 36 solar cells are connected in series to make a 17V module.
- A PV string is made with multiple modules connected in series.
- Multiple strings are connected in parallel to make a Solar Array.



PV MODULE I-V CHARACTERISTICS

I-V curve represents a 'snapshot' of all the potential combinations of current and voltage possible from a module under specified environmental conditions. Every solar cell has a characteristic I-V curve, where ISC and VOC are quoted to help characterize a cell.



SHORT CIRCUIT CURRENT (I_{SC}): A photovoltaic module will produce its maximum current when there is essentially no resistance in the circuit. This would be a short circuit between its positive and negative terminals. This maximum current is called the short circuit current (Isc). When the module is shorted, the voltage in the circuit is zero.

OPEN CIRCUIT VOLTAGE (V_{OC}): The maximum voltage in a PV module is produced 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.

MAXIMUM POWER (P_{MAX}): The power available from a photovoltaic module at any point along the curve is expressed in watts (W). Watts are calculated by multiplying the voltage times the current (W = VA). 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 since the current is zero. There is a point on the "knee" of the curve where the maximum power output is located. Maximum power (Pmax) is the product of current at maximum power times the voltage at maximum power.

CURRENT AT MAXIMUM POWER (I_{MP}): The current that results in maximum power under given conditions of light and temperature, used as the "rated" current of a device. This value occurs at the "knee" of the I-V curve.

VOLTAGE AT MAXIMUM POWER (V_{MP}): The voltage that results in maximum power under given conditions of light and temperature, used as the "rated" current of a device and to determine how many cells or modules are needed to match a load voltage requirement. This value occurs at the "knee" of the I-V curve.

MODULE ENERGY OUTPUT

For a specific load, PV module output depends on the following factors:

- Irradiance or light intensity
- Temperature

Solar irradiance directly affects the module energy output. If light falling on a solar module increases twice, it will produce twice as much current. The open circuit voltage does not change dramatically with irradiance; however, it increases slightly with higher irradiance. This is why modules should be completely unshaded during operation. A shadow across a module can almost stop electricity production.

Module temperature affects the output voltage inversely. Higher module temperatures will reduce the voltage by 0.04V/°C to 0.1V/°C, for every one-degree centigrade rise in temperature.

This is why the modules should be installed in such way that there is enough air circulation in the back of each module, so that its temperature does not rise and reducing its output. An air space of 4 – 6 inches is usually required to provide proper ventilation.

STANDARD TEST CONDITIONS (STC):

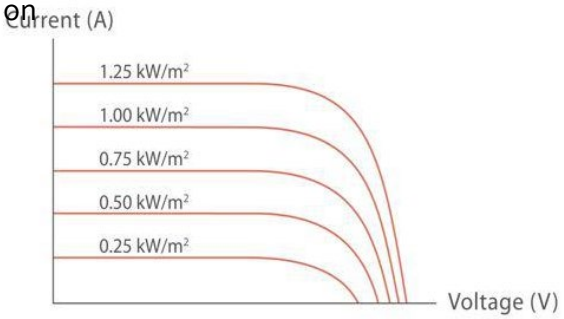
The specifications in manufacturers' data sheets are all determined using standard test conditions (STC) which are considered as below:

- Cell Temperature 25°C
- Irradiance of 1000 W/m²
- Air Mass of 1.5

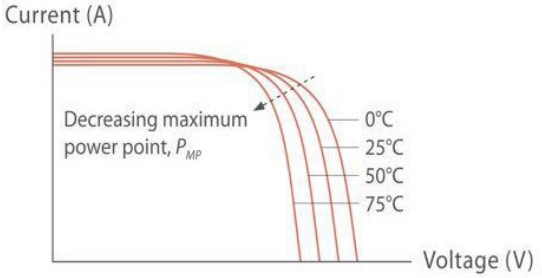
For a specific load, PV module output depends on two major factors:

- Irradiance or light intensity
- Temperature

The higher the solar radiation it receives, the higher is the current a module will produce. The voltage will remain the same.



As the temperature of a solar cell increases, the open circuit voltage V_{OC} decreases but the short circuit current I_{SC} increases marginally.



Example:

On a clear sunny day, a 1kWp PV array received 6 Peak Sun Hours. Expected output can be determined as follows:

Peak Power Output X Peak Sun Hours = Expected Output 1kW x 6PSH = 6kWh

The calculation above shows the maximum theoretical energy output, which will never be produced in a real PV system. The actual output would be a lot lower than calculated because of

inefficiencies of and losses in the PV system (known as derating factors). Losses in a solar PV system arise from weather factors, site constraints and voltage drop.

A summary of typical losses is provided in the following table. Estimated loss for a solar microgrid system depends on system design, component selection and site operating temperature and normally total loss is around 30%.

Cause of loss	*Estimated Loss (%)	De-rating Factor
Temperature	10%	0.90
Dirt	3%	0.97
Manufacturer's Tolerance	3%	0.97
Shading	2%	0.95
Orientation	0%	1.00
Tilt Angle	1%	0.99
Voltage Drop	2%	0.98
Inverter	5%	0.95
Loss due to irradiance level	3%	0.97
Distribution & transmission	2%	0.98
Total de-rating factor (multiplying all de-rating factors)		0.70

** Typical losses in PV systems. Actual loss will be as per site conditions.*

Example:
On a clear and a sunny day, a 1kWp PV array received 6 Peak Sun Hours.
Expected output can be determined as follows:

Expected Output = Peak Sun Hours x Peak Power Output x Total derating factor
= 1kWp x 6 x 70%
= 4.2kWh

PERFORMANCE DEGRADATION OVER LIFE CYCLE:

The performance of a PV module will decrease over time. The degradation rate is typically higher in the first year upon initial exposure to light and then stabilizes. Factors affecting the degree of degradation include the quality of materials used in manufacture, the manufacturing process, the quality of assembly and packaging of the cells into the module, as well as maintenance levels employed at the site. Generally, degradation of a good quality module is about 20% during the module life of 25 years @ 0.7% to 1% per year.

Example:

On a clear and a sunny day, a 1kWp PV array received 6 Peak Sun Hours (hours). Total loss (de-rating factor) in the system is estimated as 0.70 (70%)

Expected output can be determined as follows:

Expected Output = Peak Sun Hours x Peak Power Output x Total derating factor

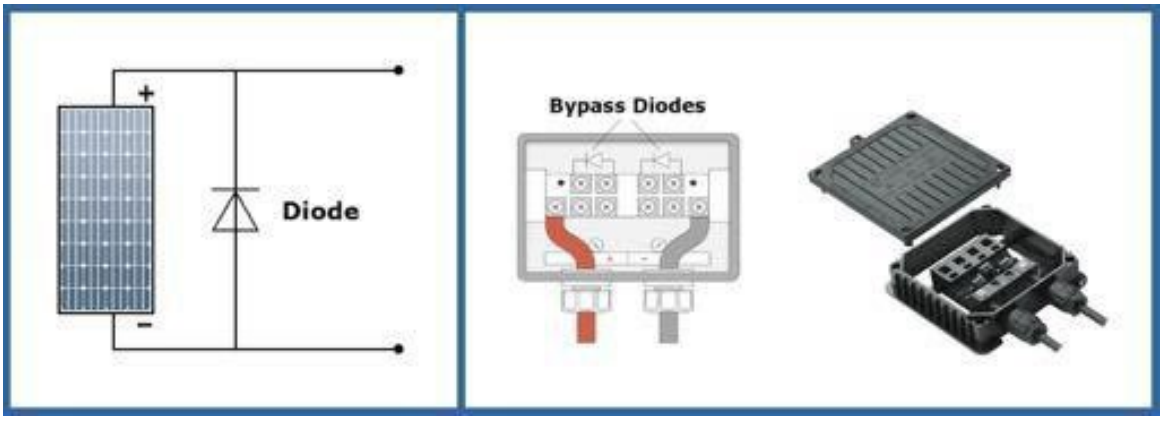
= 1kWp x 6 hour/day x 0.70
= 4.2kWh per day (1st year)

Now considering degradation of module as per the indicative profile above (example only, actual degradation of module will be based on module quality and climatic conditions)

Energy generation:
= 3.83kWh per day (on 10th year)
= 3.39kWh per day (on 25th year)

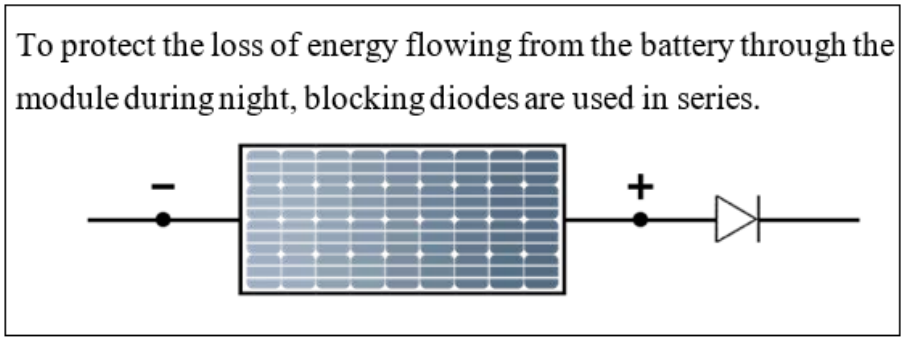
BYPASS DIODES

When a cell in photovoltaic module is damaged or a part of module is shaded, the shaded cells will not be able to produce as much current as the unshaded cells. Since all the cells are connected in series, the same amount of current will flow through the damaged or shaded cell that will now act as a resistance and become hot and energy generated in the module will be lost. This is known as 'hotspot' phenomenon. This can be avoided by using a bypass diode in the module in parallel to the output terminal as shown in the diagram below.



BLOCKING DIODES

During daylight, an array has more voltage potential than the battery, so current flows from the array into the battery. But at night, the module potential drops to zero, and the battery could discharge all night backwards through the module. This would not be harmful to the module but would result in loss of precious energy from the battery bank. Diodes placed in the circuit between the module and the battery can block any nighttime leakage flow.



CONFIGURATIONS OF SOLAR PV MICROGRID SYSTEM

Solar PV microgrid systems are custom designed for their situation. The following factors are generally considered while determining the system configuration for solar microgrid system.

- Target consumer and type of electrical appliances to be operated.
- Load size and daily energy demand
- Time of operation
- Correlation with load on a daily, weekly, and seasonal scale

- Installed cost and maintenance costs.
- User specific preferences
- Local regulations/ constraints/ benefits
- Photovoltaic only or hybrid generation

The system configuration should be chosen to satisfy the design criteria, to make it most cost-effective, efficient, reliable system operation and long life. Economic evaluation of different options, if required, may be carried out based on life cycle costing.

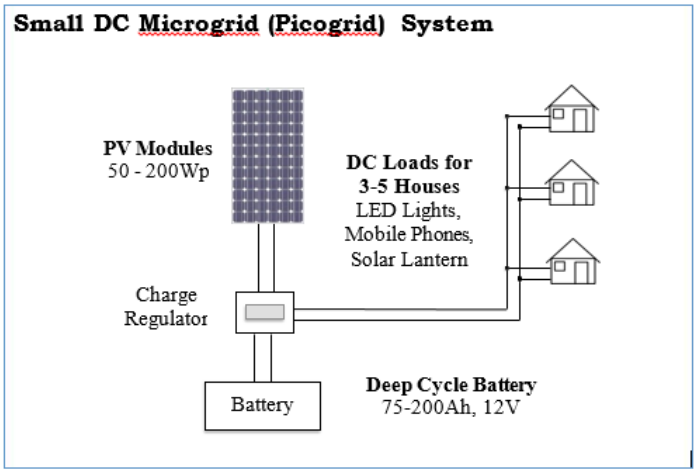
For reference purpose, we can group solar micropower or microgrid system types into five broad categories:

- Small DC microgrid (Pico-grid) system
- Large DC microgrid system
- AC Power microgrid system
- AC – DC combined microgrid system
- PV-Generator hybrid microgrid system

In the following pages typical system configurations are described.

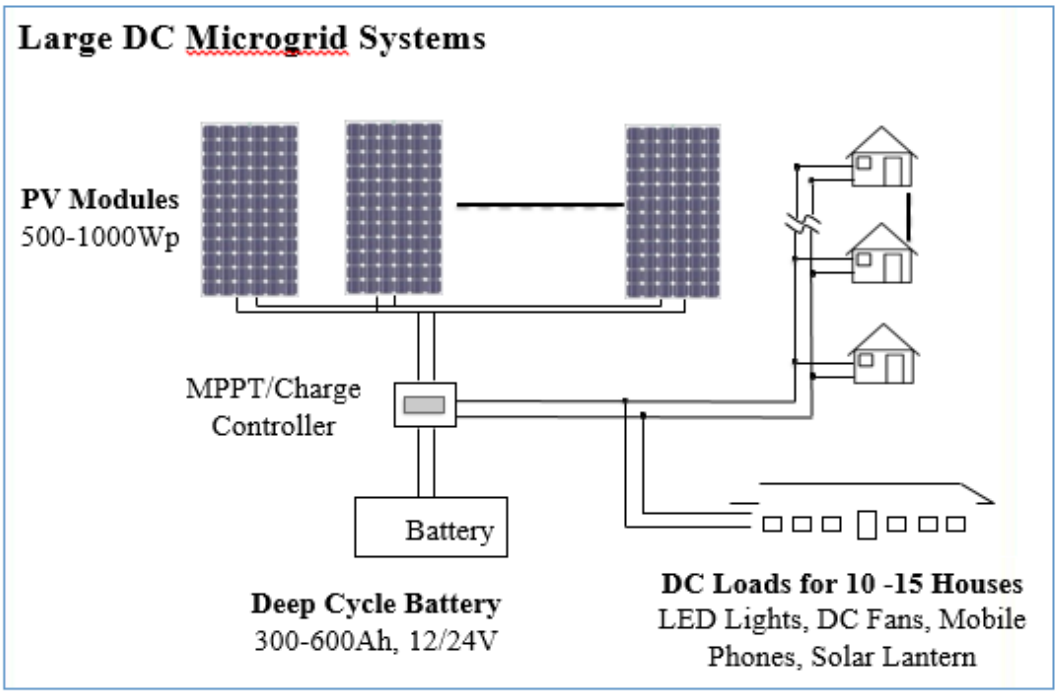
SMALL DC MICROGRID SYSTEM

This configuration is like a solar home system shared by 3-5 houses to meet basic electricity demand for 2-3 LED lighting per house, mobile charging and charging of solar lanterns, etc. Typical battery capacity could be 75-200Ah, 12V and array capacity shall be 50-200Wp based on availability of solar radiation on the site. Generally, a typical charge regulator is used to protect the battery from deep discharge and overcharge.



LARGE DC MICROGRID SYSTEM

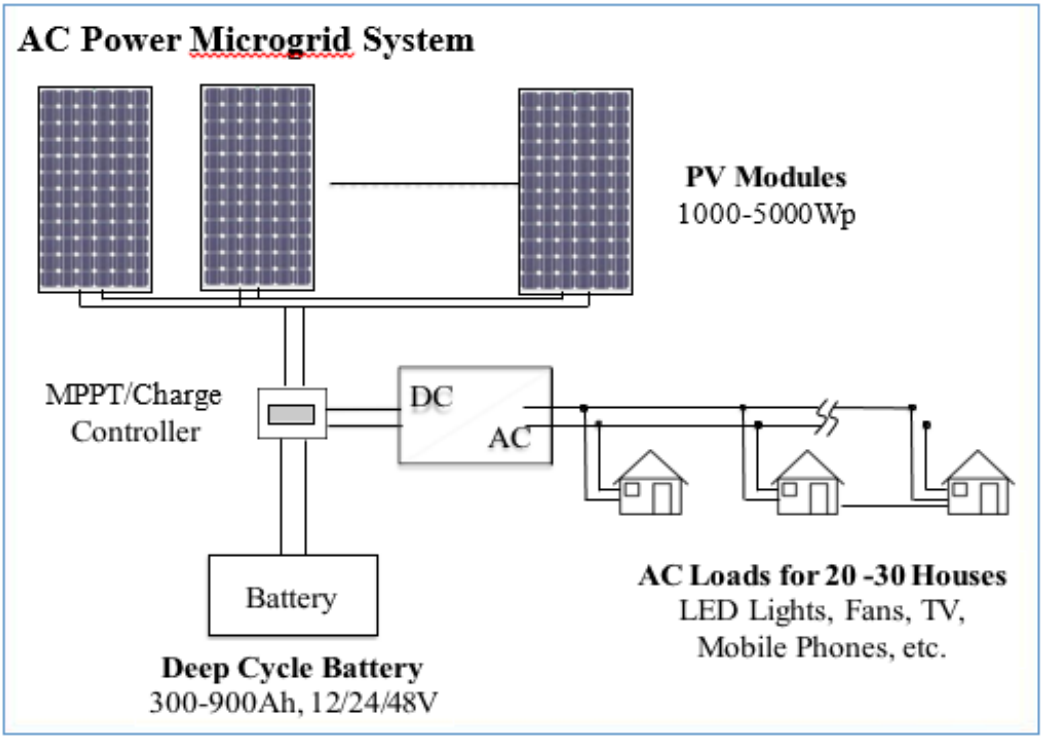
This type of system can be designed by adding more modules and batteries. A large single charge controller or multiple charge controllers would be needed to handle the increased current from the array. If number of loads is more, a DC circuit breaker distribution box could be used. Typical array size of these types of systems may be 500 watts to few kilowatts with nominal system voltage 12, 24 or 48V based on size of the system. Similarly, battery bank capacity may be of 300Ah to 600Ah.



AC POWER MICROGRID SYSTEM

AC appliances can be powered by adding a DC-to-AC inverter. In general, system size more than 1000 watts can be designed for standalone AC operation. Depending on the capacity of the system and type of inverter, various types of AC appliances could be operated by this type of system.

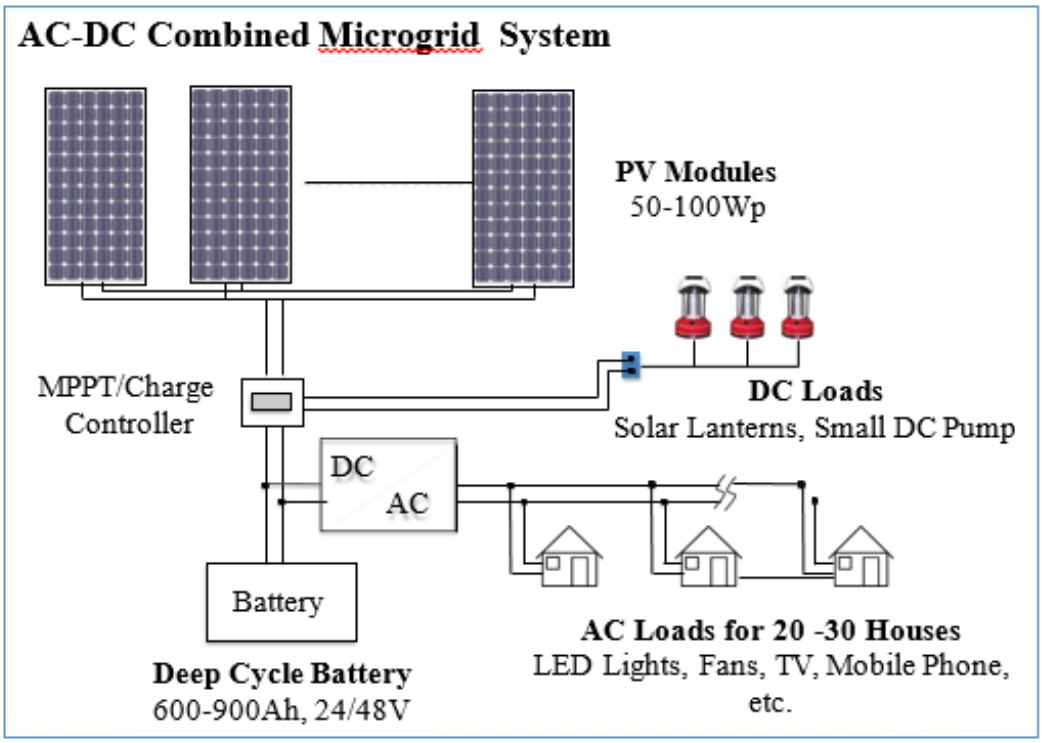
Using an AC standalone system is convenient as most of the electrical and electronic appliances available in the market run on AC. However, care has to be taken, particularly in small system for overloading of the system and inverter, as the users may not be aware of limitation of the system, and they may tend to think as conventional AC system and end up discharging the complete battery capacity using the loads continuously or damage the inverter connecting loads of larger than the inverter capacity. When low quality or inverters with square wave or modified square wave form are used, some electrical or electronic equipment may not function or even get damaged.



AC – DC COMBINED MICROGRID SYSTEM

Design and operational features of this configuration is like the AC power system as mentioned in the previous section. The only additional feature in this configuration is facility to use DC appliances directly from the regulator without going through the inverter. If the user has some

DC loads and these are efficient, it is recommended that DC loads be used directly from the DC bus bar. This might reduce the size of the inverter and increase overall efficiency of the system, as there is no conversion loss for DC loads.

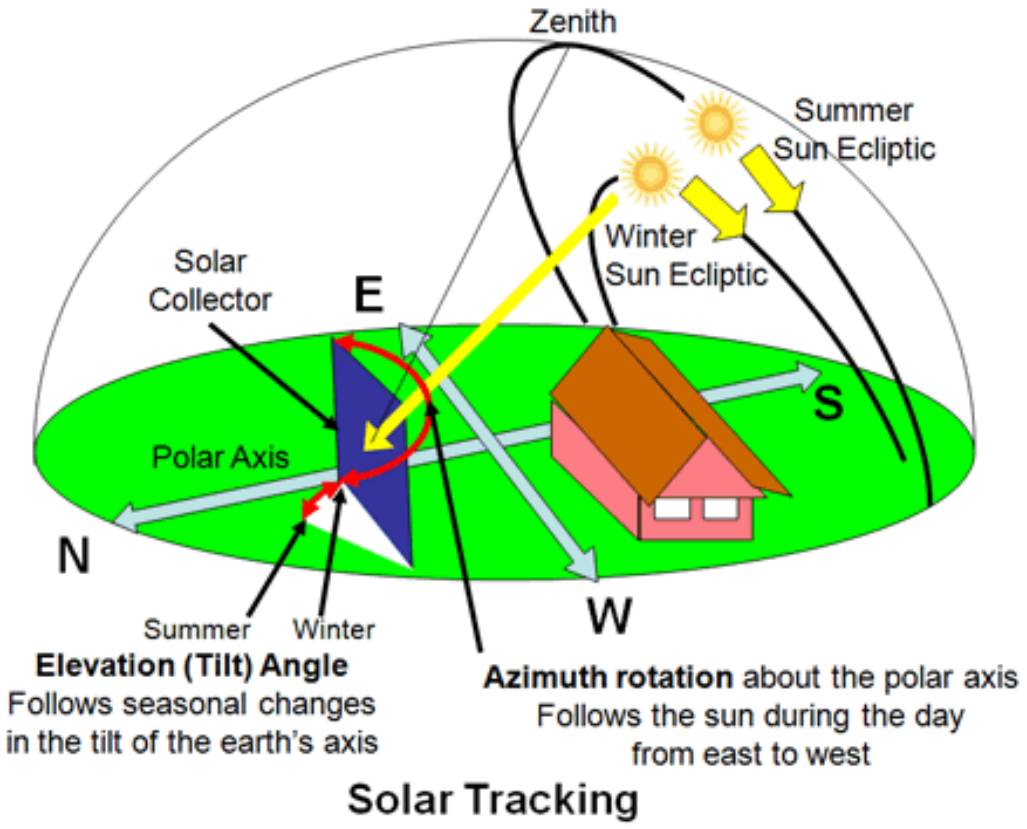


INSTALLATION & COMMISSIONING

1. **Site survey & planning**: The installer shall gather all design documents and engineering drawings of the system including site layout, system schematic, single line diagrams, drawings for structure and foundations, distribution systems, module and battery interconnection drawings, control system drawing, etc. The installer shall also have information (data sheet) on the major components such as modules, controls, inverter, and batteries and must be familiar with the instruction manual for installation of such equipment's. The first step of installation is to visit the site and finalize the layout of the equipment's. If site layout is already given, this should be verified at site identifying actual locations for installation of equipment's and verify the distances and dimensions.

2. **Solar Array Location**: For a solar photovoltaic system, it is crucial that the solar array is installed at a location that is free from any shading throughout the day. Finding a shadow free location for placement of array is usually not an issue for remote sites, where ample space and options for locating may be available. Shadow during winter season is much

longer that the shadow during summer season due to change in earth's altitude. There may be shadow from nearby trees and houses or even shadow from mountains, which is not very far from the site. Sometime shadow in the early morning and late afternoon cannot be avoided due to very low altitude of sun. In such situation arrays must be placed in such a way that there is no shading between the hours of best insolation, usually from 8 a.m. to 4 p.m., on the day with the longest shadows, December 21 in the Northern Hemisphere.



Solar Tracking

3. **Using Solar Pathfinder:** The most accurate and convenient way to place the array away from any tall object that can possibly cause shadow is to use the solar pathfinder. When you use a solar pathfinder there is no need to measure distance or height of any objects that can create shadow at any point of time during the year. Just placing the solar pathfinder in the potential array location, you will understand if there is any shadow. If there is any shadow image seen in the pathfinder, move away from that point to the direction where the shadow can be avoided. Solar pathfinder should be located at the four corners of the array to ensure that the complete array is shadow free.

If you do not have access to a solar pathfinder, use the following calculations to ensure that the array will be located away from potential shading. However, these methods require some measurement, calculation, and good assumptions to decide whether the array will be shadow free for all days of the year.

4. **Applying Rule of Thumb:** The general rule of thumb is locating the array at a distance away from the object that is at least twice the height of the object. This will ensure that the object will not cast a shadow for 4 hours either side of solar noon.

5. **Space Between Two Rows:** When PV modules are installed in multiple rows, consideration must be given so that one row of modules does not cast a shadow on the row behind. Calculations need to be done to find the minimum distance between PV Array rows to avoid winter mid-day shading.

6. **Other Equipment Location:** The next step of site survey is to determine the location of the control equipment, inverter, battery bank, earth pits and cable route.

- Controls and inverter should be placed in such a way that access is controlled.
- Switches are to be in a place which is easily accessible.
- Batteries should be installed in a separate room closed to the inverter /control room and access to the room should be controlled.
- Batteries to be in cool and dry and well-ventilated place.

Location of battery bank in a separate well-ventilated room

Power distribution lines connecting the load centers.

WHAT IS A SOLAR SITE SURVEY?

A solar site survey is an on-ground process. The professionals gather several pieces of information that might be essential to calculate the efficiency of a solar panel for the site and the optimum size of the panel required. The various pieces of information that are gathered include:

- The local climatic conditions of the area.
- The physical details of the site and rooftops.
- The power consumption needs of the customer.
- Shades, if any, on the potential site or roof.

This site survey is carried out by a learned professional, and based on his observations, a 3D model of the site is prepared and used for the system design. During a solar site survey, three basic elements are taken into consideration. These include:

- **Feasibility**: The first thing they pay attention to is whether installing a solar panel is worth it. They check the solar panel's efficiency compared to the cost of the panel and its maintenance. Accordingly, they suggest the user decide if solar panels will be beneficial for them.

- **Viability**: Another aspect that they check is if the solar panel would give the user a financial benefit in the long run compared to the traditional source of electricity.
- **Power Requirements of the User**: During the on-sight survey, the professionals also consider the customer's energy requirements and calculate what percentage of the requirement would be covered by the electricity generated by the solar power.

WHAT IS THE NEED FOR A SITE SURVEY BEFORE INSTALLATION OF A SOLAR PANEL?

Every minute detail regarding the site is important for the efficiency of the solar panels. While the site owner is aware of the area, the solar module providers need to be well acquainted with the site. They must have a thorough analysis regarding every aspect that affects the use of solar panels by the user.

The information accumulated by the professional during the site survey plays a major role in deciding every little aspect of the solar panel installation, ranging from the size of the panel to be used to the place that would be best for the installation of a solar panel.
The importance of a solar site survey is to ensure that:

- The site does not have any shaded areas due to trees, staircases, water tanks, AC units, etc.
- There should be clear and easy access to the site and solar panel for future maintenance procedures.
- There should be a proper orientation to the sunlight.
- The dimensions of the roof structure or the potential solar panel area should be taken.
- The energy requirements of the customer should be calculated.

Actions Performed During a Solar Site Survey

To ensure that the solar panel installed performs exceptionally well and with optimum efficiency, it is extremely important to have a proper site survey performed by experts like Waaree. As per the survey data, the engineers and designers of the company can come up with a customized solution as per the customer's requirements. Below is a list of tasks performed during the solar site survey.

The inclination of Solar Module: Inclination of the solar module is one of the most important factors affecting the solar panel's efficiency. Part of the site survey is to ensure that the solar panels are installed in such a way that they receive the maximum amount of sunlight for the longest period throughout the day. For instance, since India is present in the northern

hemisphere, the solar panel should be facing towards the true south to attain the maximum output.

1. **Inspection of Roof Structure:** While several countries have a uniform roof structure, India, with its diverse climate conditions, has different types of rooftops. With this, the importance of site survey and inspection of roof structures plays a major role. A few aspects that are taken into consideration during the roof structure inspection include the dimension of the roof, its inclination, the materials used for the construction of the roof, the rooftop direction, and its feasibility.

2. **Shading Estimation of the Site:** The site survey expert must ensure that a large area is free of any shaded region to ensure maximum efficiency. If a shadow falls on the solar panel at any part of the day, the efficiency of the PV system can be significantly reduced. With trees and high buildings generally present around the place, it is extremely important to have a proper shading estimation of the site.

3. **Load Analysis**: Load analysis, or usage analysis, is the comprehensive analysis of the essential elements like AC and DC converters and electricity usage. The process also helps analyze the overall energy generation and evaluate the units of electricity that can potentially be saved.

4. **Financial Analysis:** Considering the project's financial viability is another important aspect of the solar site inspection. The Indian Government offers several incentives and financial aid to users who install solar panels for their electricity requirements. In the financial analysis, the general cost of the panel installation, the system's economic applicability, and other essential financial parameters are considered.

A solar site survey before the installation of panels helps you get information regarding the potential efficacy of the solar PV system and helps you make an informed decision regarding the viability of the solar panels for your requirements. With Waaree at your service, you can achieve the best and most accurate site inspection results and high-quality solar PV systems as per your requirements. We are the largest and best solar module manufacturers in India and are known

worldwide for our high-quality products and services.

Video on Site Survey - https://www.youtube.com/watch?v=DuU2mOU5eMI (PLAY THIS VIDEO Till 11.05 MINS)

TOOLS FOR INSTALLATION

Some tools for installing and maintaining photovoltaic power systems are listed below.

Sl. No.	Tools and equipment for Installation
1	First aid kit
2	System service logbook
3	Datasheet & O&M manual
4	This manual
5	Paper/Pencil
6	Multimeter, digital voltmeter, with at least 10A current capability, spare batteries
7	Clamp on DC ammeter
8	Wrenches: Specific sizes, for all mounting bolts; Adjustable, for unexpected on-site problems; Vice-Grips for variable and heavy duty
9	Compass and Sun Pathfinder
10	Screw Drivers: flat Blade, in sizes for all mounting hardware; Phillips, in sizes for all mounting hardware; Small jewelry size, for adjusting controls
11	Linesman pliers, nose pliers
12	Nut drivers 1/4in and 5/16in
13	Measuring tape (25m)
14	Tilt Angle indicator, or plumb line and protractor
15	Hydrometer
16	Safety goggles
17	Rubber gloves
18	Electrical Tape
19	Wire Crimping, Stripping and Cutting Tool (s)
20	Miscellaneous for connections: Split bolts, wire nuts, lugs, solder-less connectors
21	A hand drill or DC operated electric drill
22	DC soldering iron
23	Hacksaw

24	Utility knife
25	Hammer
26	Ladder

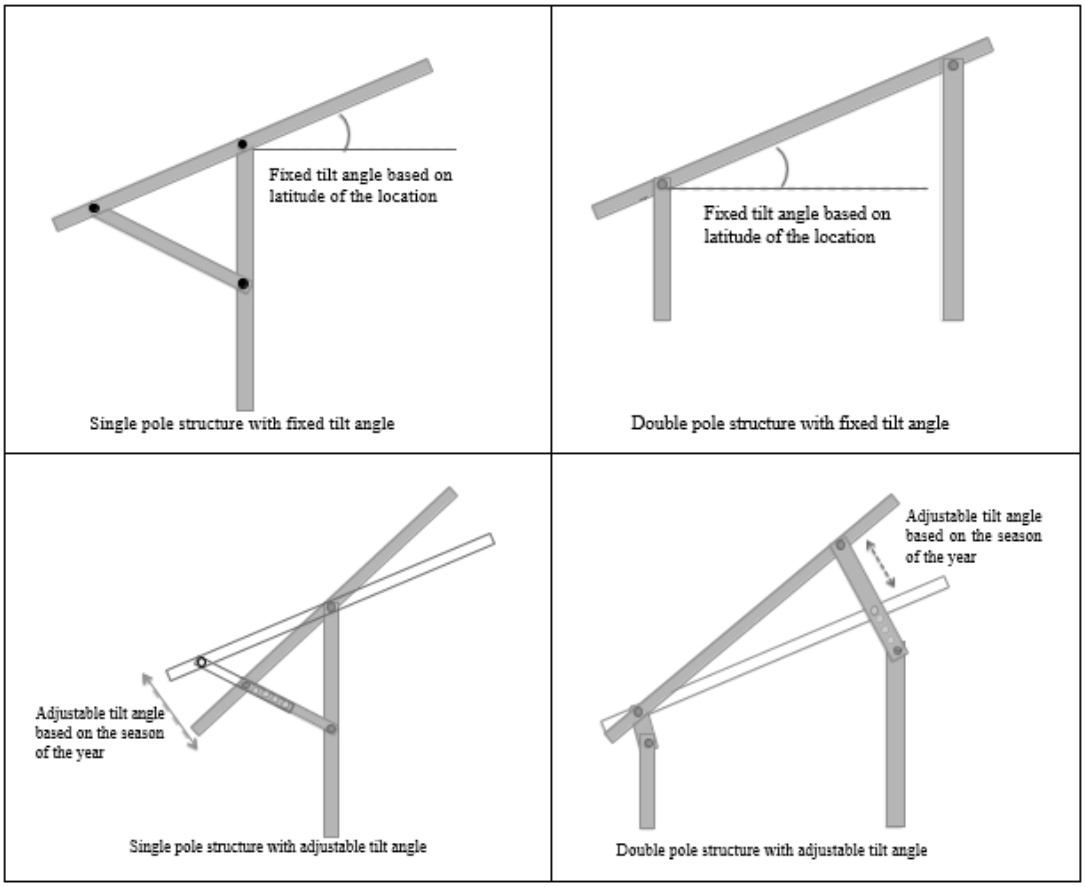
INSTALLATION OF MOUNTING STRUCTURE

Generally, PV arrays for solar microgrid system are installed in the ground as there is ample of space available in rural area and finding a appropriate roof for installation of PV arrays may not be easy.

The ground mounting system has the following advantages:

- It is easier to have seasonal or daily tracking provision in a ground mounted structure.
- Easy cleaning and maintenance access of PC array
- Better air flow keeps the modules cool hence will have better performance.
- Easy maintenance of structure, cable tray, electrical connectors, and cable etc.
- Easy to expand PV array capacity if required.

Array mounting structure could be different types depending upon site, system capacity maintenance plan, type of soil, wind velocity, waterlogging possibility etc. Conceptual drawing of few commonly used array structures is presented below:



TOOLS REQUIRED FOR OPERATION AND MAINTENANCE

Solar microgrid systems are generally installed in remote locations. Therefore, it is important that all essential tools, spares, and consumables are kept in the site ready for use. A list of such tools and materials are listed below. Some systems may require special tools not listed here. In such cases, tools required as per site condition or special tools recommended by the equipment manufacturer should be used. Person responsible for O&M of solar microgrid systems must familiar and equipped with these tools & equipment. Also, they must be kept in a secured location and maintained properly. Measuring instrument must be checked regularly for its functionality and accuracy.

LIST OF TOOLS AND MATERIALS REQUIRED FOR O&M OF SOLAR MICROGRID SYSTEMS

Tools	Needed for			
	Inspection	Troubleshooting	Maintenance	Repair
First aid kit	X	X	X	X
System service logbook	X	X	X	X
Datasheet & O&M manual	X	X	X	X
This manual	X	X	X	X
Paper/Pencil	X	X	X	X
Multimeter	X	X	X	X
Clampon ammeter	X	X	X	X
Hydrometer	X	X	X	X
Screwdrivers	X	X	X	X
Nut drivers 1/4in and 5/16in	X	X	X	X
Measuring tape (25m)	X	X	X	X
Angle measuring device	X	X	X	X
Compass	X	X	X	X
Flashlight	X	X	X	X
Sun Pathfinder	X	X	X	X
Safety goggles		X	X	X
Rubber gloves		X	X	X
Combination square		X	X	X
Wire strippers			X	X
Crimping tool			X	X
Needle nose pliers			X	X
Linesman pliers			X	X

Tools	Needed for			
	Inspection	Troubleshooting	Maintenance	Repair
Diagonal cutters			X	X
DC soldering iron			X	X
Hacksaw			X	X
Battery terminal cleaner			X	X
Battery terminal puller			X	X
Clamp spreader			X	X

Utility knife			X	X
Hammer			X	X
Cell water filler			X	X
Cleaning brush			X	X
Small container			X	X
Caulking gun			X	X

RECOMMENDED MATERIALS AND SUPPLIES LIST FOR REPAIR OR MAINTENANCE

- Distilled water
- Baking soda
- Wire nuts
- Crimp connectors
- Ring, spade, and lug terminals
- Load, inverter, and charge controller fuses
- Rosin core electrical solder
- Conduit connectors
- Cable ties
- Rags or paper towels
- Dish soap or pulling grease.
- Red and black electrical tape
- Assorted screws and nails
- Cable, wire and/or conduit, as needed.
- Silicone sealant

		
Multimeter	Clampon ammeter	Hydrometer
		
Screwdrivers	Nut drivers	Crimping tool set
		
Measuring tape	Angle gauge	Laser distance/ angle meter
		
Compass	Sun Pathfinder	Combination square
		
Battery Safety accessories	Battery water filler	Battery Maintenance kit

Tools and accessories for O&M and troubleshooting of microgrid system

Preventive Maintenance

A sample maintenance schedule is presented below to indicate typical frequencies of maintenance actions.

Weekly Maintenance:

Clean PV array from dust, birds drop. Use clean water and avoid hard water.

Observe battery state of charge (SOC) using hydrometer. In case of VRLA battery use voltmeter to measure voltage to check corresponding SOC.

SOC	Specific Gravity	Battery Voltage	
		12 volt	24 volt
100%	1.265	12.68	25.35
90%	1.250	12.60	25.20
80%	1.235	12.52	25.05
70%	1.225	12.44	24.88
60%	1.210	12.36	24.72
50%	1.190	12.28	24.56
40%	1.175	12.20	24.40
30%	1.160	12.10	24.20
20%	1.145	12.00	24.00
10%	1.130	11.85	23.70
0 %	1.120	11.70	23.40

Monthly Maintenance:

If flooded lead acid batteries are using check electrolyte level and top up if required. Wipe electrolyte residue from the top of the battery.

Inspect all terminals for corrosion and loosened cable connections. Clean and tighten as necessary. After cleaning, add antioxidant to exposed wire and terminals.

Annual Maintenance:

Check array wiring for physical damage and wind chaffing

Check array mounting hardware for tightness.

Inspect inverter - remove dust or dirt, inspect system wiring for poor connections. Look for signs of excessive heating, inspect controller for proper operation.

Inspection and maintenance of Earthing and Lightening Protection

- Use an ohmmeter to check the continuity of the entire grounding system.
- Make sure that all module frames, metal conduit and connectors, junction boxes, and electrical components chassis are earth grounded.
- Inspection and maintenance of System Wiring
- Visually check all conduit and wire insulation for damage.
- Check for loose, broken, corroded, or burnt wiring connections.
- Check if all equipment's are connected with proper wire and conduit
- Make sure all wiring is secured, by gently but firmly pulling on all connections.

- Check all terminals and wires for loose, broken, corroded, or burnt connections or components.

Maintenance of distribution system

Appropriate design and use of good quality components in a microgrid power distribution system is extremely important for overall performance and revenue generation. Undersized distribution cable may cause voltage drop and energy loss in the distribution and low-quality components will cause frequent breakdown in power distribution. Both will contribute towards low system performance, revenue loss and poor services to the users.

A periodic verifications and maintenance of distribution system is also essential. The distribution lines, power connections, switchboard and all its equipment may get physically damaged and continue to degrade whether they operate or not.

The following verification must be made by a qualified person during installation:

- The distribution cables and its components are not exposed to extreme optimum environmental and operating conditions.
- There distribution cables, poles, guy wires and isolators and are not subject to any excessive stress and physical damage.
- Outdoor joints, connectors, fuses, and switches are placed in IP65 rated boxes.
- If insulated cables are used, ensure that cables are UV stabilizes and certified to use in outdoor.
- Ensure that provision for expansion and contraction is considered for distribution cables due to change in temperature.
- Ensure that a galvanized steel wire is used to supports the entire route of distribution line.
- Ensure that all safety requirement and regulations are followed based on the voltage level of the distribution system.

Carry out Civil/Mechanical Maintenance of the solar PV Plant

In this chapter guidance is provided about relevant design aspects and the issues which commonly arise during the construction of foundations for conventional spread footings. These foundations are usually located at depths not more than about 5 m below ground but in certain instances can be considerably deeper. The construction of piled foundations and caissons is dealt with in this Chapter.

Sometimes it is economical to carry out soil compaction, replacement, or other soil improvement procedures to found on weak soils at shallow depth. These specialized procedures are also briefly discussed in this chapter.

Function

The primary function of foundations is to provide adequate support to the structures which they carry. This implies sufficient load bearing capacity to safely resist the effects of the various combinations of permanent and transient loads transmitted to the founding strata, without excessive deformation, which could otherwise compromise the integrity of the structure or impair its use. The safe or allowable bearing pressure is therefore a function of the ultimate load bearing capacity of the ground at the founding level and the load-settlement characteristics of the underlying layers.

In the case of rock foundations, the allowable bearing pressure is determined from rock mechanics principles, with due regard to the degree of weathering, the inclination of the rock strata, the presence of shear planes, fissures, and clay gouges in the bedding planes, among other factors. On intact rock foundations, bearing capacity may be less critical than other criteria, such as safety against overturning of earth retaining components for example.

The interaction between the structure and the ground when founding on compressible soils is an important consideration regarding the articulation of the structure, usually to a greater degree than when founding on rock. The deformation of soils under load can vary greatly depending on the type, depth and characteristics of the soil, which are determined from in situ or laboratory tests. When it is uneconomical or unsafe to found at shallow depth due to the estimated magnitude of the deformation, it becomes necessary to resort to soil improvement or support on piles or caissons.

EXPLAIN TO ASSIST IN SITE SURVEY FOR INSTALLATION OF SOLAR MODULES AND PUMP

A Site survey is a mandatory step in the overall solar process. Our sales manager will visit your site to conduct a site survey after which our Engineering and Design team creates a customized solution from the detailed data gathered.

An ideal site survey should contain the following parameters:

1. **Climate condition of site:** The solar irradiation level, temperature, and variation in wind speed at the site provides an estimate of the potential for the solar PV installation and the specific components required. For instance, at low solar irradiation level sites an

efficient solar panel is required as compared to high solar irradiation sites. Similarly solar panels work more efficiently in colder regions as compared to hotter regions. Also, installation design of solar system should consider the worst wind load on the panels and the structure they are placed on.

2. **Type of property and its roof:** Defining the type of property as residential, commercial, industrial, or institutional is essential as the structure of the property and its roof type determines the design of solar system. The type of roof is also important as there can be various types such as RCC, Metal sheet, Aluminum sheet and Asbestos. A roof can be flat or sloping with a specific potential to carry weight of panels, so this helps determine many other factors dependent on this information.
3. **Location of solar PV array:** It is important to determine the ideal solar PV array during the site survey. South, south-east and south-west are three directions of the property where solar PV array can be installed.
4. **Shade analysis:** Ideally, the location where solar PV array is to be installed should be shadow free. During site survey, any obstructions such as adjacent buildings, trees, water tanks, dish antennas, parapet walls, etc. should be noted as any obstacles can cause shade which can impact electricity generation. Shadow analysis is done to ensure maximum sunlight is captured throughout the year during the time frame of 9:00am to 3:00pm.
5. **Space availability:** The space needed for a 1kW solar system is 80sqft. So, for a 10kW system the space needed is 800sqft. During site survey, the potential area is measured on the roof or the ground and on this basis the solar PV system is designed. The structure and type of roof (flat or slope), its direction, nearby obstructions and its accessibility impact the location where solar PV array is to be installed.
6. **Size and location of existing electrical connection:** To get the correct information on the size and location of the connection it is necessary to answer a few questions. Is it a single phase or a three-phase electrical connection? At what voltage and frequency electricity is supplied to the property? Where is the main connection of the property to the electricity grid? These questions will help analyze the site survey better.
7. **Location for mounting solar system components:** Once the ideal location of the PV installation is decided, , the location and diagram of mounting other components is to be specified in site survey. Factors such as distribution box, the inverter and the wiring route of the whole system should be determined as well. If the installation is off grid, the placement of the battery is also necessary.

With a recent increase in the use of solar panels across the world, the importance of a solar site survey before the installation has also increased. Using solar panels has proved to be an effective and eco-friendly method of generating electricity. It is also one of the most economical methods

of electricity generation as the electricity charges are considerably reduced. The place where the solar panels are placed is one of the most important factors in determining the efficiency of the solar panel.

The panels are mostly placed on rooftops or on some upraised platforms that gain maximum sunlight for the longest part of the day. To ensure that the solar panels are placed on the spot to ensure their maximum efficiency, it is important to have a thorough solar site survey before the installation begins.

SOLAR PANEL MAINTENANCE

Since there are no moving parts, solar panels require very little maintenance. Once you have covered the installation cost of solar panels, there are not many costs associated with maintaining them. Having said that, you should inspect them a few times per year for dirt or some other things that might have piled on top. It is important that the panels are clean and there is nothing blocking them from efficiently absorbing the sun.

Before cleaning the panels, yourself, you should consult with your installer about the warranty conditions. Some solar panel manufacturers could terminate the warranty if any self-cleaning is done. For a general cleaning, you can just use a normal garden hose to wash the face of the panels. You should do this in the morning or evening. Also avoid spraying them with cold water while they are hot because that might damage them.

Moreover, If the panels need some more cleaning that the hose cannot provide, you can use a sponge with soapy water to scrub them. You can also get the services of a cleaning company. This is advisable if the panels are too high or need more thorough cleaning.

You should have your system examined every 4-6 years by an installer. It is also a good idea to ask your installer about specific maintenance requirements for your solar system. If you want to take the next step and get solar panels for your home, then look no further. Fill in the contact form to compare up to 3 quotes from suppliers near you. Green Match's service is free of charge and without further obligations.

SOLAR PANEL INSTALLATION PROCESS

The most common location for the installation of solar PV panels is the roof. Most roofs typically have the desired specifications for the installation, so that panels get the maximum sunlight.

Nevertheless, if installation on the roof is not applicable or desired, the solar panels could also be mounted on the ground. You just need to make sure that there are no objects blocking access to the sun.

The following steps explain solar panel installation on a roof:

1. **Set Up Scaffolding:** Firstly, you must erect scaffolding to ensure safety during the whole installation process when being on the roof.
2. **Install Solar Panel Mounts:** Then, the solar panel mounting system must be set up. This will support the base of the solar panels. The whole mounting structure must be tilted and have an angle between 18 to 36 degrees to have maximum sunlight exposure.
3. **Install the Solar Panels:** When the mounts are set up, the solar panel itself must be installed on the mounting structure. Make sure to tighten up all the bolts and nuts so that it stays stable.
4. **Wire the Solar Panels:** The next step in the installation process is to install the electrical wiring. In most cases, MC4 connectors are used because they are suited for all types of solar panels. Make sure to shut off the household's electricity supply during the wiring installation.
5. **Install Solar Inverter:** After that, the solar inverter must be connected to the system. It is typically installed near the main panel, and it could be both indoors and outdoors. Inverters are more efficient if kept in a cooler place. If the inverter is outdoors, it should be kept out from the afternoon sun. If it is installed indoors, the garage or utility room are usually the best places, since they stay cool for most of the year and have ventilation.
6. **Bond Solar Inverter and Solar Battery:** Thereafter, the solar inverter must be connected to the solar battery. The solar battery storage can save you from worrying about the lack of usable energy during cloudy times, it can also lower the solar panel battery costs during installation.
7. **Connect the Inverter to the Consumer Unit:** The inverter should be connected to the consumer unit to generate electricity. A generation meter should also be connected to monitor the amount of electricity the solar panels produce. You can use your computer or other device to check your solar system's performance. For example, you can check how much electricity you generate at different times and decide what time is suitable for using your washing machine or other utilities.
8. **Start and Test Solar Panels:** The final step is to switch the power on and test the newly installed solar panel system. After that, the solar panel installation process is completed.

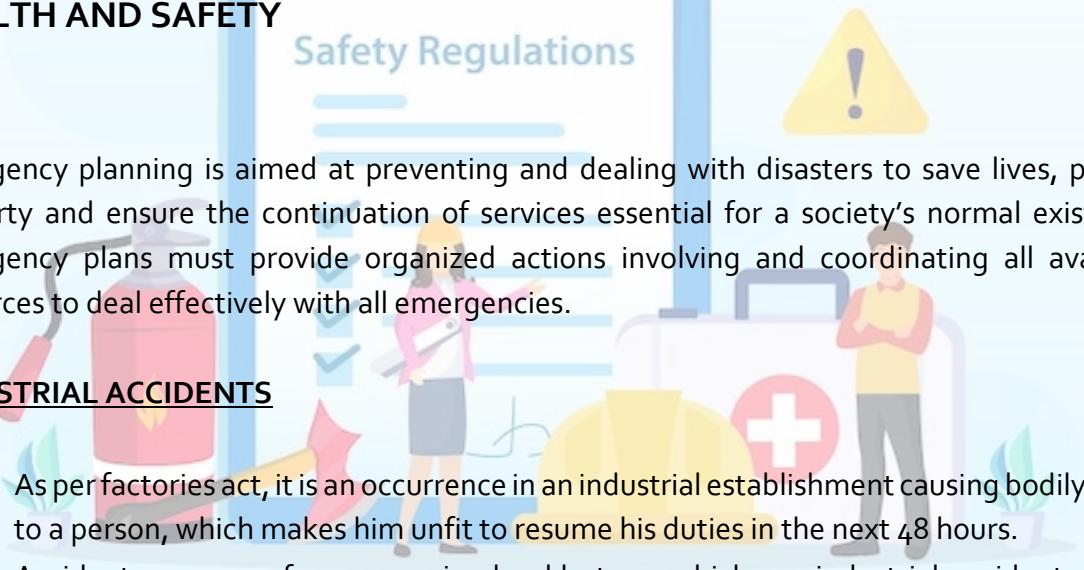
CHAPTER 4: MAINTAIN PERSONAL HEALTH & SAFETY AT WORKPLACE

LEARNING OBJECTIVES:

- Explain the requirements for safe work area.
- Identify contact person for reporting the violation of safety policies at workplace and provide information about incident/violation.
- Explain the importance of administering first aid.
- Identify the personal protective equipment used for the specific purpose.
- Identify the hazards associated with photovoltaic installations including electric shock and required mitigating measures.
- Identify work safety procedures and instructions for working at height and handling heavy material.
- Explain the importance of occupational health & Safety standards and regulations for installation of Solar PV system.
- Incorporate good housekeeping practices and infection control guidelines.

Video on Safety precautions: https://www.youtube.com/watch?v=6TYMndTekpI

HEALTH AND SAFETY



Emergency planning is aimed at preventing and dealing with disasters to save lives, protect property and ensure the continuation of services essential for a society's normal existence. Emergency plans must provide organized actions involving and coordinating all available resources to deal effectively with all emergencies.

INDUSTRIAL ACCIDENTS

- As per factories act, it is an occurrence in an industrial establishment causing bodily injury to a person, which makes him unfit to resume his duties in the next 48 hours.
- Accidents can vary from a sprained ankle to a vehicle, or industrial accident, where people are seriously injured or killed.

UNSAFE ACTS AND UNSAFE CONDITIONS: In a factory/ manufacturing facility, you, as a security guard are also responsible to see that the safety instructions are being followed by the workers. Besides you will also be required to monitor and audit the safety conditions on the production and other shop floors. As such you should know various unsafe acts and conditions in the manufacturing organizations. Some of these are as follows: -

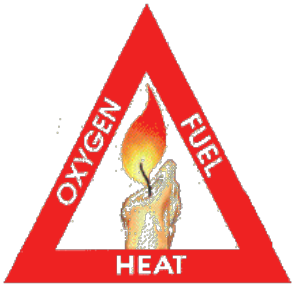
Safety/ Personal Protective Equipment: While there will be Safety Department in the companies, nevertheless it is for the security to ensure that the workers and other employees follow the safety instructions. As security guard you are required to ensure that the workers/ employees going into the areas which have certain unsafe conditions, safety. PPE should be worn by them. Some of these are:

- Helmet, earmuffs and dust masks
- Safety boots
- Rubber/ asbestos gloves
- Safety belt
- Welding goggles
- Protective jackets, trousers
- Fire suits made of fire resistant and Nomex fabric.
- BA Equipment

Triangle of Combustion: All combustion process involves three important elements. These are:

- A combustible material or fuel must be present.
- Oxygen, there is abundant supply of oxygen in the atmosphere.
- Heat (the two materials when heated to combustion temperature, fire will break out)

Combustion will occur if the three factors present. Removal of one of them caused the triangle to collapse and further combustion stop. As such, this principle is used for prevention of fire/ firefighting. See triangle of fire below. On its right is the Tetrahedron which has the fourth, indicating the chain reaction which helps fire to sustain itself and develop? Even as there is no chain reaction, there will be no fire. In fact, three elements as mentioned above combine to create the self-sustaining chain reaction.



Principle of Extinction: From the triangle of fire, if any one of the elements of this triangle is kept away, there may not be any fire and the method for achieving this is known as Principle of fire extinction. These are as under: -

Cooling: This will ensure removal of Heat. There are many media helpful in reducing temperature of burning substance, e.g., water, CO_2, earth etc. nevertheless, the same should not be used on metal fire, which will have substantially high temperature and cause water (H_2O) to split into its elements, two parts of hydrogen and one part oxygen, both of which are highly combustible, and will cause explosion. In fact, pouring of water on the metal fire is like adding fuel to fire.

Blanketing/ Smothering: The term indicates the coverage of the seat of fire and preventing air supply to the combustible which has reached at its ignition temperature e.g., foam is used the burning substances from exposure to atmosphere, thereby stopping the supply of oxygen.

Starvation: Fire has hunger for materials that are burning, which can be in all states (solids, liquids, gases), and are termed as fuel. Removal of fuel from the fire bed is known as starvation. This can be achieved by segregation of fuel from the fire or subdividing the fire into small parts and addressing them separately, when they are easier to extinguish.

CLASSIFICATION OF FIRE AND METHODS TO EXTINGUISH

- **Class A:** Fires on all combustibles of carbonaceous origin come under this category. These include paper, cellophane, coal, plastics, wood, grass; cloth etc., the best method for extinguishing these types of fires is by cooling, essentially with water.

- **Class B:** Liquids fires caused by combustible liquids, such as petrol, diesel, oils paints, thinner etc. water is the only liquid that does not catch fire, unless exposed to excessive temperature such as molten/ red hot metals. These should be extinguished by smothering with foam type extinguishers. Do not use water, as the water is lighter than most of these liquid substances and therefore remain exposed to heat and oxygen. Dry Chemical Powder (DCP) type extinguishers can also be used.

- **Class C**: Gases found in industry, such as Ammonia, LPG, Methane is extinguished by blanketing/ smothering by use of CO_2 type of extinguisher or other inert gases like Nitrogen, Argon etc.,

- **Class D:** Fires involving metals like Aluminum, Magnesium, Titanium etc. come under this category. These metals take considerable amount of heat to ignite and when ignited, liberate large amounts of heat. DCP acts as the best media as it acts on the principle of Blanketing.

- **Class E:** Electrical fires. In fact, the electricity, when not handled in safe manner is only the cause. After the power is disconnected, it only remains one of the other classes, based on the element/ material that has caught fire.

- **Class K:** Cooking gases and oil. Essentially refer to Kitchen fires

Extinguishing media: Any substance that is useful to put out fire is called extinguishing media. Currently the following are used:

- Water
- Mud and sand
- Foam
- Dry chemical powder
- Carbon dioxide

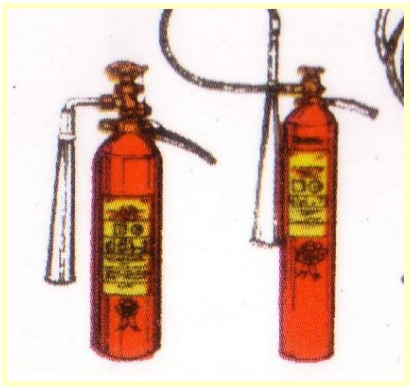
TYPES OF FIRE EXTINGUISHERS

Fire extinguishers are designed to eject firefighting media on the fire from safe distance. These are small and portable instruments generally 5, and 9 liters containing the extinguishing media of different types as mentioned above, with a system.

- **Water (Stored pressure) Type** - Water type extinguisher has water under pressure of approx. 150 lbs./ Sq in, in the container at ejected with CO_2 cartridge, and nozzle to direct the water under pressure to the seat of fire.
- **Foam extinguisher**- Chemical Foam, Mechanical Foam with CO_2 cartridge to expel the foam when operated.
- **Dry chemical powder (DCP)** extinguisher also uses CO_2 cartridge to expel the contents with force, when then extinguisher is operated. Here again the DCP is stored under pressure.

All three above have CO_2 cartridge, a cap assembly, safety pin, and a nozzle. DCP type also has a pressure gauge to show the pressure. At times, water type will also have a pressure gauge.

CO_2 extinguisher are generally the CO_2 cylinders of different sizes with a bib cock for release of the gas, a discharge tube and an applicator to direct the gas to the seat of fire.



Water (Stored Pressure)	ABC (DCP)	Foam	Carbon dioxide

OPERATION PROCEDURE

1. Remove the safety clip.
2. Strike the plunger with hand.
3. Project the nozzle/ discharge tube towards the seat of fire and sweep left and right.

Similarly, at the level of fire brigade, they are equipped with fire tenders with similar extinguishing media. They could be equipped with:

- Water Tender
- Foam Tender
- CO_2 Tender
- DCP Tender
- Crash Tender, designed to address the air crashes at the airports.

Nevertheless, most of the fire tenders have a large tank filled with water, and medium sized extinguishers with extinguishing media, such as CO_2, and foam. They also have the hoses and hose reels mounted.

IDENTIFICATION OF FIRE EXTINGUISHERS

Type (Fire / Extinguisher)	CLASS A Combustible materials (e.g. paper & wood)	CLASS B Flammable liquids (e.g. paint & petrol)	CLASS C Flammable gases (e.g. butane and methane)	CLASS D Flammable metals (e.g. lithium & potassium)	Electrical Electrical equipment (e.g. computers & generators)	CLASS F Deep fat fryers (e.g. chip pans)	Comments
Water	✓	✗	✗	✗	✗	✗	Do not use on liquid or electric fires
Foam	✓	✓	✗	✗	✗	✗	Not suited to domestic use
Dry Powder	✓	✓	✓	✓	✓	✗	Can be used safely up to 1000 volts
CO2	✗	✓	✗	✗	✓	✗	Safe on both high and low voltage
Wet Chemical	✓	✗	✗	✗	✗	✓	Use on extremely high temperatures

FIXED FIREFIGHTING INSTALLATIONS

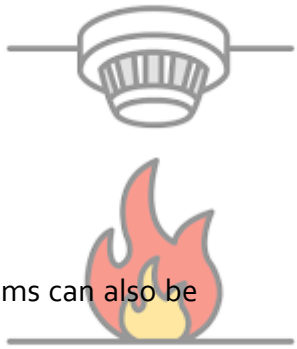
These are such installations which are installed permanently in the buildings to prevent/ extinguish fire in the very early stage and are also called the part of the fire first aid. These come in handy, till the Fire Brigade arrives at the scene. Some of these are: -

- **Smoke/ heat/ flame detectors:** They detect smoke/ heat/ flame, and are designed to operate the alarms, as well as the sprinkler system.
- **Risers and Down-comers:** These are the pipes moving water under pressure to various firefighting appliances. Risers raise water from basement/ ground installed water tanks and down comers are the pipes bringing water from the roof top water tanks under pressure to various appliances.
- **Drenchers**: The appliances, which drench the walls to cool them, when the fire breaks out / when, operated.
- **Sprinklers:** These are in all the rooms as per the designs generally with the detectors. The combination senses the fire, sends the message to break the safety bulb, thereby sprinkling water/ inert/ extinguishing gases where installed.
- **Hose reels:** They are installed in floors as per the design of the firefighting appliances in the building and are available to be used immediately. They eject water at short range say between 10-20 meters.
- **Hose Pipes:** They are pipes, whose diameter is very wide, as such can flood the water when operated. These are also planned to be made available on all the floors.

- **Manual Call Point (MCP):** These are installed at easily visible and approachable locations, where they can be easily operated by anyone to warn all inmates of the building in case of outbreak of fire or any other crisis like incident/ accidents.
- **Fire Hydrants:** Hoses are required are the outlets from where the hoses are used to extract and throw water under pressure at the seat of fire.
- **Fire Pumps:** Maintain the water under requisite pressure in the risers and down comers, as well as supply water in the hydrants.

SAFETY SYSTEMS AND FIRE ALARM SYSTEMS

These are installed to detect heat and smoke. Because heat and smoke rise, the monitors or detectors are located on the ceiling. When they sense a change, a signal is sent to the main control panel, which in turn will: -

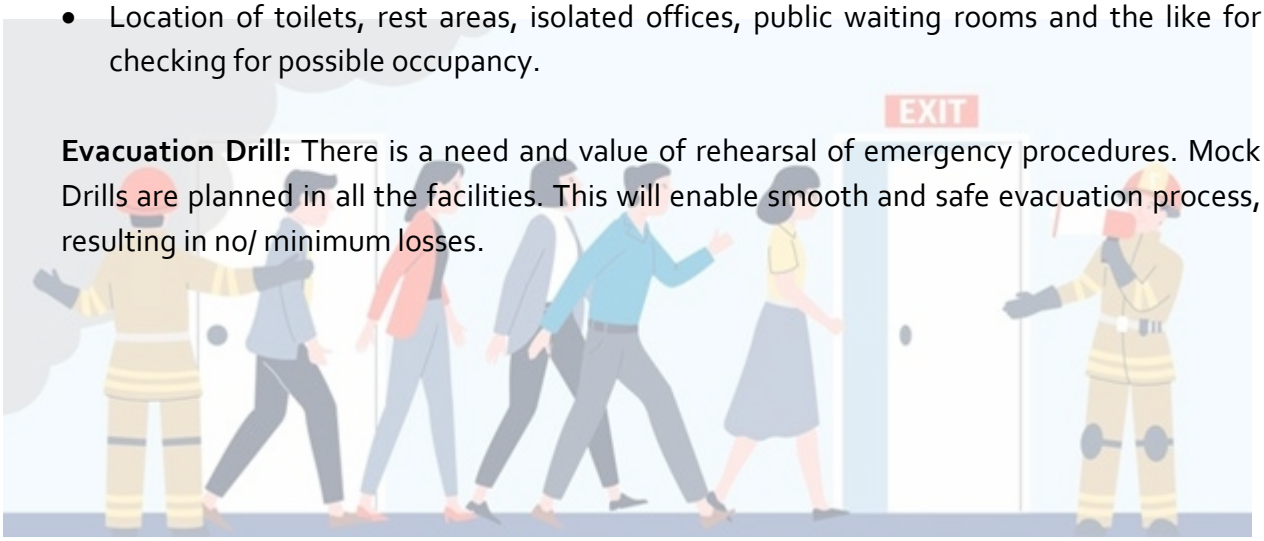


- Sound an alarm.
- Activate lights.
- In many cases turn off ventilation systems
- Open smoke extraction devices
- Immobilize lifts and equipment.
- Release fire doors and contact the emergency services. Fire alarm systems can also be activated by break glass devices (also referred to as Manual Call Points).
- Security Guards' Checks
- There should be no leakage of liquids/ particularly harmful liquids.
- There should be no obstructions in the parking/ traffic circles.
- Under the dangerous conditions, the employees and workmen should use safety equipment, such as helmets, safety belts, boots, goggles, and gloves.
- No one should play around and move around casually near the running machines.
- Keep safe distance from the earth moving machines, and cranes.
- Switch off the unattended machines and power switches.
- Do not allow smoking and naked fire in the areas near FOL storage.
- Take care that to identify the leakage of gas by smell.
- Packing and other stores should be kept in order and with care.
- Maintain proper housekeeping and cleanliness. This is important precaution to avoid accidents.
- Gas cutting and welding should be carried out with care in dangerous areas.

EVACUATION PROCESS

Every organization will have an evacuation procedure/ drill. The same is carried out through the designated evacuation routes, through the emergency/ fire exits. The routes are laid down on the principle of safety. They are laid out and have dimensions and arrangements, which facilitate the safe and prompt evacuation to the designated assembly areas. You may be detailed for controlling and guiding evacuation in a department or a floor. Evacuation drills should be practiced, and all concerned should:

- Be aware of its existence.
- Know what they must do in an emergency.
- Know their responsibilities.
- Location of toilets, rest areas, isolated offices, public waiting rooms and the like for checking for possible occupancy.



Evacuation Drill: There is a need and value of rehearsal of emergency procedures. Mock Drills are planned in all the facilities. This will enable smooth and safe evacuation process, resulting in no/ minimum losses.

2023

SOLAR PV PROJECT HELPER - SOFT SKILLS

SECTOR: GREEN JOBS

QP CODE: SGJ/Q0111

COURSE CURRICULUM: PATHWAYS TO PROGRESS

TABLE OF CONTENTS

CHAPTER 1 - THE GREETING GAME

LEARNING OBJECTIVES

- Demonstrate the correct way of greeting each other.
- Apply corporate grooming norms.

Modus Operandi

A

This is how the Greeting game will be played:

- Dividing the class into two halves.
- Making each group stand in a straight line.
- One person from each of the groups must go all the persons in the other group, shake hand with him/her, while saying 'Hello' the person
  Thus, there are two people who are doing this activity in parallel.
- Continuing with this activity till every participant has got an opportunity to greet all the others in the room.

B

This is how the Grooming game will be played:

- Each participant will write the name of the male participant and the name of the female participant who he/she feels is the best groomed.
- The names will be collected.
- The persons receiving the maximum number of votes will be honoured as the 'Best Groomed Male/Female' in the class.
- In case of a tie, the trainer's decision will be final.
- There should be unique winners in different days of the program, as far as possible.

CHAPTER 2 - I CAN SPEAK IN ENGLISH

LEARNING OBJECTIVES:

- Explain the given statements/phrases.
- Able to use the given phrases as required.

Introduction:

The following phrases are some of the most used ones in the English Language. Correct usage of these sentences can take you a long way in building your confidence in being able to speak in English language.

First you will need to understand the meaning of the phrases.
We are also sharing some sentences for each phrase to help you understand the meaning and usage of each.

Next, you will need to frame similar sentences and use these phrases.

Session 1

1. How are you?

Question: "We haven't caught up in a while. How are you doing?"
Response: "I'm doing well, thank you. How about you?"

2. I don't know.

Question: "Excuse me, could you please pass the salt?"
Response: "Oh, I'm sorry. Here you go."

3. Excuse me.

4. Can you help me?

Question: "I'm having trouble with my computer. Can you help me fix it?"
Response: "Certainly, I'd be happy to help. Show me the issue."
Nice to meet you.

5. Nice to meet you.

Question: "Have you met our new seller, Jessica?"
Response: "No, I haven't. Nice to meet you, Jessica!"

6. Good morning/afternoon/evening/night.

Question: "What time is our meeting tomorrow morning?"
Response: "Good morning! Our meeting is at 10 AM tomorrow."
See you later.

7. See you later.

Question: "Are you leaving the office now?"
Response: "Yes, I have to go. See you later!"

8. Have a good day.

Question: "Any plans for the weekend?"
Response: "Not much, just relaxing. Thanks, have a good day!"

9. No problem.

Question: "Sorry for the delay in the project submission."
Response: "No problem at all, these things happen."

10. How's it going?

Question: "I heard you started a new project. How's it going?"
Response: "It's going really well, thanks for asking!"

11. I don't understand.

Question: "Could you explain the process again? I don't understand."
Response: "Certainly, let me break it down for you."

12. Can you repeat that?

Question: "I missed what you said. Can you repeat that?"
Response: "Of course, I'll repeat it for you."

13. How much is this?

Question: "I'm interested in buying this. How much is it?"
Response: "This item is Rs.20."

14. What time is it?

Question: "I forgot my watch. What time is it now?"
Response: "It's 3:30 PM."

15. Where is the bathroom?

Question: "Excuse me, where is the nearest bathroom?"
Response: "Go down the hall and take a left. It's on your right."

16. I'm happy/sad.

Question: "You seem really cheerful today. Are you happy about something?"
Response: "Yes, I just got some good news. I'm happy!"

17. How can I help you?

Question: "I'm a bit lost in this project. How can I help you?"
Response: "I appreciate your offer. Let's work on this together."

18. Let's schedule a meeting.

Question: "There's a lot to discuss about the upcoming project. Should we schedule a meeting?"
Response: "Absolutely. Let's schedule a meeting for tomorrow."

19. I'll get back to you on that.

Question: "Do you have an answer to the client's query?"
Response: "I need to gather more information. I'll get back to you on that."

20. Can you send me the report?

Question: "The deadline is approaching. Can you send me the report as soon as possible?"
Response: "Certainly, I'll send it to you by the end of the day."

21. What's the status of the project?

Question: "I've been away for a week. What's the status of the project?"
Response: "We've made good progress, and everything is on track."

22. I need your input on this.

Question: "I'm finalizing the proposal. I need your input on the budget section."
Response: "Sure, I'll review it and get back to you with my thoughts."

23. We need to meet the deadline.

Question: "The client is expecting the deliverables by Friday. We need to meet the deadline."
Response: "Agreed. Let's prioritize and ensure we meet the deadline."

24. I appreciate your hard work.

Question: "I noticed your extra effort on the project. I appreciate your hard work."
Response: "Thank you. It's a team effort, and I'm glad to contribute."

25. What are your thoughts on this?

Question: "I presented the proposal. What are your thoughts on it?"
Response: "I think it's well-thought-out. I support the proposal."

Session 2

1. I'll take care of it.

Question: "There's a minor issue with the website. Can you handle it?"
Response: "Don't worry. I'll take care of it right away."

2. Could you please clarify?

Question: "I didn't quite understand the last point. Could you please clarify?"
Response: "Certainly, let me explain that in more detail."

3. Let's discuss this in the meeting.

Question: "I have some concerns about the project. Can we discuss this now?"
Response: "It's an important discussion. Let's discuss this in the meeting tomorrow."

4. I'm running late for the meeting.

Question: "Are you coming to the meeting? It's about to start."
Response: "I got caught up in another task, and now I'm running late for the meeting."

5. Can you update me on your progress?

Question: "It's been a while since we last talked. Can you update me on your progress?"
Response: "Sure, let me give you a brief overview of what we've accomplished."

6. This is a priority.

Question: "We have several tasks on our plate. What should we prioritize?"
Response: "This particular task is a priority. Let's focus on completing it first."

7. What's the agenda for the meeting?

Question: "I just joined. What's the agenda for today's meeting?"
Response: "We'll be discussing the quarterly goals and progress updates."

8. I'll share the document with you.

Question: "Have you completed the report? I need to review it."
Response: "I haven't finished yet, but once it's done, I'll share the document with you."

9. I'll forward this to the appropriate person.

Question: "There's a customer complaint. What should we do about it?"
Response: "I'll take care of it. I'll forward this to the appropriate person for resolution."

10. This requires our immediate attention.

Question: "I received an urgent email. What should I prioritize?"
Response: "This matter requires our immediate attention. Let's address it first."

11. What are the next steps?

Question: "We've completed the initial phase. What are the next steps in the project?"
Response: "Now that we have the groundwork, let's discuss the next steps."

12. I'm attending a workshop tomorrow.

Question: "Will you be available for a meeting tomorrow afternoon?"
Response: "I'm sorry, I won't be available. I'm attending a workshop tomorrow."

13. I'm looking forward to your feedback.

Question: "I reviewed the proposal. What are your thoughts on it?"
Response: "I value your opinion. I'm looking forward to your feedback."

14. I'm here to help if you have any questions.

Question: "I'm new to the team. Who can I go to for help if I have questions?"
Response: "Feel free to reach out. I'm here to help if you have any questions."

15. I'll make a note of that suggestion.

Question: "I have a suggestion for improving our workflow. What do you think?"
Response: "That's a valuable suggestion. I'll make a note of it for consideration."

16. It's crucial to meet our targets.

Question: "We have a tight schedule. Should we adjust our targets?"
Response: "No, it's crucial to meet our targets. Let's work efficiently to achieve them."

17. Please keep me informed of any updates.

Question: "I'm not directly involved, but I'd like to stay informed. Can you keep me updated?"
Response: "Absolutely. I'll make sure to keep you informed of any updates."

18. I'm glad to be working with you.

Question: "How's your experience working with the new team so far?"
Response: "I'm glad to be working with everyone. It's been a positive experience."

19. This is a great opportunity for us.

Question: "Should we take on this challenging project?"
Response: "Yes, I believe it's a great opportunity for us to showcase our skills."

20. I'm confident we can overcome this challenge.

Question: "This project has some difficulties. Do you think we can handle it?"
Response: "Absolutely. I'm confident we can overcome this challenge with careful planning."

21. I'll check in with you later.
Question: "Will you be available for a quick chat later in the day?"
Response: "I have a busy afternoon, but I'll check in with you later."

22. I'm happy with the progress we've made.
Question: "How do you feel about the team's progress on the project?"
Response: "I'm happy with the progress we've made so far. Everyone is doing a great job."

23. I'm excited about the opportunities ahead.
Question: "What are your thoughts on the new project?"
Response: "I'm excited about the opportunities ahead. It's a challenging but promising project."

24. Can you provide a brief overview of your findings?
Question: "I heard you conducted a market analysis. Can you provide a brief overview of your findings?"
Response: "Certainly. Let me give you a brief overview of the key findings."

25. Let's celebrate our achievements.
Question: "We successfully launched the product. What should we do to acknowledge this accomplishment?"
Response: "Let's gather the team and celebrate our achievements."

26. Let's work together to find a solution.
Question: "We've encountered a problem in the project. What's our approach to resolving it?"
Response: "Let's work together to find a solution. I believe we can brainstorm and come up with a plan."

CHAPTER 3 - INTRODUCING SELF

LEARNING OBJECTIVES:

- Identify key elements that should be a part of a good introduction.
- Include key elements that provide a well-rounded picture of who you are.
- Write an impressive introduction for yourself.
- Introduce yourself while greeting others.

When crafting a paragraph to introduce yourself, consider including key elements that provide a well-rounded picture of who you are. Here are some tips to help you create an engaging self-introduction:

- **Begin with a Greeting:**

Start your introduction with a friendly greeting. For example, "Hello" or "Hi" is often appropriate, depending on the context.

- **Name and Background:**

Clearly state your name and perhaps provide a bit of context, such as your current role or field of study. For instance, "I'm [Your Name], a [Your Occupation or Student]."

- **Professional or Academic Background:**

Share a brief overview of your professional experience or academic background. Mention any relevant accomplishments or areas of expertise. For example, "With a background in [Your Field], I have experience in [Specific Skills or Industries]."

- **Passions and Interests:**

Include a sentence or two about your personal interests or passions. This adds a human touch to your introduction. "Outside of work/studies, I'm passionate about [Your Hobbies or Interests]."

- **Connection to the Context:**

The introduction is for a specific purpose or context, briefly mention your connection to it. For example, "I'm excited to be here because [Reason for the Introduction]."

- **Unique Qualities or Characteristics:**

Highlight a unique quality or characteristic that sets you apart. This could be a skill, experience, or personal trait. "One thing that defines me is my ability to [Your Unique Skill or Trait]."

- **Future Goals or Aspirations:**

Conclude by briefly mentioning your future goals or what you hope to achieve. "Looking ahead, I aspire to [Your Future Goals or Aspirations]."

- **Closing Statement:**

End your introduction with a closing statement. Express enthusiasm about connecting with others or participating in the specific context. For instance, "I'm looking forward to meeting and collaborating with all of you."

Remember, the tone and level of detail may vary depending on the setting. Whether it's a professional environment, a casual gathering, or an academic setting, tailor your introduction accordingly.

Keep it concise, positive, and authentic to make a memorable first impression.

CHAPTER 4 - WHATSAPP FOR COMMUNICATION

LEARNING OBJECTIVES:

- Discuss the importance of caution while using WhatsApp for corporate communication.
- Use WhatsApp as an effective mode of communication.

In a vibrant start-up, Gurvinder, a young and enthusiastic marketing coordinator, was extremely excited about the launch of a ground-breaking campaign for a new product.
As the team brainstormed ideas, she received a witty and cheeky message from her friend, Javed. Intending to share a light-hearted joke about office antics, she accidentally forwarded it to the entire project team on their dedicated WhatsApp group. Unfortunately, this group had a representative from the client's organisation also. The team, including project leads and the CEO, saw the unintended jest. Tension immediately filled the air as the team realized the potential impact on the project's perception and their professional relationships.

The next morning, an emergency meeting was called to address the situation. Emma, feeling a mix of embarrassment and regret, took ownership of the error. The CEO expressed concern about maintaining a professional image, especially during a critical project phase.

To rectify the situation, the team decided to send a follow-up message, acknowledging the mistake, and emphasizing their commitment to the project's success.
Surprisingly, the client responded positively, appreciating the human side of the team. The incident, though initially awkward, became an unintentional icebreaker, fostering a more open and collaborative atmosphere among sellers.

The company learned valuable lessons about the importance of double-checking recipients on messaging platforms, especially when dealing with professional communication. They also implemented a brief training session on maintaining a balance between a friendly work environment and the need for professionalism.

- Do you think such situations do happen in real life?
- How can such situations be averted?

WHATSAPP - TOOL FOR CORPORATE COMMUNICATION

WhatsApp proves to be a potent tool for corporate communication when employed strategically.

Below are various ways to effectively leverage WhatsApp in a corporate setting:

- **Collaborative Work:** Establish specialized groups for project teams or departments, promoting real-time communication, file sharing, and updates. This enhances collaboration and maintains everyone in the loop.
- **Timely Announcements:** Utilize WhatsApp to distribute urgent updates, announcements, or crucial news to the entire team. This guarantees swift dissemination of critical information.
- **Swift Decision-Making:** Capitalize on the instant nature of WhatsApp for expeditious decision-making. Teams can discuss ideas, provide feedback, and reach decisions rapidly, particularly in time-sensitive situations.
- **Event Coordination:** Form groups for coordinating events, workshops, or team-building activities. WhatsApp serves as a convenient platform for discussing logistics, sharing updates, and managing RSVPs.
- **Customer Support:** Leverage WhatsApp for customer support by providing a dedicated number for inquiries and assistance. This facilitates direct and personalized communication with clients or customers.
- **Efficient Document Sharing:** Share documents, presentations, and other files directly through WhatsApp. This simplifies access to important resources without the need for additional email exchanges.
- **Employee Engagement:** Engage employees through WhatsApp by sharing company updates, achievements, and behind-the-scenes glimpses. This fosters a sense of belonging and keeps employees informed about the organization's progress.
- **Training and Development:** Establish groups for training sessions or professional development discussions. This is particularly useful for remote teams or employees not physically present in the office.
- **Surveys and Feedback:** Conduct quick surveys or gather feedback from sellers through WhatsApp. This informal approach encourages more candid responses compared to formal surveys.
- **Task Assignments and Tracking:** Assign tasks and track progress within WhatsApp groups. This proves to be an efficient way to keep everyone accountable and informed about the status of ongoing projects.
- **Broadcast Lists for Announcements**: Employ the broadcast list feature to send messages to multiple contacts without creating a group. This is useful for one-way communication, such as company-wide announcements.

- **Employee Recognition:** Utilize WhatsApp to publicly recognize and appreciate employees for their achievements. This contributes to a positive work culture and motivates others.
- **Crisis Communication:** In times of crisis or emergencies, WhatsApp can serve as a quick and direct communication channel for disseminating important information to employees.
- **Integration with Other Tools:** Integrate WhatsApp with other corporate tools and platforms for seamless communication. Some companies use it in conjunction with project management tools or CRM systems.
- **Privacy and Security Measures:** Establish clear guidelines on the use of WhatsApp for corporate communication and ensure that privacy and security measures are in place, especially when dealing with sensitive information.

Explore as many of these features as possible, to understand how these can be used to increase efficiency at work.

CHAPTER 5 - ACTIVE LISTENING

AN ACTIVITY

LEARNING OBJECTIVES:

- Apply Active Listening Skills

Game 1

1. **Prepare Bingo Cards with participants:**

- Create Bingo cards with 5x5 grids.
- In each square, write down a prompt related to active listening skills. For example:
  Maintains eye contact.
  Nods in agreement
  Asks clarifying questions.
  Paraphrases the speaker's message.
  Provides constructive feedback.
  Avoids interrupting.
  Demonstrates empathy, etc.

2. **Rules of the game:**

- The goal is to actively listen during discussions.
- Mark off the corresponding squares on their Bingo cards when you observe someone demonstrating the listed active listening behaviors.

3. **Discussion Rounds:**

- Divide the class into groups of 4/5
- Each participant will narrate a story/ an experience.
- During the narration one participant from the group will be the 'observer'
- All the others actively listen to the speakers during these rounds.
- The observer to mark off the corresponding squares on his/her Bingo cards when he/she observe active listening behaviors.
- Every time a complete row, column, or diagonal of marked squares is ticked off, it is a Bingo.
- Celebrate the winners and ask them to share their observations and experiences.

Reflection:

- What active listening behaviors were most observed?
- How active listening behavior contributed to effective communication.

Game 2

This game is based on the various behaviors related to active listening.
These are:

1. **"Providing empathetic responses"**
2. **"Asking open-ended questions"**
3. **"Maintaining eye contact"**
4. **"Reflecting on the speaker's emotions"**
5. **"Paraphrasing the speaker's message"**
6. **"Using non-verbal cues effectively"**

Instructions:

- One participant must act out one behaviour without speaking, while the other participants guess the active listening behavior being demonstrated.
- Participant must share the chosen behavior with the trainer.
- Time limit is 2 minutes for each turn.
- In case of a miss, trainer can pass it on to the next participant or give out the answer.

- Each participant must enact at least one behavior during the session.
- One behaviour can be enacted only once until the entire set of 6 bahaviours has been enacted once.

Reflection:

- Summarize the key active listening behaviors highlighted during the game.
- Encourage participants to apply these behaviors in their everyday interactions.

CHAPTER 6 – SELF MOTIVATION

What is Motivation?

Motivation is what pushes us to achieve our goals, feel more fulfilled and improve our quality of life.
Self-motivation is the force that drives you to do things.
People who are self-motivated tend to be more organized, have goods time management skills and more self-esteem and confidence.
Understanding and developing your self-motivation can help you take control of many other aspects of your life.
Everyone's motivation is different and it can fluctuate day to day!

Types of Motivation

Intrinsic motivation:

- Desire to do something because it is enjoyable
- Not worried about external rewards such as praise or awards
- Enjoyment experienced is sufficient to want to perform the activity

Extrinsic motivation:

- Desire to do something because of external rewards such as awards, money and praise
- May not enjoy certain activities but can be motivated to do them to receive some external reward.

What Motivates You?

Obligation

What about a task that has neither intrinsic or extrinsic motivators??

Obligation comes from our personal ethics and sense of duty, what is right and what is wrong.

Examples:

- You might feel obliged to go to a party because you were invited by a friend
- if you go to the party with an open and positive attitude this may add an intrinsic motivator of fun and enjoyment.

Pick out the Positives

We all know it's easier to get out of bed in the morning when we are facing 'happier activities' that day.

It's much easier to cope with stress and long hours if we enjoy what we do.

When thinking about tasks, try to identify what motivates you to do that task- think about both the intrinsic and extrinsic motivators.

If you are having trouble getting motivated write them down and list the motivators for each and what positives will come from the activity.

Example:

Task	Intrinsic Motivators	Extrinsic Motivators	Obligations	Positives?
Completing my assignment	Sense of achievement and accomplishment.	If I give it enough time, I can get a good grade. My lecturer will be really happy and I want to make a good impression	The assignment has to be done or I won't pass the course	Reading will be interesting and an opportunity to learn
Going to the cinema on Friday	Get to spend time with my friend and I enjoy movies.			Spending time with friends makes me happy
Working a double shift		More money at the end of the month to go on a trip.		

CHAPTER 7 – PROBLEM SOLVING

You will learn to apply the 7- step process of problem solving in this session.

Problem solving is a process of working through the details of a problem to reach a solution.
Someone seeking to solve a problem may use the seven steps of problem solving.

The 7-steps in problem solving are:

1)Define and Identify the Problem
2)Analyze the Problem
3)Identifying Possible Solutions
4)Selecting the Best Solutions
5)Evaluating Solutions
6)Develop an Action Plan
7)Implement the Solution

Let us understand in detail.

1) **Define and Identify the Problem**

- Write down a statement which summarizes the problem. This statement may be long if the problem is complex.
- Set a goal for solving the problem.
- Example: The computer will boot up but immediately turn itself off.
  When the problem is solved the computer will be usable

2) **Analyse the Problem**

Ask these questions:
•How long has the problem been going on?
•What are the causes of the problem?
•What are the effects and symptoms of the problem?
•Are there multiple steps to solving this specific problem?

3) **Identifying Possible Solutions**

Brainstorming
•Those working to solve the problem should come up with as many solutions as possible.
•Often one person's ideas may spur the ideas of others.
•All ideas should be written down to evaluate later.

4) **Selecting the Best Solutions**
   - In this step use the brainstormed list of possible solutions.
   - Discuss each of the possible solutions and why they may or may not work.
   - Select the most feasible solution.

5) **Evaluating Solutions**
   - Make a T chart with pros of the solution on one side and the cons on the other.
   - Ask these questions after making the T chart:
     •What are the advantages of each solution?
     •Are there any disadvantages to the solution?
     •Do disadvantages outweigh advantages?
     •Would the solution actually solve the problem?

6) **Develop an Action Plan**
   - Make a step by step plan which should include:
     •Tasks, what is to be done
     •Estimated time to complete each task
     •Who will do each task
   - When this plan is complete post it where it will be seen.

7) **Implement the Solution**
   - Follow the steps in the Action Plan
   - If things start to get complicated make a three-column chart:
     •What could go wrong?
     •How can you prevent this from happening?
     •How will we fix it if something does go wrong?
   - Evaluate results:
   - Is the problem solved?

Common Mistakes in problem Solving

- The problem is not well defined or there is denial that the problem exists.
- Goals are not clearly defined.
- Opinions, emotions, feelings, and self-interest interfere with objective thinking.
- Individuals or groups jump to unwarranted conclusions.
- Individuals or groups are afraid to make mistakes.

Activity:

- Get into groups of 4/5
- Identify a problem that is common for all of you
- Apply the 7-step method to solve the problem
- Present the problem and its solution to the class

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CONTACT INFORMATION:
EMAIL ID: INFOINDIA@PCIGLOBAL.IN

REGISTERED OFFICE ADDRESS:
ADDRESS: F-87, OKHLA INDUSTRIAL ESTATE PHASE -3, NEW DELHI – 110020