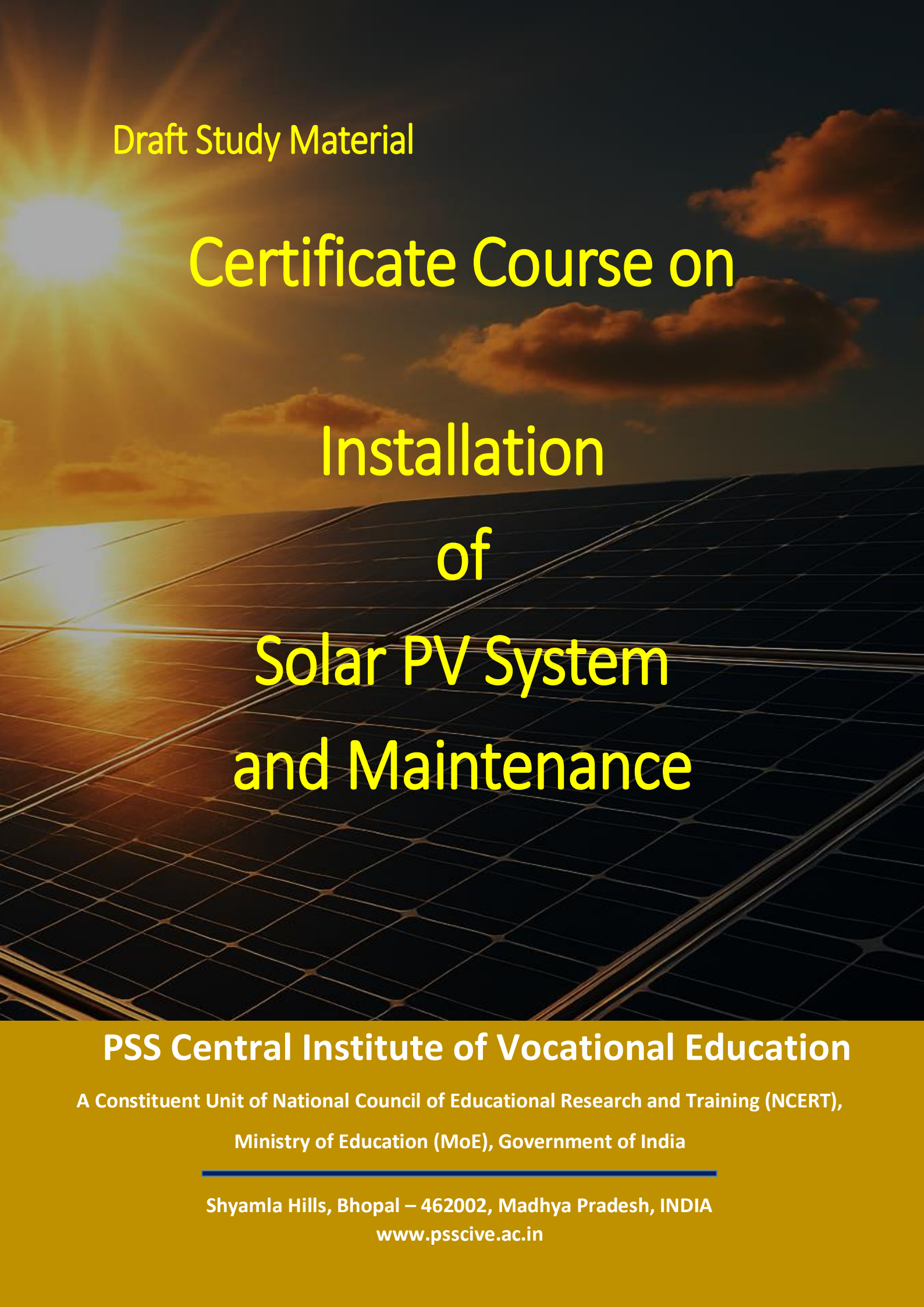




Draft Study Material

Certificate Course on Installation of Solar PV System and Maintenance

PSS Central Institute of Vocational Education

A Constituent Unit of National Council of Educational Research and Training (NCERT),

Ministry of Education (MoE), Government of India

Shyamla Hills, Bhopal – 462002, Madhya Pradesh, INDIA

www.psscive.ac.in

CERTIFICATE COURSE
ON
INSTALLATION OF SOLAR
PV SYSTEM
AND
MAINTENANCE

FOREWORD

The National Education Policy (NEP) 2020 emphasises the integration of vocational education into mainstream learning to enhance employability and meet the growing demands of emerging sectors. In alignment with this vision, the PSS Central Institute of Vocational Education (PSSCIVE), Bhopal, has been taking consistent initiatives in developing competency-based curriculum, training modules, and certificate courses for learners and vocational trainers.

The present **Certificate Course on Installation of Solar PV System and Maintenance** has been developed to prepare skilled manpower in the renewable energy sector. This course aims to equip learners with technical knowledge, hands-on competencies, and practical skills required for the installation, operation, and maintenance of solar photovoltaic (PV) systems. It also highlights industry practices, safety procedures, and sustainability aspects, thereby bridging the gap between theoretical knowledge and practical application.

I appreciate the efforts of the Department of Engineering and Technology, PSSCIVE, and the team of experts and resource persons who contributed their valuable knowledge and expertise in designing this course. Their dedication has ensured that the content is relevant, practical, and aligned with the industry requirements.

This initiative will contribute to creating a workforce capable of supporting India's renewable energy transition and achieving the national vision of clean and sustainable energy. I am confident that this course will benefit students, trainers, and institutions in strengthening vocational education and skill development.

We look forward to the cooperation and support of all stakeholders in making this initiative a success and in advancing vocational education for nation-building.

Dr. Deepak Paliwal
Joint Director
PSSCIVE, Bhopal
August 2025

PREFACE

The paradigm shift in Indian education envisioned by the National Education Policy 2020 (NEP 2020) underscores the importance of integrating vocational education, competency-based learning, and practical exposure to prepare learners for future job markets. In line with this vision, the PSS Central Institute of Vocational Education (PSSCIVE), Bhopal, has undertaken the development of a Certificate Course on Installation of Solar PV System and Maintenance.

This course has been designed to equip learners with comprehensive knowledge and practical skills in the field of renewable energy, particularly focusing on the installation, operation, and maintenance of solar photovoltaic (PV) systems. It introduces students to the fundamentals of solar energy, system components, site assessment, installation procedures, safety practices, troubleshooting, and preventive maintenance. The curriculum is aligned with the National Skills Qualifications Framework (NSQF) to ensure relevance with industry standards and employability.

The course has been structured to promote experiential learning through hands-on activities, demonstrations, case studies, and problem-solving exercises. It not only aims to develop technical competencies but also nurtures an understanding of sustainable practices, thereby preparing a workforce capable of contributing to India's transition towards clean and green energy.

We express our sincere gratitude to the Ministry of Education, NCERT, industry experts, and all stakeholders for their valuable support and collaboration in developing this course. Their contributions have enriched the curriculum with practical insights and industry-oriented perspectives.

It is our firm belief that this certificate course will serve as a stepping stone for learners aspiring to build careers in the renewable energy sector, while also supporting India's larger mission of energy security and sustainability.

Dr. Saurabh Prakash

Head and Professor

Department of Engineering & Technology

PSSCIVE, Bhopal

ACKNOWLEDGEMENT

The PSS Central Institute of Vocational Education (PSSCIVE), Bhopal, expresses its sincere gratitude to all individuals and institutions whose valuable contributions and dedicated efforts have made possible the development of the Certificate Course on Installation of Solar PV System and Maintenance. We extend our appreciation to the Ministry of Education (MoE), Government of India, and the National Council of Educational Research and Training (NCERT) for their constant support and guidance.

We extend our heartfelt thanks to the Director, NCERT, for his constant support and guidance. We also acknowledge the contributions of our colleagues at the National Council of Educational Research and Training (NCERT), National Skill Development Corporation (NSDC), Skill Council for Green Jobs (SCGJ) and the Sector Skill Council for Management and Entrepreneurship and Professional Skills for their academic support and cooperation in the development of the qualification file and curriculum.

We are especially grateful to Prof. Saurabh Prakash, Course Coordinator, for his untiring efforts and significant contribution to the development of this learning outcome-based curriculum. We sincerely acknowledge the contribution of Mr. Ankit Singh Chauhan, Assistant Professor in the Department of Engineering and Technology, for valuable suggestions and editorial support in composing the material.

This collective effort reflects our shared vision of strengthening vocational education and equipping learners with the skills necessary to contribute to India's renewable energy future.

TEAM PSSCIVE
August 2025

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Installation of Solar PV System and Maintenance

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MODULE 01: INTRODUCTION TO SOLAR ENERGY

Solar energy is an abundant and renewable source of energy that harnesses sunlight through technologies like solar panels to generate electricity or heat. It can be used for residential, commercial, and industrial purposes, providing a sustainable alternative to fossil fuels.

This process involves converting sunlight into usable energy with photovoltaic cells for electricity or solar thermal systems for heating. Besides its environmental benefits, solar energy promotes energy independence and can lead to significant cost savings on utility bills.

As technology advances and costs decline, solar energy is becoming more accessible to consumers. It plays a vital role in meeting global energy demands and combating climate change by reducing greenhouse gas emissions, making it essential for a sustainable energy future.

SESSION 1: INTRODUCTION TO ENERGY

Energy is very important for everything in life. It helps us do work and is measured in a unit called **joules**. **Power** tells us how fast we can do work, and it is measured in **watts**.

There is a rule called the **Law of Conservation of Energy**. It says that energy cannot be made or destroyed; it just changes from one form to another. Everything we do, whether it is people or nature, uses energy in different ways. The word "energy" comes from a Greek word that means "work."

The amount of work something can do depends on how much energy it gets.

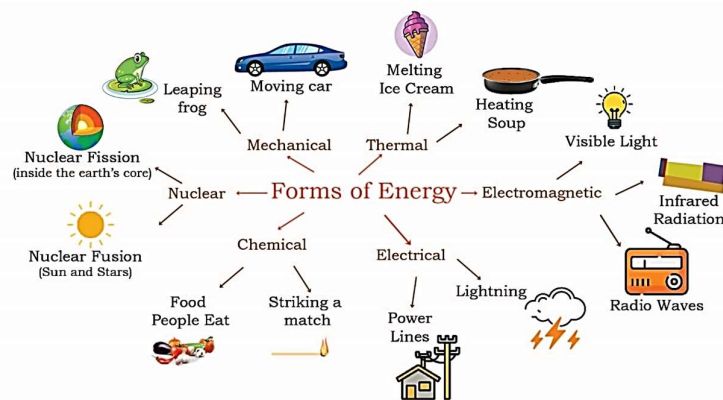


Fig. 1.1: Form of energy

Energy can be classified in several ways based on the following criteria:

1. Primary and Secondary Energy
2. Commercial and Non-commercial Energy

3. Renewable and Non-Renewable Energy
4. Conventional and Non-Conventional Energy

Primary and Secondary Energy

Primary Energy

Primary energy is an energy form found in nature that has not been subjected to any human-engineered transformation process. It is the energy contained in raw fuels, and other forms of energy, including waste, received as input to a system. Primary energy can be non-renewable or renewable.

Examples - Coal, oil, natural gas, and biomass (such as wood).

Secondary Energy

Secondary energy is the **energy produced by the primary energy source**, or energy available in its natural state in the environment.

Examples -Electricity, refined automotive fuel, hydrogen, compressed air, and microwave radiation.

Commercial Energy and Non-Commercial Energy

Commercial Energy

The energy sources that are available in the market for a definite price are known as commercial energy.

Examples – Electricity, coal, natural gas, and electricity petroleum.

Non-Commercial Energy

The energy sources that are not available in the commercial market for a price are classified as non-commercial energy. which are traditionally gathered, and not bought at a price used especially in rural households. These are also called traditional fuels.

Examples- Firewood, cattle dung, agricultural wastes,

Renewable and Non-Renewable Energy

Renewable Energy

The definition of renewable energy includes any type of energy generated from natural resources that are infinite or constantly renewed.

Examples – Solar energy, wind, hydropower, geothermal energy, and tidal power.

Non-renewable Energy

Non-renewable energy is the conventional fossil fuels such as coal, oil, and gas, which are likely to deplete with time the non-renewable energy sources are very limited and are

likely to exhaust with time. The most common examples of non-renewable energy sources are petrol and diesel fuels.

Example-Natural gas, oil, coal, or nuclear.

Conventional and Non-Conventional Energy Resources

Conventional Energy

Conventional energy resources which have been traditionally used for many decades and were in common use around the oil crisis of 1973 are called conventional energy resources, e.g., fossil fuel, nuclear and hydro resources.

Non-conventional energy

Non-conventional energy resources which are considered for large-scale use after the Oil crisis of 1973, are called non-conventional energy sources, e.g., solar, wind, biomass, etc.

INTRODUCTION TO RENEWABLE ENERGY SOURCES

Renewable energy sources are that energy sources derived from existing natural processes such as sunlight, wind, running water, biological processes, and the current flow of energy from geothermal heat flow. A common definition of renewable energy sources is that renewable energy is obtained from an energy resource that is rapidly replaced by a natural process such as power generated by the sun or wind. Currently, the best and most accessible alternative energy sources include solar power, wind power, and hydroelectric power. Other renewable sources include geothermal and ocean energy, as well as biomass and ethanol as renewable fuels.

Solar Energy

Sun is the prime source of all types of energy. Sun rays fall on earth and work as one of the major components of photosynthesis. Photosynthesis is the process by which plants generate food for themselves as presented in Fig. 1.2 below.

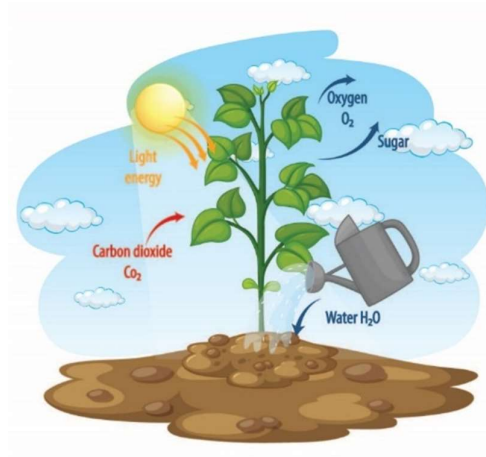


Fig. 1.2: Photosynthesis process

Sun rays heat the ocean, creating various wind speeds. Solar power is an appealing option because it is sustainable, renewable, and reduces emissions.

Modern solar power systems for homes and industries use photovoltaic (PV) technology to harness the sun's energy. "Photo" means "produced by light," and "voltaic" refers to "electricity produced by a chemical reaction." Photovoltaic cells convert solar energy into electricity through a chemical process. Each cell contains a semiconductor, which is a solid material that can conduct heat or electricity under certain conditions. The common semiconductors used in these cells include silicon, germanium, and gallium arsenide. Most commonly, silicon is used in various forms such as single-crystalline, multi-crystalline, or thin-layer, with impurities like boron or phosphorus added and covered with a silk screen. The cells connect through a circuit and frame to form a module.

These semiconductors allow electrons, freed from impurities by sunlight, to move quickly into the circuit, generating electricity.

Commercial residential PV modules typically produce between 10 watts and 400 watts of direct current (DC). To use this power for everyday electrical devices and to connect to the electric grid, a PV module needs an inverter to change the direct current into alternating current (AC). PV modules can also be used in solar power plants. The method of using solar energy is illustrated in Fig. 1.3.

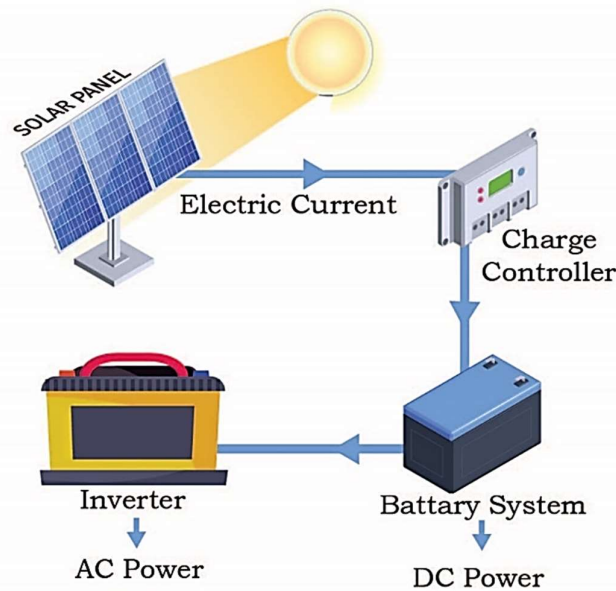


Fig. 1.3: Solar energy generation system through the solar panel

Wind Energy

The wind is the movement of air, caused when the earth's surface is heated unevenly by the sun. Wind energy can be used to generate electricity. The wind energy generation system through wind power is presented in Fig. 1.4.

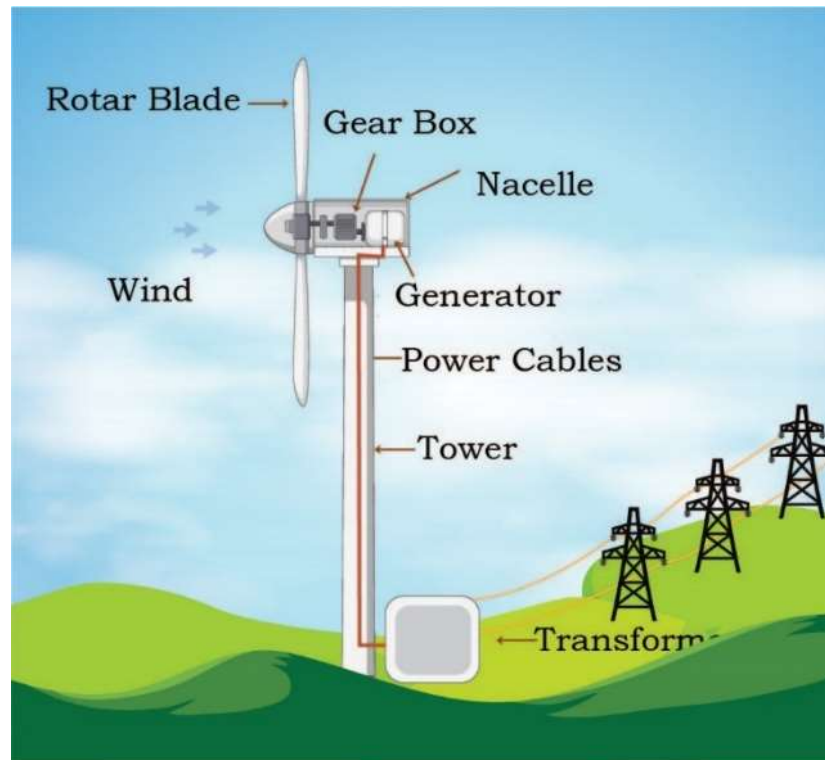


Fig. 1.4: Wind energy generation system through wind turbine

Hydroelectric Power

Hydroelectric power is also known as hydropower. Hydroelectric power is a renewable source of energy that generates power by using a dam or diversion structure to change the natural flow of a river or other body of water. The water cycle plays a vital role in the production of hydroelectric power, in this system electricity is produced using the energy of water, in which water is not exhausted and can also be used for other purposes. There are several types of hydel facilities, though they are all powered by the kinetic energy of flowing water as it moves downstream. Hydropower (hydel) utilizes by turbines and generators to convert that kinetic energy into electricity.

Accumulation of energy from water is possible due to the gravitational potential energy stored in water. As water flows from high potential energy (high ground) to lower potential energy (lower ground), the potential energy difference thereby created can be partially converted into kinetic energy, and then converted into electricity via the use of a generator. The force of the water being released from the reservoir through the penstock of the dam spins the blade of a turbine. The turbine is connected to the generator that produces electricity. The hydro-electric energy generation system is shown in Fig. 1.5

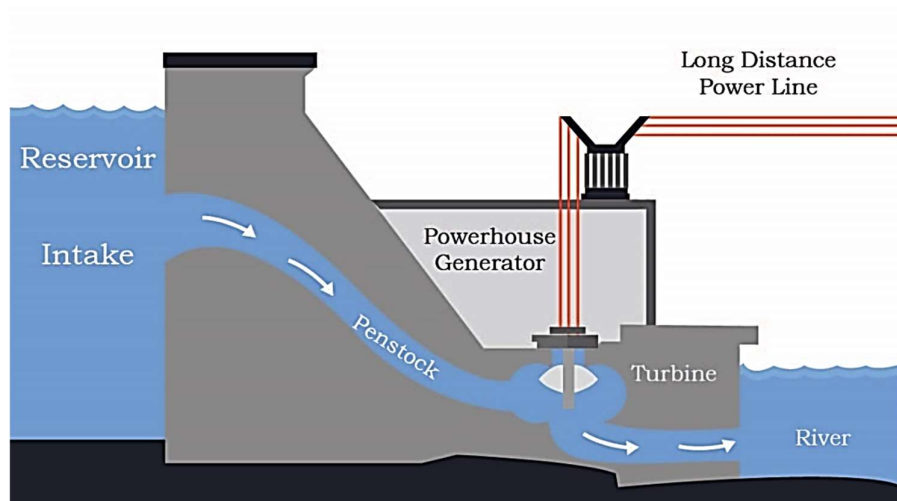


Fig. 1.5: Hydro-electric energy generation system through the hydro-electric dam

Geothermal Energy

Geothermal energy is one of the renewable energy sources that is not dependent on the sun. Geothermal energy depends on the heat generated beneath the Earth's surface. Geothermal energy is a type of renewable energy obtained from the core of the Earth. It drives by the heat generated during the original creation of the planet and the subsequent radioactive decay of materials. These thermal energies are stored in rocks and fluids in the center of the earth. There are two main applications of geothermal energy, which include producing electricity at specialized power plants, and direct heating puts to direct use the temperature of water piped under the earth's surface. The pictorial view of harnessing geothermal energy is shown in Fig. 1.6.

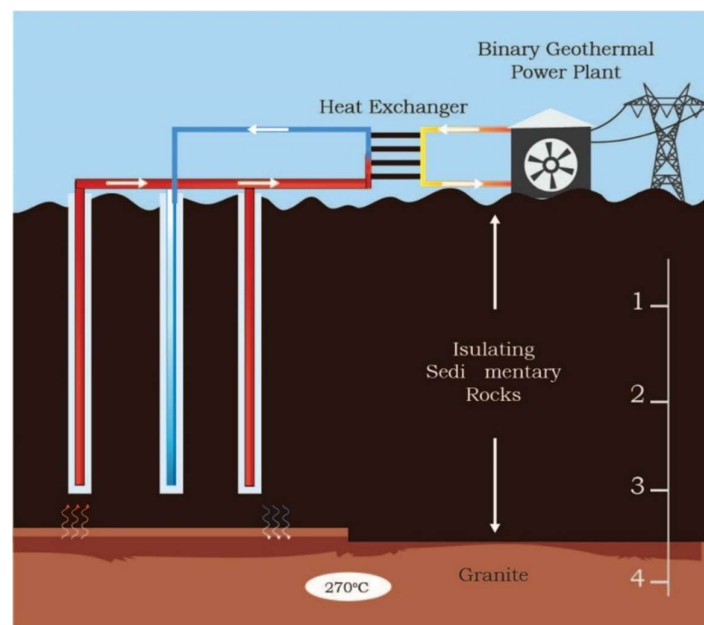


Fig. 1.6: Geothermal energy generation system

Biomass Energy

Biomass contains stored chemical energy from the sun. Plants produce biomass through photosynthesis. Biomass can be directly burned to generate heat and can be converted into renewable liquid and gaseous fuels through various processes. The flow diagram of biomass sources is shown in Fig. 1.7.

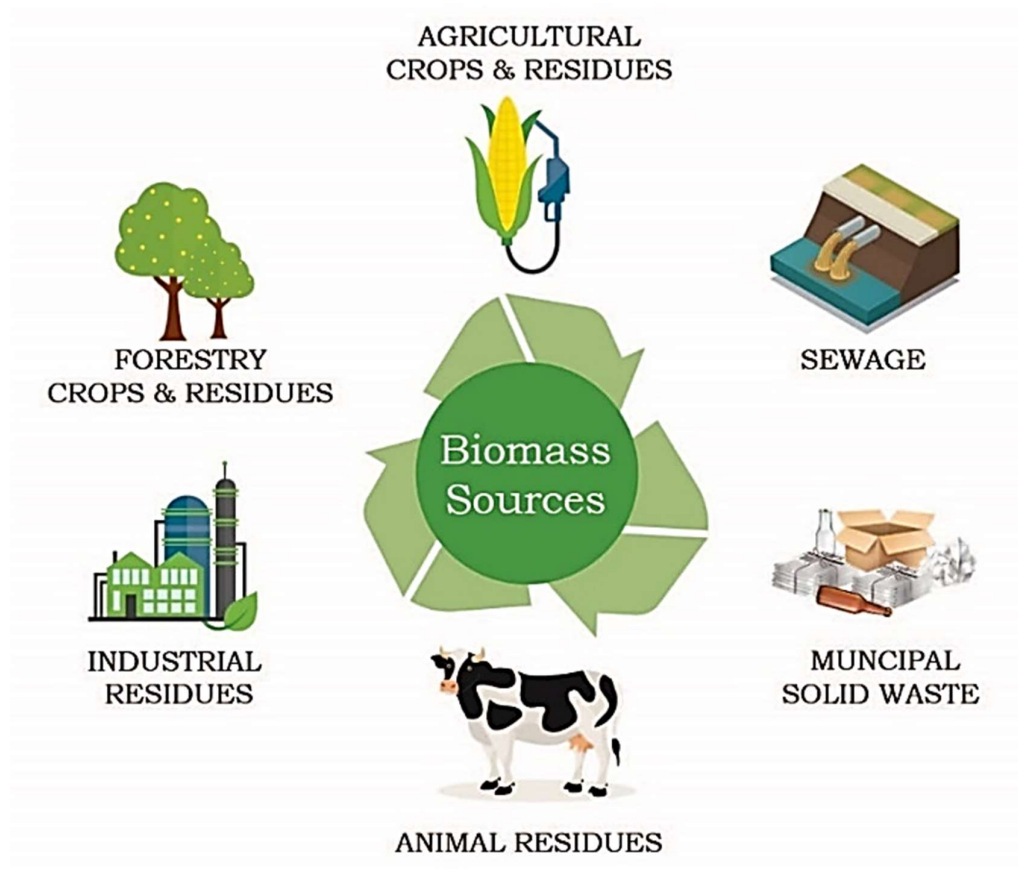


Fig. 1.7: Biomass energy generation system

Ocean Energy

About 70% of the Earth's surface is covered by oceans, which have the potential to supply humans with large amounts of renewable energy. Ocean energy (also referred to as ocean energy) refers to the energy carried by ocean waves, salinity, tides and ocean temperature differences. The movement of water in the world's oceans due to tides, generates enormous kinetic energy, this energy can be used to generate electricity to power houses, transport, and industries.

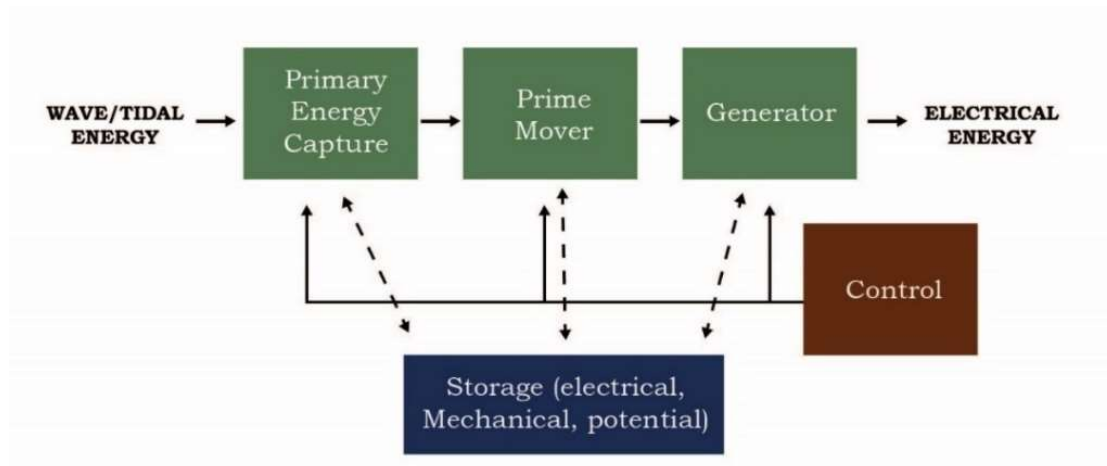


Fig.1.8 (a): Flow diagram of tide/wave energy use

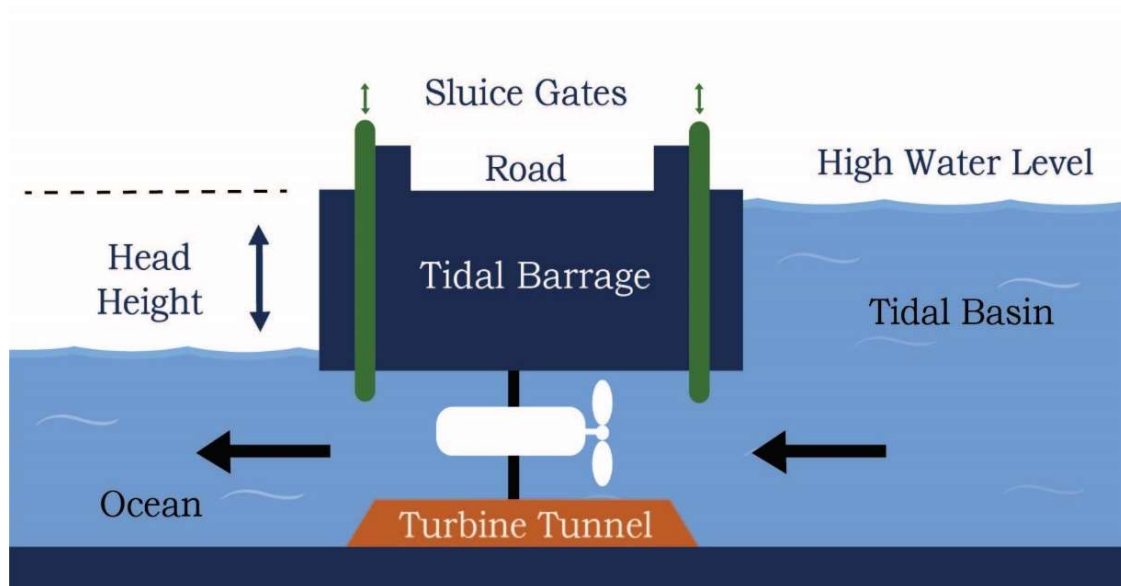


Fig. 1.8 (b): Tide/Wave Energy Use

Advantages and Disadvantages of Renewable and Non-renewable Energy Resources

Every technology has certain advantages and disadvantages. Proper judgment is required for selecting a particular technology. Some of the advantages of various energy technologies are presented in Table 1.1, which may be helpful in the selection of particular technology. Judicious judgment is required for the selection of any technology considering the prevalent location and sites.

Table 1.1 Advantages and disadvantages of renewable and non-renewable energy resources.

Energy Resource	Advantages	Disadvantages
Fossil fuels	● Provide a large amount of thermal energy per unit of mass ● Easy to get and easy to transport ● Can be used to generate electrical energy and make products, such as plastic	● Non-renewable ● Burning produces smog ● Burning coal releases substances that can cause acid precipitation ● Risk of oil spills
Nuclear	● A very concentrated form of energy ● Power plants do not produce smog	● Produces radioactive waste ● Radioactive elements are non-renewable
Solar	● An almost limitless source of energy ● Does not produce air pollution	● Expensive to use for largescale energy production ● Only practical in sunny areas
Water	● Renewable ● Does not produce air pollution	● Dams disrupt a river's ecosystem available only in areas that have rivers
Wind	● Renewable energy source ● Relatively inexpensive to generate ● Does not produce air pollution	● Only practical in windy areas where the minimum wind speed is in the range of 12-14 km/h and not beyond 90 km/h.
Geothermal	● An almost limitless source of energy ● Power plant requires little land	● Only practical areas near hot Spots ● Wastewater can damage soil
Biomass	● Renewable energy source	● Requires a large area of farmland ● Produces smoke

ACTIVITY

- 1) Make a table of advantages of various renewable energy
- 2) Draw the layout of the geothermal power plant.
- 3) Make a list of renewable energy sources.
- 4) Make a table of advantages of various non- renewable energy
- 5) Draw the layout of the wind power plant.

CHECK YOUR PROGRESS**A. Short Answer Question**

- 1) Explain the Energy and its type.
- 2) Describe the source of renewal energy source.
- 3) Difference between renewal energy and non-renewal energy?
- 4) Explain the solar energy sources and their advantages.

B. Fill in the blank

- 1) Sun is the prime source of all types of **Energies.**
- 2) Renewable sources includeandenergies. **Geothermal, Ocean**
- 3) The most promising alternative energy sources include.....and hydroelectric power. **Solar power**
- 4) Modern residential solar power systems use to collect the sun's energy. **Photovoltaic (PV)**

C. Multiple choices Question

- 1) The ability to do work is known as
 - a) **Energy**
 - b) Work
 - c) acceleration
 - d) Force
- 2) Measuring a unit of energy is
 - a) **Joule**
 - b) frequency
 - c) ohm
 - d) all of these
- 3) The rate of doing work is called
 - a) **Power**
 - b) Pascal
 - c) current
 - d) watt

- 4) Which is not a Common primary energy source?
- a) coal
 - b) oil
 - c) natural gas
 - d) **fire**
- 5) The energy sources that are available in the market for a definite price are known as
- a) **commercial energy**
 - b) non-renewal energy
 - c) hydraulic energy
 - d) None of these

SESSION 2: SOLAR ENERGY**Potential of Solar Energy**

Solar energy has the greatest potential of all the sources of renewable energy. Solar energy arrives at the earth from the sun. Solar energy is the energy from the sun, which we are converted into electrical energy or thermal energy. Solar energy is the cleanest and most abundant renewable energy source available and has some of the richest solar resources in the world. Solar technologies can harness this energy for a variety of uses, including generating electricity, Solar water pumping, Solar cooking and solar water heating for domestic, and industrial use.

The solar power where the sun hits the atmosphere is 10^{17} watts, whereas the solar power on the earth's surface is 10^{16} watts. The total global power demand for all needs of civilization is 10^{13} watts. Therefore the sun gives us 1000 times more power than we need. If we can use 5% of this energy, it will be 50 times what the world will require. The energy radiated by the sun on a bright sunny day is about 1000 watts/m², this energy is used by solar panels to produce electrical energy. However, one of the units of large space required, the uncertainty of availability of energy at a constant rate, due to clouds, winds, haze, etc., there is the finite application of this source in the generation of electric power.

The research in solar energy is being carried out in universities and educational and research institutions, public sector institutions, Bharat Heavy Electricals Limited, and Central Electronic Limited are carrying out a coordinated program of research in the solar sector.

The applications of solar energy are:

- (1) Heating and cooling of the residential building.
- (2) Solar water heating.
- (3) Solar drying in the food industry.
- (4) Solar distillation on a small community scale.
- (5) Salt production by evaporation of seawater.
- (6) Solar cookers.
- (7) Solar energy utilization for water pumping.
- (8) Solar furnaces.
- (9) Solar electric power generation by: -
 - (i) Solar ponds.
 - (ii) Steam generators heated by rotating reflectors.

- (iii) Reflectors with lenses and pipes for fluid circulation (cylindrical parabolic reflectors).
- (10) Solar photovoltaic cells can be used for the conversion of solar energy directly into electricity or for water pumping in rural for agricultural purposes.

APPLICATIONS OF SOLAR ENERGY

Heating and cooling of the residential buildings

The solar Heating and cooling system generally maintains the temperature of the building. Solar heating systems convert solar radiation into heat. These systems are used to increase the temperature of a heat transfer fluid, which can be air, water, or a particularly designed fluid. The hot fluid can be used directly for hot water needs or space heating/cooling needs, or a heat exchanger can be used to transfer the thermal energy to the final application. The heat generated can also be stored in a suitable storage container for use in the hours when the sun is not available. Solar thermal technologies are also used to heat swimming pools and to provide hot water for commercial buildings and industrial process heat. The solar collector is the key component of a solar thermal heating and cooling system the heat from solar collectors is directly used for warming the living spaces of buildings. When the building does not require heat, the warmed air or liquid from the collector can be moved to a heat storage container. The solar space heating system is illustrated in Fig. 1.9.

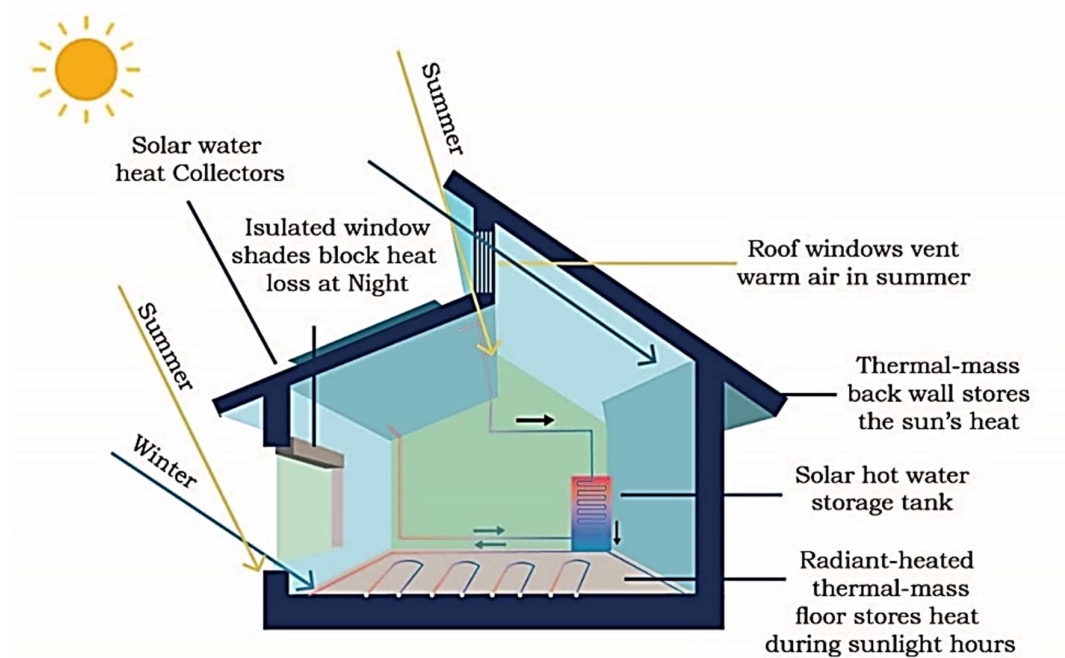


Fig. 1.9: Solar Space Heating System

The heat from solar energy can be used to cool buildings, using the absorption cooling principle operative in gas-fired refrigerators. A great deal of current research is being devoted to developing systems requiring lower operating temperatures, but it will probably be several years before solar collectors will be commercially viable.

Solar water heating system

A solar water heater commonly comprises a blackened flat plate metal collector with associated metal tubing, facing the general direction of the sun. The collector is provided with a transparent glass cover and a layer of thermal insulation below the plate. The collector tubing is coupled by a pipe to an insulated tank that stores hot water during non-sunny periods. The collector absorbs solar radiation and by transferring and regulating the heat to the water circulating through the tubing by gravity or by a pump, hot water is supplied to the storage tank. The view of the solar water heating system is presented in Fig. 1.10.

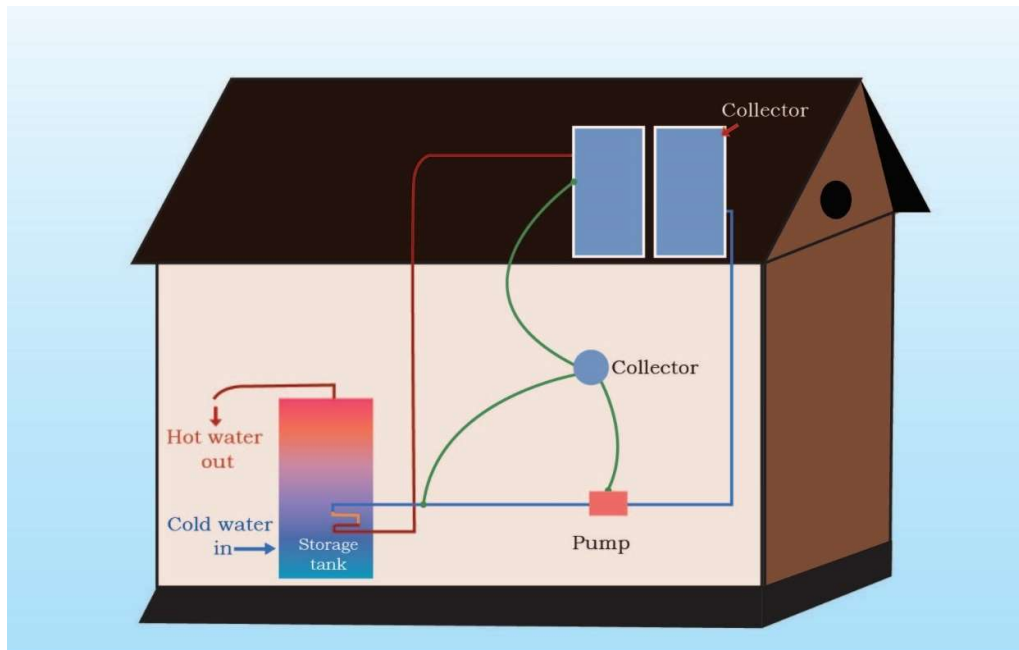


Fig. 1.10: Solar water heating system

Solar Dryers

Solar dryers are devices that use solar energy to dry substances, especially food and agricultural products. Fig. 1.11 depicts the typical solar drying system. The basic function of a solar dryer is to heat the air to a constant temperature with solar energy, which facilitates the extraction of humidity from crops inside a drying chamber.

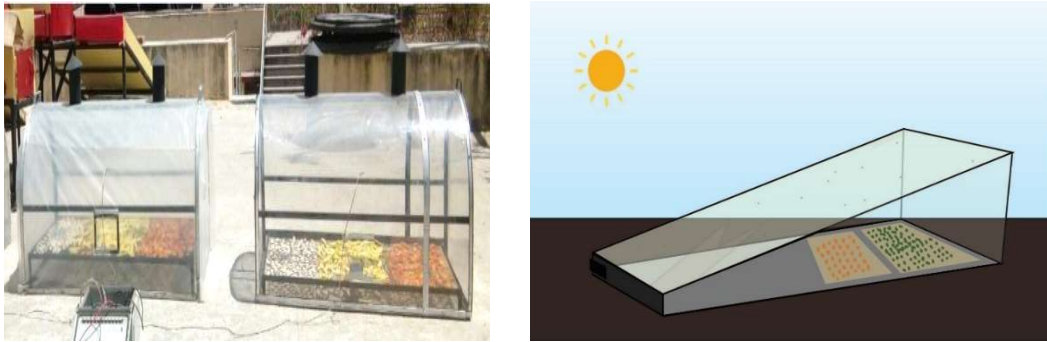


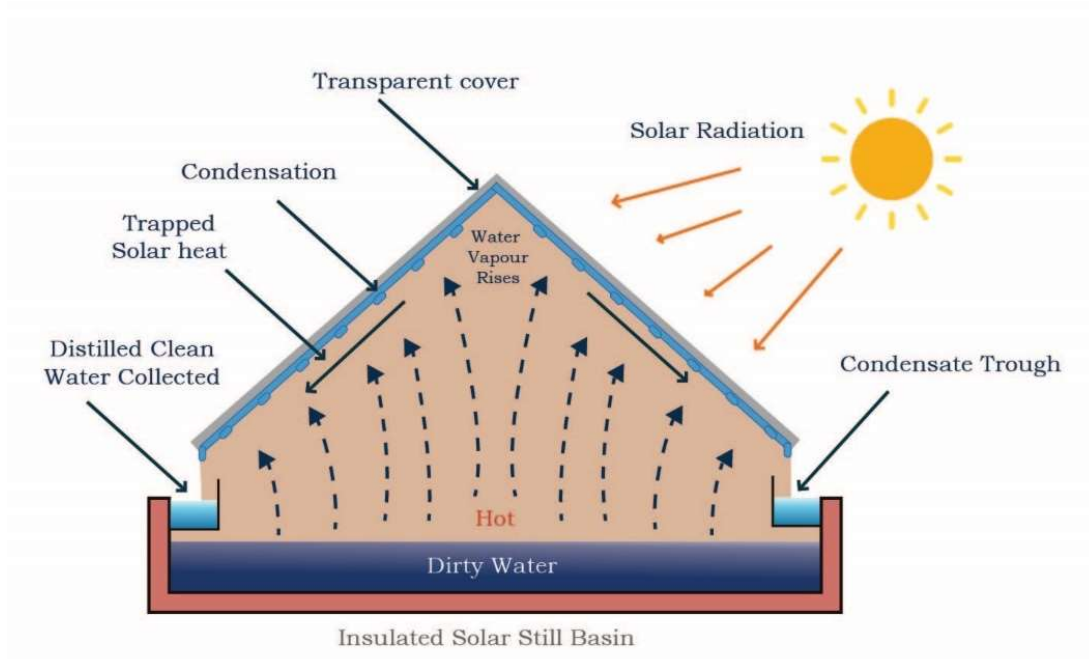
Fig. 1.11: Solar dryer system

Solar Distillation

The basic method of solar distillation is to admit solar radiation through a transparent cover to a shallow, covered brine basin; water evaporates from the brine and the vapour condenses on the covers which are so arranged that the condensate flows therefrom into collection troughs and hence into a product-water storage tank. In arid, semi-arid, or coastal areas, there is abundant sunlight that can be used for converting brackish or saline water into potable distilled water. The solar distillation unit is shown in Fig. 1.12.



(a) Solar distillation unit



(b) Line diagram of solar distillation

Fig. 1.12: Solar distillation unit

Solar Cooker

A solar cooker is an appliance that uses the energy of direct sunlight to heat, cook or pasteurize drinks and other food substances. The solar cooker contains a box that has a black-coated surface. The black surface absorbs heat and raises the temperature of the box significantly to a level to cook the food. Fig. 1.13 shows the typical image of a solar cooker.

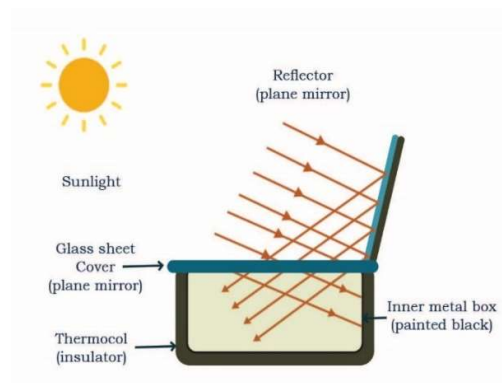


Fig. 1.13: Solar cooker

Solar Water Pumping

A solar water pumping system is essentially an electrical pump system in which the electricity is provided by one or several Photo Voltaic (PV) panels. A typical solar-powered water pumping system consists of a solar panel array that powers an electric motor, which in turn powers a submersible pump or surface pump. Solar water pumping systems are beneficial in the agricultural and industrial sectors. Fig. 1.14 illustrates the typical solar water pumping system.

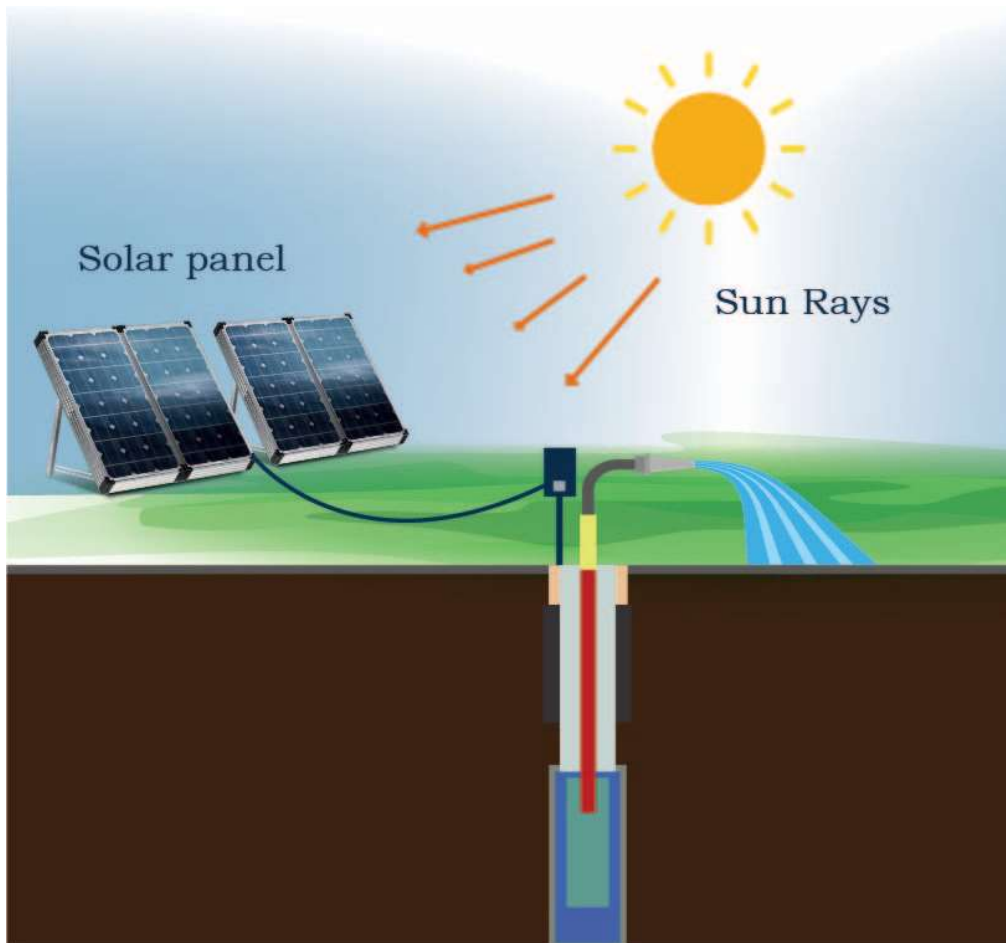


Fig. 1.14: Solar water pumping

PRACTICAL EXERCISE

- (1) Draw a sketch the of solar cooker system.
- (2) Draw a line diagram of the solar distillation unit.
- (3) Draw a line diagram of the Solar space heating system.
- (4) Draw a line diagram of the Solar water pumping.
- (5) Sketch the solar water heating system.

CHECK YOUR PROGRESS

A. Short Answer Question

Q.1. Explain solar energy and its application.

Q.2. What are the working principles of the solar cooker system and the name of its components?

Q.3. Name the major component of the solar water heating system.

Q.4 what is solar radiation?

B. Fill in the blank

1. Solar energy has the greatest potential of all the sources of..... **renewable energy**
2. Solar....., which can be used for the conversion of solar energy directly into electricity. **Photovoltaic cells**
3. The heat from is directly used for warming the living spaces of a building in conventional ways e.g., throughand hot air registers. **solar collectors, radiators**
4. The collectoris connected by a pipe to anthat stores hot water during non-sunny periods. **Tubing, insulated tank**

C. Multiple Choice Question

- 1) Solar electric power generation by
 - a) Solar ponds
 - b) Steam generators heated by rotating reflectors
 - c) Reflectors with lenses and pipes for fluid circulation
 - d) **All of these**
2. which devices use solar energy to dry substances, especially food and agricultural products?
 - a) **Solar dryers**
 - b) solar distiller
 - c) solar compressor
 - d) none of these
3. The solar cooker contains a box that has.
 - a) **Black coated surface**
 - b) White coated
 - c) surface

- d) silver-coated surface
- e) All of these

4. The Pyranometer measures

- a) Direct Radiation
- b) Diffusion Radiation
- c) **Both a and b**
- d) None of the above

5. the solar heater's function is to convert the solar energy into

- a) Radiation
- b) Electrical Energy
- c) **Thermal Energy**
- d) None of the above

SESSION 3: SOLAR PHOTOVOLTAICS (PV) TECHNOLOGY**BASICS OF SOLAR PHOTOVOLTAICS**

Photovoltaics (PV) involve the technology of converting sunlight directly into electricity as shown in Fig. 1.16. The term “photo” means light and “voltaic” means electricity. A photovoltaic (PV) cell, also known as a “solar cell” is a semiconductor device that generates electricity when light falls on it.

French scientist Edmond Becquerel first observed the photovoltaic effect in 1839, a phenomenon not fully understood until the development of the quantum theory of light and solid-state physics in the early 1900s. Since its first commercial use in powering orbital satellites of the US space programs in the 1950s.

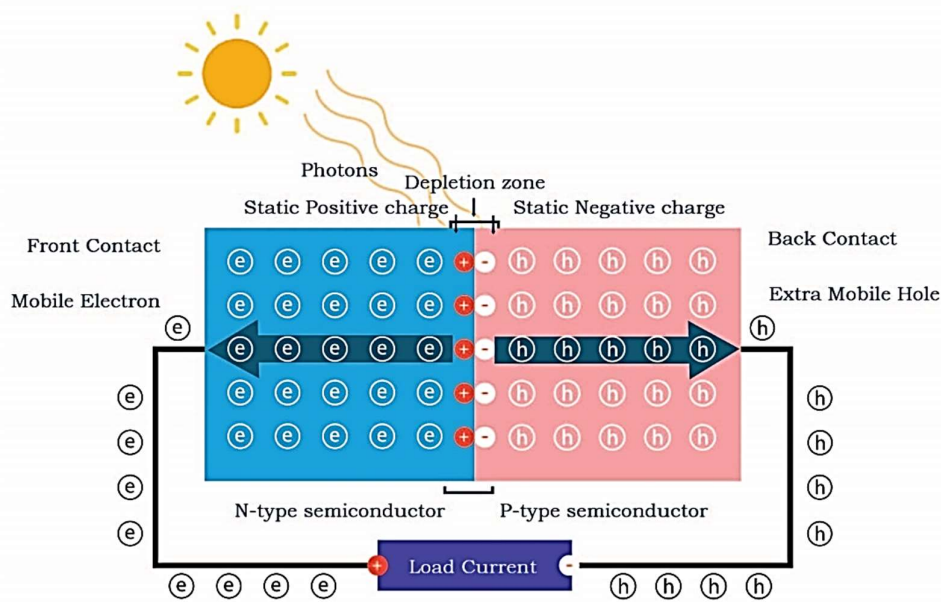


Fig 1.16: Photovoltaic effect

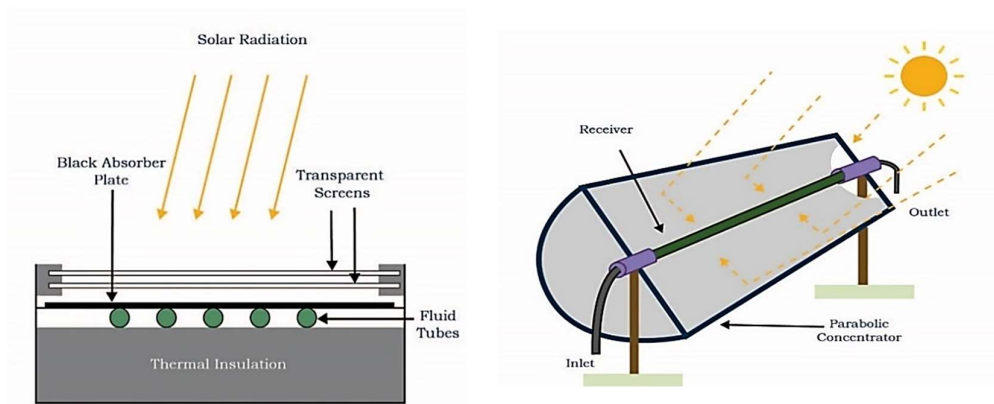
Most of the photovoltaic cells in use today are silicon-based; solar cells made from other semiconductor materials are expected to become a viable competitor in the PV market in terms of performance and cost.

Photovoltaic and Photovoltaic Cells

When sunlight strikes a photovoltaic cell, the photons of the absorbed sunlight eject the electrons from the atoms of the cell. The free electrons then move through the cell, creating and filling in holes in the cell. Due to this movement of electrons and holes, the flow of electric current takes place and generates electricity. The physical process in which a PV cell converts sunlight into electricity is known as the photovoltaic effect. A single PV cell typically produces about 1 watt to 2 watts of power. To increase power output, multiple PV cells are linked together to form modules, which are further assembled into larger units called arrays. PV enables designers to build PV systems with

various power outputs for different types of applications. A complete PV system consists not only of PV modules, but also the “balance of system” (BOS) - the support structures, wiring, storage, conversion devices, like inverter, variable frequency drive, etc. i.e. everything else in a PV system except the PV modules.

Two major types of Photovoltaic systems are available in the marketplace today: flat plates and concentrators. The flat plate systems build the Photovoltaic modules on a rigid and flat surface to capture sunlight. Concentrator systems use lenses to concentrate sunlight on the Photovoltaic cells and increase the cell power output. Comparing the two systems, flat plate systems are comparatively, less complicated but employ a larger number of cells while the concentrator systems use smaller areas of cells but require more sophisticated and expensive tracking systems. Unable to focus diffuse sunlight, concentrator systems do not work under cloudy conditions. The flat plate solar collector and concentrating solar collector are represented in Fig. 1.17 (a) & (b) respectively.



(a) Flat plate solar collector

(b) Concentrating solar collector

Fig. 1.17: Solar collectors

Types of PV cell materials

PV cells are made up of semiconductor materials. The major types of materials are crystalline and thin films, which vary from each other in terms of light absorption efficiency, energy conversion efficiency, manufacturing technology, and cost of production.

CONVERTING PHOTONS TO ELECTRONS

Solar cells used in remote lighting systems, calculators, satellites, etc. are photovoltaic cells or modules (modules are usually a group of cells electrically connected and packaged in a frame). Photovoltaic, a combination of the words photo and voltaic in which "photo means light" and "voltaic means electricity", converts sunlight directly into electricity. Photovoltaic (PV) cells are made of unique materials known as semiconductors, such as silicon, which is currently the most commonly used. More than 95% of solar cells

produced worldwide are made of the semiconductor material silicon (Si). When light hits the cell, a certain part of it is absorbed within the semiconductor material. This means that the energy of the absorbed light is transferred to the semiconductor. The energy loosens the electrons, allowing them to flow freely. PV cells also contain one or more electric fields that force free electrons to flow in a certain direction by light absorption. This flow of electrons is a current, and by placing metal contacts on the top and bottom of the PV cell, we can draw that current to be used externally. For example, current can power a calculator. This current, together with the cell's voltage (which is the result of its built-in electric field or fields), defines the power (or wattage) that the solar cell can generate.

FUTURE SCOPE OF SOLAR PV

India's plan to become of the largest solar power markets in the world has received a massive boost as the latest estimate of its solar power potential.

The National Institute of Solar Energy in India has calculated the country's solar power potential at about 750 Gigawatts, a Newly released document by the Ministry of New & Renewable Energy (MNRE) shows. The solar power potential has been estimated using the waste-land availability data in each state and jurisdiction of India. The calculation is based on the assumption that only 3% of the total wasteland available in a state is used for the development of solar power projects. In the solar energy sector, many large projects have been proposed in India as shown in the above Fig. 1.18.



Fig.1.18: Future of solar energy in India

India has tremendous scope for generating solar energy. The geographical location of the country stands to its benefit for generating solar energy as presented in Fig. 1.18. The reason being India is a tropical country and it receives solar radiation almost throughout the year, which amounts to 3,000 hours of sunshine. This is equal to more than 5,000 trillion kWh. Almost all parts of India receive 4-7 kWh of solar radiation per sq. meters. This is equivalent to 2,300–3,200 sunshine hours per year. States like Andhra Pradesh, Bihar, Gujarat, Haryana, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, and West Bengal have great potential for tapping solar energy due to their location. Since the

majority of the population lives in rural areas, there is much scope for solar energy to be promoted in these areas. The use of solar energy can reduce the use of firewood and dung cakes by rural households.

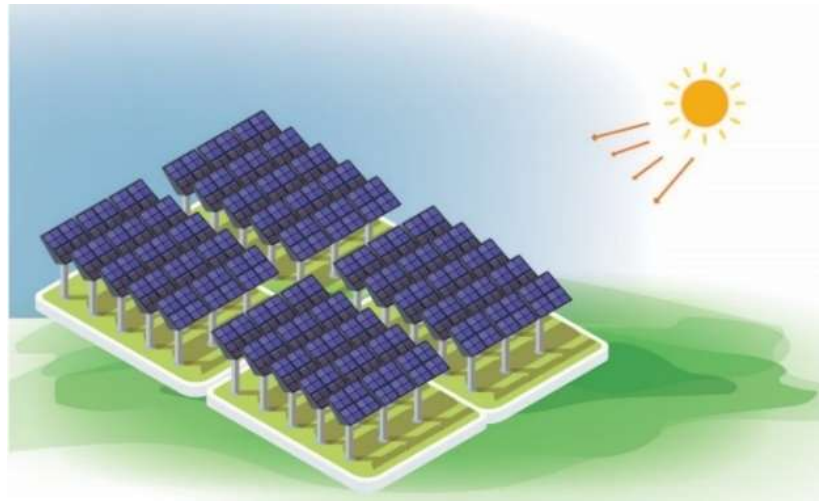


Fig. 1.19: Solar energy generation unit

According to the estimation, Rajasthan and Jammu & Kashmir have the higher solar power potential. Rajasthan, with its healthy resource of solar radiation and availability of vast tracts of waste-land in the form of the Thar Desert, has a potential of approx 142 GW. Jammu & Kashmir obtains the highest amount of solar radiation in India and has a significantly large area of wasteland in Ladakh. The state has an approximated potential of 111 GW. However, this estimate may also include the land currently under Pakistan's control.

Maharashtra and Madhya Pradesh both have more than 60 GW of solar power potential. These are among the largest of the Indian states and thus have large wasteland resources. Both these states have ambitious solar power policies and plan to implement large-scale solar power projects. Gujarat, the leading Indian state in terms of installed solar power capacity, has an estimated potential of 36 GW. The state has large tracts of land covered with marshes but these lands also support a wide variety of wildlife. Gujarat already has an installed capacity of close to 900 MW of solar power and has already started developing utility-scale solar power projects over water canals. Agricultural states like Punjab and Haryana expectedly rank low in terms of estimated solar power potential. Punjab would find it difficult to make available land for large solar power projects and has thus decided to concentrate efforts to set up solar power projects over rooftops and canals. India's current solar power installed capacity is around 3 GW or less than 0.5% of the estimated potential. Naturally, there exists a massive opportunity to tap this potential. As a result, the Indian government has increased its solar power capacity addition target five-fold. Instead of the initial target to install 22 GW of solar power capacity by 2022, the government now plans to add 100 GW of capacity. This includes 20 GW of ultra-mega

solar power projects, with an installed capacity of 500 MW or more, across 12 states as against India's total Solar Capacity is 750 GWh.

Thar Desert has some of India's best solar power projects, estimated to generate 700 to 2,100 GW. On March 1st, 2014, the then Chief Minister of Gujarat, Narendra Modi, was inaugurated at Diken in the Neemuch district of Madhya Pradesh, India's biggest solar power plant. The Jawaharlal Nehru National Solar Mission (JNNSM) launched by the Centre is targeting 20,000 MW of solar energy power by 2022. Gujarat's pioneering solar power policy aims at 1,000 MW of solar energy generation. In July 2009, a \$19 billion solar power plan was unveiled, which is projected to produce 20 GW of solar power by 2020. About 66 MW is installed for various applications in the rural area, amounting to be used in solar lanterns, street lighting systems, solar water pumps, etc.

PRACTICAL EXERCISE

1. Draw a block diagram of the photovoltaic effect.
2. Sketch a solar collector with nomenclature.
3. Draw a series connection of six solar cells.
4. Sketch a single solar panel.

CHECK YOUR PROGRESS

A. Fill in the blank

1. The solar cells used on and satellites are photovoltaic cells. **Calculators**
2. The term "photo" meansand "voltaic" means..... **Light, electricity**
3. which materials are used in PV cell..... **Silicon**
4. PV cell converts sunlight into electricity is known as the..... **Photovoltaic effect**

B. Multiple Choice question

1. One single PV cell produces up to power
 - a) 12 watts
 - b) 10-watt
 - c) 2-watt
 - d) All of these
2. Full name of PV
 - a) **Photovoltaic**
 - b) photocopy
 - c) photosynthetic
 - d) None of these

3. Name of Two major types of PV systems are available in the marketplace

- a) **Flat plate and concentrators**
- b) Circular, rectangular plate
- c) Thermal plate
- d) None of these

4. Full name of NISE

- a) **National Institute of Solar Energy**
- b) National Institute of Science Energy
- c) Neutral Intensity of Solar Energy
- d) none of these

5. the efficiency of solar cells is about

- a) 10%
- b) 25%
- c) **15%**
- d) 60%

C. Short answer question

1. Explain the function and working principle of PV.
2. which material we use in the PV cell and why?
3. Photovoltaic effect and its type?
4. what are solar panels?
5. What are the advantages of solar energy?

SESSION 4. SOLAR POWER GENERATION AND APPLICATION**SOLAR POWER GENERATION**

Generation of energy through the root of solar energy is achieved with the application of solar cell power plants. The sun is the main source of energy for the earth the energy of from the sun reaches to the earth in the form of electromagnetic radiation.

About 5,000 trillion kWh per year of energy come over India's land area with most parts receiving 4-7 kWh/m²/day. Solar photovoltaic energy can be used effectively in India, which can provide huge opportunities in the field of solar energy.

Solar power also provides the ability to produce electricity on a distributed basis and enables rapid capacity addition within a short time. Off-grid solar plants and low-temperature applications will be advantageous from a rural electrification perspective and meet other energy needs for power and heating and cooling in both rural and urban areas. From energy security and reliable perspective, solar is the most secure of all sources, since it is abundantly available. Theoretically, a small fraction of the total incident solar radiation can meet the entire country's power requirements.

Solar energy is available in huge quantity to full fill all the energy needs of the whole world.

SOLAR PV SYSTEM

A photovoltaic system is made up of one or more solar panels which are combined with an inverter, battery, charge controller, and other electrical and mechanical hardware that uses energy from the sun to generate electricity. Photovoltaic systems can vary greatly in size from small rooftop systems to very large utility-scale production plants.

Solar Photovoltaic power generation and a reliable supply of power to require not only PV modules but many other components as well. The other components include the following:

- a) **Battery:** A battery stores electricity produced by a solar electric system. The energy storage capacity of a battery is measured in watt-hours, which is the amp-hour rating times the voltage.
- b) **Fuses and Isolation Switches:** These allow PV installations to be protected from accidental shorting of wires allowing power from the PV modules and system to be turned "OFF" when not required saving energy and improving battery life.
- c) **Inverter:** For converting DC electricity to AC electricity, DC electricity may either come from PV modules or it can come from batteries.
- d) **Wiring:** The final component required in and PV solar system is the electrical wiring. The cables need to be correctly rated for the voltage and power requirements. A thin telephone or bell wire will not work!
- e) **Charge Controller:** This device regulates the rates of flow of electricity from the PV array to the battery and the load. This controller keeps the battery fully charged

without over-charging it. When the controller senses that the battery is fully charged, it reduces or stops the flow of electricity from the PV Array.

- f) **Maximum power point tracker (MPPT):** A maximum power point tracker is an electronic DC to DC converter that optimizes the match between the solar array (PV panels), and the battery bank or utility grid. Many times, the charge controller or inverter (Grid connection) performs the function of charge controller and MPPT.

Broadly PV System Divided into Three Categories:

1. Standalone Solar PV Systems/Off-Grid PV Systems
2. Grid Connected PV Systems.
3. Hybrid Solar PV Systems.

1. Standalone Solar PV Systems/Off-Grid PV Systems

The off-grid / autonomous solar plant is illustrated in Fig. 1.20. The different components of the solar plant are as follows.

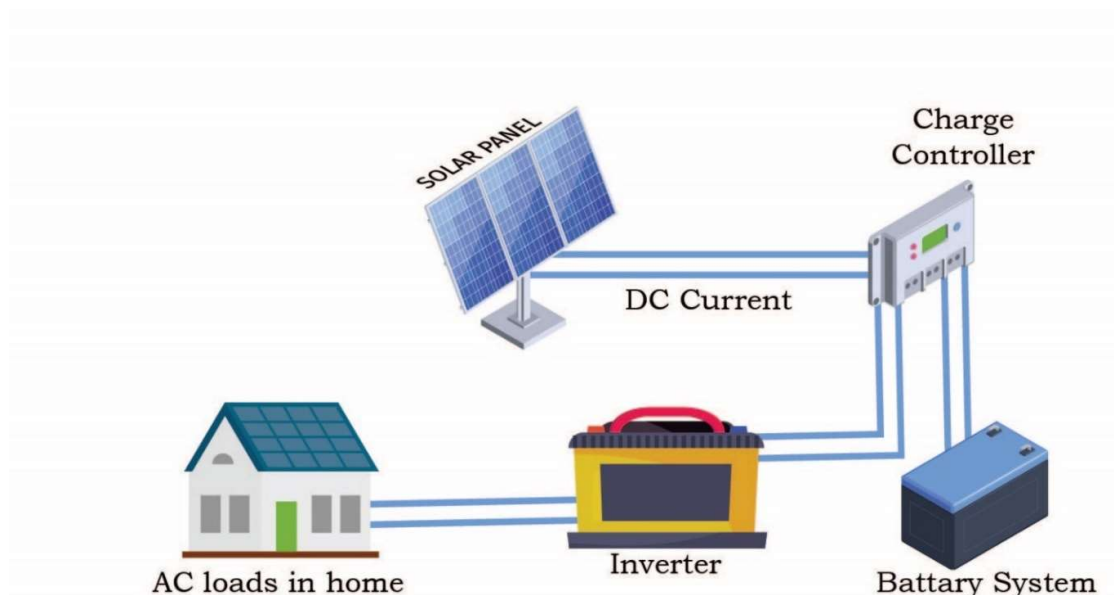


Fig. 1.20: Off-Grid System

off-grid systems work independently of the grid but have batteries that can store the solar power generated by the system. The system usually consists of solar panels, battery, charge controller, grid box, inverter, mounting structure, and balance of systems. The panels store enough sunlight during the day and use the excess power generated at night.

These systems are self-reliant and are important for areas where the power grid is not available, and can provide power for critical loads. When the battery is not sufficiently charged to supply the loads, Generator is used.

2. Grid Connected PV Systems

In a grid-connected system, power is fed into the grid during the daytime and takes power from the grid during the night. PV array supplies the current only when sunlight falls on it. The photovoltaic array produces DC power and this must be converted into ac power for local use and feeding into the grid so inverters are used along with the PV array. An inverter converts DC supply into AC and feeds the solar power to the grid or supply to the consumer. In case of low power availability from PV generators, the local load can be fed from the grid. A grid-connected solar power plant is shown in Fig. 1.21.

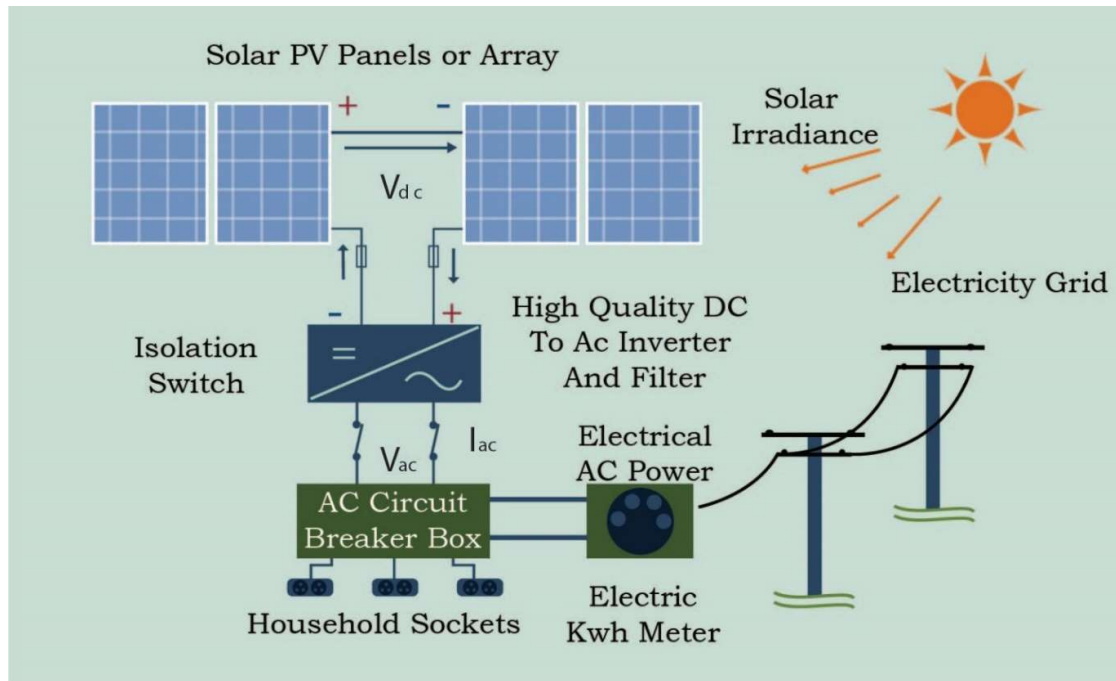


Fig. 1.21: Grid-connected solar power plant

At the time of excessive generation, the energy can be stored and may be used at the time of low generation. The regulation and dispatch unit regulate the flow of power from the photovoltaic power system into the grid and vice-versa. A grid-connected system requires additional components to regulate voltage, frequency, and waveform to meet the requirement of feeding the power into the grid.

3. Hybrid Solar PV System

This system is the combination of on grid solar system and an off-grid solar system. It has a battery backup in it to store power and it also has the ability to feed surplus electricity into the main grid. A hybrid solar system will work even during a power cut which means you always have electricity in your homes. In some cases, auxiliary sources of energy like diesel generator is used in addition to solar PV modules and grid.

LIMITATIONS OF SOLAR PHOTOVOLTAIC ENERGY CONVERSION

- High initial cost
- Irregular supply of solar energy

- Require battery storage to supply power at night
- Low efficiency
- Require a large area
- Do not generate power during the cloudy season.

CURRENT SCENARIO OF ENERGY GENERATION IN INDIA

Primary energy consumption in India has nearly tripled between 1990 and 2021, reaching an estimated 916 million tons of oil equivalent. Power is among the very critical components of infrastructure, important for the economic growth and welfare of nations. The existence and development of adequate infrastructure are necessary for the sustained growth of the Indian economy.

India's power sector is one of the most diversified in the world. Sources of power generation range from conventional sources such as coal, lignite, natural gas, oil, hydro and nuclear power to viable non-conventional sources such as wind, solar, and agricultural and domestic waste. Electricity demand in the country has increased rapidly and is expected to rise further in the years to come. In order to meet the increasing demand for electricity in the country, massive addition to the installed generating capacity is required.

India plans to boost the solar market share to by 2030 as part of the country's plan to reduce air pollution and use cleaner-burning fuels. The pie chart of energy generation in India is shown in Fig. 1.22.

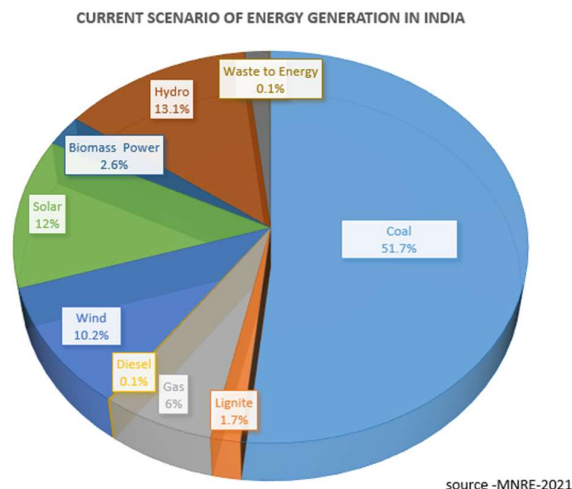


Fig. 1.22: Energy generation in India

The National Institute of Solar Energy has assessed the Country's solar potential of about 748 GW, assuming 3% of the wasteland area to be covered by Solar PV modules. Solar energy has taken a central place in India's National Action Plan on Climate Change, with the National Solar Mission as one of the key Missions. National Solar Mission (NSM) was launched on 11th January 2010. NSM is a major initiative of the Government of India with

active participation from States to promote ecologically sustainable growth while addressing India's energy security challenges. It will also constitute a major contribution by India to the global effort to meet the challenges of climate change. The Mission's objective is to establish India as a global leader in solar energy by creating the policy conditions for solar technology diffusion across the country as quickly as possible. The Mission targets installing 100 GW of grid-connected solar power plants by the year 2022. This is in line with India's Intended Nationally Determined Contributions (INDCs) target to achieve about 40 per cent cumulative electric power installed capacity from non-fossil fuel-based energy resources and to reduce the emission intensity of its GDP by 33 to 35 per cent from the 2005 level by 2030.

To achieve the above target, the Government of India has launched various schemes to encourage the generation of solar power in the country, like the Solar Park Scheme, CPSU Scheme, Defence Scheme, Canal bank & Canal top Scheme, Bundling Scheme, Grid Connected Solar Rooftop Scheme, etc.

Practical Exercise

1. Draw the Block diagram of an off-grid / autonomous solar plant?
2. Make a pie chart of energy generation in India?
3. Make a table of state-wise lar generation?
4. Draw the line diagram of the grid-connected solar system.

Check your Progress

A. Fill in the blank

1.supplies the current only when sunlight falls on it. **PV array**
2. The photovoltaic array produces **DC power**
3. An converts DC supply into AC. **Inverter**
4. 1 mega Joule (MJ) is equal to..... **278 KWh**
5. Watt/hour is a unit of **Energy**

B. Multiple Choice Question

1. full name of DC.
 - a) **Direct current**
 - b) Direct customer
 - c) Duplicate current
 - d) None of these
2. NSM was launched on 11 January.
 - a) **2010**

b) 2021

c) 2019

d) 2018

3. In a grid-connected system, power is fed into the grid during

a) **Day time**

b) evening time

c) sunset

d) None of these

5. Full form of MNRE

a) **Ministry of New and Renewable Energy**

b) Ministry of renewable energy

c) Ministry of non-renewable energy

d) None of these

C. Short answer question

1. Explain the working principle of the off-grid power generation system?

2. Name of the major components of the grid power generation system?

3. Name of Solar cell power plant components and their working?

SESSION 5: GOVTS' INITIATIVES/SCHEMES AND PROGRAMMES (PM SURYA GHAR, PM KUSUM, SOLAR PARKS, ETC.)

The Government of India has started many programmes and schemes to promote the use of renewable energy, especially solar power. These schemes have been designed not only to provide clean energy but also to help households, farmers, industries, and the nation as a whole move towards a sustainable future. Below are some of the major government initiatives explained in detail.

1. PM Surya Ghar: Muft Bijli Yojana (2024)

This is one of the newest schemes launched by the government. It encourages people to install solar panels on the rooftops of their houses. By using sunlight, families can generate their own electricity and reduce their dependence on the power grid. Under this scheme:

- About 1 crore households in India will be given support to set up rooftop solar systems.
- Families will get up to 300 units of free electricity every month, which means a big reduction in electricity bills.
- The government also provides financial assistance and subsidies so that common people can afford the cost of solar installation.

This scheme has two major benefits: it saves money for families and also reduces the use of electricity produced from coal or fossil fuels, which is harmful to the environment.

2. PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan)

Farmers in India often depend on diesel or grid electricity for running water pumps. To reduce this dependency and give them energy security, the government launched the PM-KUSUM scheme in 2019. It has three main components:

1. Small Solar Power Plants – Farmers or groups of farmers can set up small solar plants (up to 2 MW capacity) on barren or unused land. They can sell the generated electricity to the power grid and earn an additional income.
2. Standalone Solar Pumps – Farmers can install solar-powered water pumps for irrigation. These pumps run without diesel or electricity from the grid, saving fuel costs and protecting the environment.
3. Solarisation of Existing Grid-Connected Pumps – The pumps that are already connected to electricity grids can be powered with solar energy. Farmers can use the electricity they need and sell the extra power back to the grid.

This scheme helps farmers save money, earn extra income, and reduce carbon emissions at the same time.

3. Solar Parks Scheme

India has a huge electricity demand, and to meet this need in an eco-friendly way, the government promotes solar parks. These are large areas of land where many solar power plants are set up together.

- Each solar park is usually of 500 MW capacity or more.
- The government provides all the basic facilities such as land, water supply, and connections to the electricity grid.
- Private companies can come and set up solar projects easily, without worrying about infrastructure.

This scheme has made it easier to develop solar energy on a large scale and has created jobs in construction and maintenance of these projects. The target is to set up 40 GW capacity from solar parks by 2024–25.

4. Jawaharlal Nehru National Solar Mission (JNNSM)

This was launched in 2010 and is one of the most important steps taken by India to promote solar energy.

- At first, the target was to generate 20 GW of solar power by 2022, but later the target was revised to 100 GW.
- The mission focuses on three areas:
 - Grid-connected projects (large solar plants connected to electricity supply networks).
 - Rooftop solar systems (small-scale installations on homes, schools, and offices).
 - Off-grid applications (such as solar lanterns, solar street lights, and solar water pumps for areas without electricity).
- It also supports the manufacturing of solar panels and cells in India, reducing import dependency.

This mission is part of India's larger plan to achieve 500 GW of renewable energy capacity by 2030.

5. Rooftop Solar Programme (Phase II)

To encourage more people to use solar energy at home, the government provides financial assistance up to 40% for installing rooftop solar panels up to 3 kW.

- A. For systems between 3–10 kW, a subsidy of 20% is given.
- B. This programme mainly focuses on the residential sector.

- c. The target is to achieve 40 GW rooftop solar capacity across the country.

This programme directly helps families to reduce electricity bills and encourages self-reliance in energy production.

6. International Solar Alliance (ISA)

India, along with France, launched the ISA in **2015** during the Paris Climate Conference. It is a global initiative with over 100 member countries.

- Its aim is to promote **cooperation in solar energy** across the world.
- Member countries work together to share technology, reduce the cost of solar power, and encourage financing of solar projects.
- India also proposed the idea of “**One Sun, One World, One Grid**”, which is about connecting different countries through a common grid to share solar power when and where it is available.

This has made India a leader in the global movement for clean energy.

Check Your Progress

A. Multiple Choice Questions

1. What is the main objective of the PM Surya Ghar: Muft Bijli Yojana?
 - a) To provide free water to households
 - b) To encourage installation of rooftop solar panels and provide up to 300 units of free electricity per month
 - c) To provide free internet to rural areas
 - d) To set up large solar parks for industries
2. Which of the following is NOT a component of the PM-KUSUM scheme?
 - a) Small solar power plants up to 2 MW
 - b) Standalone solar-powered water pumps
 - c) Solarisation of existing grid-connected pumps
 - d) Financial support for electric vehicles
3. What is the primary focus of the Solar Parks Scheme?
 - a) To provide rooftop solar systems for households
 - b) To set up large areas of land with multiple solar power plants, providing infrastructure for private companies
 - c) To distribute solar lanterns to rural areas
 - d) To manufacture solar panels in local villages

4. Which initiative aims to connect different countries through a common solar grid?
 - a) PM Surya Ghar
 - b) Rooftop Solar Programme (Phase II)
 - c) International Solar Alliance (ISA)
 - d) PM-KUSUM

B. Fill in the Blanks

1. Under the PM-KUSUM scheme, farmers can set up small solar power plants up to _____ capacity on barren or unused land.
2. The Rooftop Solar Programme (Phase II) provides financial assistance of up to _____ for residential rooftop solar installations up to 3 kW.
3. The Jawaharlal Nehru National Solar Mission (JNNSM) initially targeted 20 GW of solar power by 2022, which was later revised to _____.
4. The “One Sun, One World, One Grid” concept was proposed under the _____ initiative.

C. Answer the following Questions

1. Explain the PM Surya Ghar: Muft Bijli Yojana. How does it benefit households and the environment?
2. Describe the three components of the PM-KUSUM scheme and how they help farmers reduce costs and earn additional income.
3. Discuss the objectives of the Solar Parks Scheme and the role of the government in facilitating large-scale solar energy projects.
4. Explain the purpose of the International Solar Alliance (ISA) and the “One Sun, One World, One Grid” initiative. How does it make India a global leader in solar energy?

Module 2: Introduction of PV Installer

In this section, we will discuss the essential role of a photovoltaic (PV) installer in the renewable energy sector. PV installers are skilled professionals responsible for the design, installation, and maintenance of solar energy systems. Their expertise ensures that solar panels are correctly positioned and connected to optimise energy production.

As the demand for sustainable energy solutions continues to rise, the role of PV installers becomes increasingly vital in facilitating the transition to renewable energy sources. Proper installation not only maximises the efficiency of solar systems but also ensures safety and compliance with local regulations. This overview highlights the significance of PV installers in promoting clean energy and advancing solar technology.

Session 1: Role and Responsibilities of Solar Panel Installation Technician

A Solar Panel Installation Technician is an important Job role in the energy sector, for operating a solar plant used for electricity generation. The Solar Panel Installation Technician is responsible for installing the solar panel system, gathering materials required for its installation and maintenance. The person should be able to work independently on the assignment, be comfortable in performing laborious work, be a good listener, good at following instructions, be a cooperative team player and be result-oriented, with a positive attitude.

The role of a solar panel installation technician is listed as follows:

- Assessment of installation site
- Get in-depth knowledge of installation pre-requisites
- Installation and mounting of solar panels at the customer's premises
- Gather materials required for installation
- Secure the solar energy system post-installation to ensure effective functioning

Technical Responsibilities of Solar Panel Installation Technician

- Ensure number of modules and panels are as per the voltage requirement.
- Ensure proper handling of panels and other materials.
- Assess precautionary measures to be taken.
- Ensure effective functioning of the system post-installation.
- Manage wastes and workplace safety.
- Open sidebar

A Solar PV Installer is a skilled person who sets up and maintains solar power systems. Their main job is to install solar panels on rooftops or open spaces, connect them with wires, and make sure the system works safely and properly to produce electricity from sunlight. They also check the angle and direction of the panels so that they can capture maximum sunlight. Apart from installation, they test the system, fix any issues, and sometimes explain to customers how to use and take care of it. In simple words, a Solar

PV Installer helps turn sunlight into usable electricity for homes, schools, and businesses, making them an important part of creating clean and green energy for the future.

Here are some of the emerging jobs and entrepreneurial opportunities in the solar rooftop and ground-mounted project sectors, especially in countries pushing big solar goals (like India).

Emerging Jobs

- **Solar Project Manager (Rooftop & Ground-Mounted):** These roles oversee the entire project lifecycle: site surveys, permitting, procurement, scheduling, coordination of the installation team, quality control, commissioning, and handover. They're increasingly needed as more rooftop and ground solar contracts are signed.
- **Design / Technical Engineers:** Solar PV Design Engineers who do the layout, modelling (how many panels, what tilt, shadowing etc.), electrical design, civil/structural designs.
- Electrical Engineers focusing on inverters, wiring, safety standards, grid connectivity.
- For ground-mounted projects, especially, engineers for civil works (foundations, terrain levelling) and mechanical/structural design (support frames, trackers).
- **Installation Technicians & Helpers:** Hands-on roles doing panel mounting, wiring, inverter installation, mounting structures, civil work (if required), grounding, safety. These are core execution roles and growing rapidly with more installations.
- **Operations & Maintenance (O&M) Engineers / Specialists:** Once systems are installed, they need maintenance: cleaning, checking inverter performance, replacing defective components, ensuring safety, monitoring output, fault detection, regular inspections. These roles provide more stable, long term jobs.
- **Sales / Business Development / Customer Acquisition:** Because growth depends on finding customers (residential, commercial, industrial), there is high demand for people who understand solar options, subsidies/incentives, financing, can do techno-commercial proposals, negotiate with clients, explain savings etc.
- **Site Supervisors / Quality / Safety Officers:** Ensuring installations meet standards, managing teams on site, supervising workmanship, safety on site, ensuring compliance with local & national regulations.
- **Monitoring, Analytics, & Remote Operations:** With increasing digitisation, remote monitoring (via software and IoT), performance analytics, predictive maintenance, and fault detection are becoming essential. Roles here include data analysts, monitoring centre operators, and performance engineers.

Entrepreneurial Opportunities

- **Small / Local EPC (Engineering, Procurement, Construction) Firm:** Starting a firm that handles smaller residential or commercial rooftop installs—offering turnkey solutions. This could include specialised services (e.g., for rural homes, schools, and small businesses). Because of government incentive schemes, subsidies, and rising energy costs, there's good demand.

- **O&M Service Company:** Specialised maintenance business for solar installations: cleaning, service contracts, periodic inspection, inverter or module replacement. Especially in areas where people install panels and then struggle to maintain them, this is an opportunity.
- **Solar Design & Engineering Consultancy:** Offering design services, feasibility studies, shadow analysis, structural stability checks etc. May work remotely or for multiple projects.
- **Sales / Financing / Distribution Business:** Entrepreneurs who can tie up with manufacturers or distributors of solar panels/inverters / mounting structures, or who help customers with financing/loans or subsidy paperwork. Also, providing as a service—solar leasing, Power Purchase Agreements (PPAs), or BOOT (Build-Operate-Own-Transfer) models so customers need low/no upfront cost.
- **Technological Innovation / Product Services**
 - Development of better mounting structures, or low-cost trackers for ground-mount.
 - Monitoring & software platforms for performance, remote diagnostics.
 - IoT / smart cleaning systems.
 - Safety / protection systems (lightning, theft, vandalism).
- **Training & Skill Development:** As more installations happen, there's demand for skilled labour. Starting a training institute / centre (for technicians, installers, safety, design) can be a good business.
- **Waste / Recycling Business:** In the longer term, solar modules, panels, mounting materials will need recycling. Entrepreneurs who plan for that early can gain a first-mover advantage.
- **Hybrid Solar + Storage / Solar + Microgrid Solutions:** Offering integrated solutions for homes/villages / commercial establishments where solar plus battery backup or microgrid solutions are needed. This is a more complex but growing domain.

Why These Are Attractive Now

Government push and subsidies (schemes that subsidise rooftop solar) are increasing demand. Targets for solar capacity are ambitious, so supply chains, installations and O&M all need scaling. Technological improvements reducing costs make solar more competitive. Awareness among consumers that solar brings savings.

Doing a course in Solar Installation and O&M (Operations & Maintenance) has many advantages for students. One of the biggest benefits is good job prospects. With the rapid growth of solar energy in India and worldwide, companies are looking for skilled people who can design, install, and maintain solar rooftop and ground-mounted projects. This means students can work as solar technicians, engineers, project managers, or O&M specialists in reputed companies, government projects, or private firms. At the same time, the course also opens doors for self-employment. Trained individuals can start their own solar installation business, provide maintenance services, or even become entrepreneurs by offering solar solutions to homes, schools, industries, and rural communities. Since

solar energy is a clean and growing sector supported by government schemes and incentives, completing this course ensures not only a stable career but also opportunities to create your own business and contribute to a greener future.

Digital literacy and skills are very important in today's world because almost every career now uses technology in some form. Knowing how to use digital tools such as computers, smartphones, online platforms, and specialised software helps students work faster, smarter, and more confidently. For example, in the solar sector, digital skills are needed for designing systems, monitoring performance through apps, and communicating with clients online. Along with this, learning how to set career goals is equally important. Goal setting gives students a clear direction about what they want to achieve, whether it is getting a good job, starting their own business, or upgrading their skills further. When digital literacy is combined with career development and goal setting, students not only become job-ready but also future-ready. They can adapt to new technologies, plan their career path, and make informed decisions that bring long-term success and personal growth.

Basic communication skills are very important for every student and professional because they help in expressing ideas clearly, listening carefully, and understanding others. Good communication avoids confusion and builds trust in both personal and work settings. Along with communication, it is equally important to learn how to work effectively with others as part of a team. Teamwork requires cooperation, sharing responsibilities, and supporting each other to reach common goals. While working in groups, one must also show respect for gender equality and for people with disabilities. This means treating everyone fairly, valuing their contributions, and ensuring a safe and inclusive environment where no one feels left out. When students practice clear communication, teamwork, and respect for diversity, they not only become better professionals but also help create a positive and supportive workplace.

Advantages of Doing the Course in Solar Installation and O&M

Growth of the Solar Industry

The solar industry is one of the fastest-growing sectors worldwide. Governments, businesses, and individuals are increasingly choosing solar power because it is clean, renewable, and cost-effective. In India, schemes like **PM Surya Ghar Yojana** and **PM-KUSUM** are encouraging people to install solar systems in homes, farms, and industries. This means there is a constant need for skilled technicians, engineers, and maintenance professionals.

Job Prospects

- Completing a course in Solar Installation and Operations & Maintenance (O&M) opens doors to many job opportunities, such as:
- **Solar PV Installer** – mounting and connecting solar panels.
- **Solar Technician** – testing, wiring, and ensuring safe operation.

- **O&M Specialist** – cleaning panels, repairing faults, monitoring system performance.
- **Site Supervisor** – managing installation teams and ensuring safety.
- **Solar Project Manager** – planning and executing large projects.
- **Sales and Customer Support Executive** – helping customers understand systems and benefits.
- Since solar energy is expanding in residential, commercial, and industrial sectors, skilled professionals are in demand across cities and rural areas. This creates stable employment opportunities with long-term growth potential.

Self-Employment Opportunities

- Apart from jobs, students can also become entrepreneurs in the solar sector. After gaining practical knowledge from the course, one can:
- Start a small solar installation business for homes, schools, and shops.
- Offer O&M services such as cleaning and repairing solar panels.
- Provide consultancy services for solar design and system sizing.
- Work as a distributor or dealer of solar equipment like panels, inverters, and batteries.
- Develop innovative solar products for rural areas, like solar water pumps or solar streetlights.
- Entrepreneurship in this field is especially attractive because government incentives, subsidies, and financing schemes support solar adoption. This means even small businesses can grow and succeed.

Contribution to Society

Doing this course not only benefits the individual but also the community and the nation. Solar professionals contribute to reducing pollution, fighting climate change, and providing energy solutions to people in remote areas. Students become **green job creators**, making them part of India's sustainable future.

Importance of Digital Literacy, Career Development, and Goal Setting

What is Digital Literacy?

Digital literacy means being able to use digital devices, applications, and online platforms effectively and safely. It includes basic computer knowledge, internet use, handling emails, preparing documents, using mobile apps, and understanding digital security.

In the modern world, digital literacy is no longer optional—it is essential. From applying for jobs online to monitoring solar systems through mobile apps, digital skills play a role in every career.

Why Digital Literacy is Important in Careers

- **Improved Employability** – Companies expect employees to have basic digital knowledge. A technician who can use digital tools will be more valuable.

- **Efficiency** – Digital tools save time. For example, design software helps plan solar systems quickly and accurately.
- **Communication** – Emails, video calls, and online chats are standard in the workplace. Without digital literacy, communication becomes difficult.
- **Access to Opportunities** – Job portals, freelancing platforms, and networking sites provide access to national and international opportunities.
- **Adaptability** – Technology keeps changing. A digitally literate student can easily learn new tools and stay ahead.

Career Development

Career development means growing step by step in one's profession. It is not enough to get the first job; one must keep learning, upgrading skills, and moving towards bigger goals. For example, a student who starts as a Solar PV Installer can, with further learning and experience, become a Project Manager or even start their own company.

Career development requires:

- **Continuous learning** – attending workshops, short courses, or certifications.
- **Networking** – building connections with professionals and industry leaders.
- **Practical experience** – applying classroom learning in real-world projects.
- **Positive attitude** – being open to challenges and feedback.

2.4 Importance of Goal Setting

Setting goals helps students give direction to their efforts. Without goals, learning becomes aimless. Goals should be:

- **Specific** – e.g., “become a solar design engineer in three years.”
- **Measurable** – progress should be visible, like completing a certain number of installations.
- **Achievable** – goals should be realistic.
- **Relevant** – connected to one's career path.
- **Time-bound** – having a clear deadline.
- For example, a student may set a short-term goal of completing the course successfully, a medium-term goal of securing a technician job, and a long-term goal of starting a solar business. Digital skills help track and achieve these goals efficiently.

A **Solar PV Installer** plays a very important role in turning sunlight into electricity. Their main job is to install solar panels on rooftops or ground-mounted structures, connect them with inverters and wiring, and ensure the system works safely and efficiently. They also check the angle and direction of panels to capture maximum sunlight, test the system after installation, and sometimes guide customers on how to use and maintain it. In simple words, a Solar PV Installer makes sure solar systems are set up properly so that homes, schools, and businesses can get clean energy from the sun.

- Along with this role, many **emerging jobs** are coming up in the solar industry due to the rapid growth of renewable energy. Some of these are:
- **Solar Design Engineer** – designs the layout and electrical connections of solar systems.
- **Solar Project Manager** – plans and manages large solar projects.
- **Operations & Maintenance (O&M) Specialist** – ensures the installed systems keep working properly through regular checks and repairs.
- **Solar Sales and Marketing Executive** – explains solar benefits to customers and helps them choose the right system.
- **Solar Entrepreneur** – starts a business in solar installation, servicing, or equipment supply.
- **Remote Monitoring and Data Analyst** – uses software and digital tools to track solar system performance.

These emerging jobs show that the solar industry is not just about installing panels but also about designing, managing, maintaining, and innovating. This makes it a field full of career opportunities for students and young professionals.

At a Solar PV Installation project site, signs, notices, and caution boards are used to keep workers and visitors safe. Every technician, installer, and even visitor needs to understand and follow these instructions carefully. Here's how to interpret them:

Warning Signs (Yellow Triangles with Black Symbols)

- Example: "High Voltage Area" – This means the area has live electrical parts and touching them can cause shock.
- Action: Stay alert, do not touch wires or equipment without proper safety gear.

Mandatory Signs (Blue Circles with White Symbols)

- Example: "Helmet Must Be Worn" – This means it is compulsory to wear a safety helmet in that zone.
- Action: Always follow the instructions; wear a helmet, gloves, or safety shoes as indicated.

Prohibition Signs (Red Circle with a Line Through It)

- Example: "No Smoking" – Smoking or open flames are not allowed near solar panels, batteries, or electrical equipment.
- Action: Avoid restricted activities to prevent accidents.

Information or Notice Boards (Blue or Green Rectangles)

- Example: "First Aid Station Here" or "Emergency Exit" – These give useful information for safety and emergencies.
- Action: Remember these locations so you can respond quickly in case of accidents.

Caution Signs (Yellow with Black Text or Symbol)

- Example: “Slippery Surface” or “Work in Progress” – These warn you of temporary risks.
- Action: Walk carefully, avoid unsafe shortcuts, and be mindful of ongoing work.

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. The main role of a Solar PV Installer is to:
 - a) Manufacture solar panels
 - b) Approve government solar schemes
 - c) Train sales executives
 - d) Install and maintain solar energy systems
2. Which of the following is a technical responsibility of a Solar Panel Installation Technician?
 - a) Marketing solar systems
 - b) Ensuring proper handling of panels and materials
 - c) Conducting financial audits
 - d) Preparing government tenders
3. The O&M Specialist in the solar industry is mainly responsible for:
 - a) Selling solar panels
 - b) Cleaning, checking, and maintaining solar systems
 - c) Designing solar layouts
 - d) Manufacturing inverters
4. Digital literacy is important for solar professionals because:
 - a) It helps monitor system performance and communicate efficiently
 - b) It helps them avoid fieldwork
 - c) It reduces the need for teamwork
 - d) It replaces practical skills

B. Fill in the Blanks

1. A Solar PV Installer converts _____ into usable electricity.
2. Proper installation of solar systems ensures safety, efficiency, and compliance with _____.
3. A Solar Panel Installation Technician must assess the _____ before beginning the installation work.
4. Career development means growing step by step in one's _____.

C. Answer the following Questions

1. Explain the role and technical responsibilities of a Solar Panel Installation Technician.
2. Discuss the emerging job opportunities in the solar industry and explain why this sector is growing rapidly.
3. What is digital literacy, and how does it help students and professionals in the solar energy sector?
4. Describe the importance of goal setting for students pursuing a course in Solar Installation and O&M.

Module 03: Basics of Solar Energy and Electrical Concepts

Solar energy is a renewable source that uses sunlight to create electricity. It is important to understand the basics of solar energy and some key electrical concepts to use this sustainable resource effectively. Solar panels contain photovoltaic (PV) cells that convert sunlight into electricity. When sunlight hits these cells, it makes electrons move, producing an electric current. This process is connected to key electrical principles, including voltage, current, and resistance, which are important for how electric systems work.

This Module helps you to understanding these basic concepts are essential in solar technology. It helps in making informed choices about solar energy solutions and improving energy efficiency.

Session 1: FUNDAMENTALS OF SOLAR ENERGY

Solar energy comes from the sun's radiation and is a renewable and abundant energy source. We can convert sunlight into electricity or heat, which is vital for moving towards sustainable energy solutions.

There are two main types of solar technology: photovoltaic (PV) systems, which convert sunlight directly into electricity, and solar thermal systems, which utilise sunlight for heating purposes. Understanding how these technologies work helps us use them more effectively in our energy systems.

Beyond the technical side, solar energy has environmental benefits. It helps reduce greenhouse gas emissions and decreases our reliance on fossil fuels. Economically, it creates jobs in the solar industry and can lower energy costs for consumers. This highlights how important solar energy is in today's world.

SOLAR ENERGY RESOURCE

Energy potential is the amount of energy a source can provide over a certain time. Estimates show that solar radiation on Earth provides energy equivalent to 2×10^{14} tons of coal every second. Tidal energy is estimated at 3×10^9 tons of coal per year, and geothermal energy at 3×10^{10} tons per year. The solar energy reaching Earth's surface is about 15,000 times the total annual energy needed worldwide.

Many people think solar energy is limitless. This belief is misleading because, although solar radiation is abundant, it is not infinite. The sun loses about 4 million tons of mass every second due to nuclear fusion, which turns hydrogen into helium. This process produces solar radiation. The equation for this reaction is:

The supply of hydrogen is limited, which means solar energy is also finite. Experts estimate that solar energy will last for five billion years. However, the sun has already passed its halfway point in its life cycle. The sun radiates energy as a black body at a

temperature of 6000°C. While solar energy is not truly renewable, we often refer to it as renewable because it will take a very long time to run out.

Solar energy is considered renewable since its supply does not exceed the rate at which we consume it. There are two main ways to use solar energy directly:

- 1) Solar thermal use: Here, a solar collector turns sunlight into heat. This heat can warm water, heat rooms, or help generate electricity using turbines.
- 2) Photovoltaic use: This method converts solar energy directly into electricity.

SOLAR RADIATION

The sun radiates about 3.8×10^{26} Watts of power in all directions. Out of this about **1.7 10^{17} Watts** is received by the Earth. The average solar radiation outside the Earth's atmosphere is 1.35 kW/m² varying from 1kW/m² to 1.40 kW/m² (January- December).

The Earth receives solar energy from the Sun in the form of solar radiation. These radiations comprise ultraviolet, visible, and infrared radiation. The amount of solar radiation that reaches any given location of the Earth is dependent on many factors like geographic location, time of day, season, land scope, and local weather. Because the Earth is round, the sun's rays strike the Earth's surface at different angles (ranging from 0° to 90°). When sun rays are vertical, the Earth's surface gets the maximum possible energy.

The solar radiation that penetrates the Earth's atmosphere and reaches the surface differs in both amount and character from the radiation at the top of the atmosphere. In the first place, part of the radiation is reflected back into space, especially by clouds. Even, the radiation entering the atmosphere is partly absorbed by molecules in the air. The oxygen and Ozone (O₃) layer absorb nearly all the ultraviolet radiation, and water vapour, carbon dioxide absorbs some of the energy in the infrared range. In addition, part of the solar radiation is scattered (i.e., its direction has been changed) by droplets in clouds by atmospheric molecules, and by dust particles.

Based on the above factors, the types of solar radiation are as follows;

i. Beam Solar Radiation

Solar radiation that reaches the Earth's surface directly from the Sun without being absorbed or scattered is called "**direct radiation**" or **beam radiation**. It is the radiation that produces a shadow when interrupted by an opaque object.

ii. Diffuse Solar Radiation

Diffuse radiation is solar radiation received from the sun after its direction has been changed by reflection and scattering by the atmosphere. Because solar radiation is scattered in all directions in the atmosphere, diffuse radiation comes to the Earth from all parts of the sky.

iii. Total Solar Radiation

The total solar radiation received at any point on the Earth's surface is the sum of the beam and diffuse radiation. This is referred to in a general sense as insolation at that point. More specifically, insolation is defined as the total solar radiation energy received on a horizontal surface of a unit area (e.g., 1 m^2) on the ground in unit time (e.g. 1 day). The various types of solar radiation are represented in the sketch in Fig. 3.1.

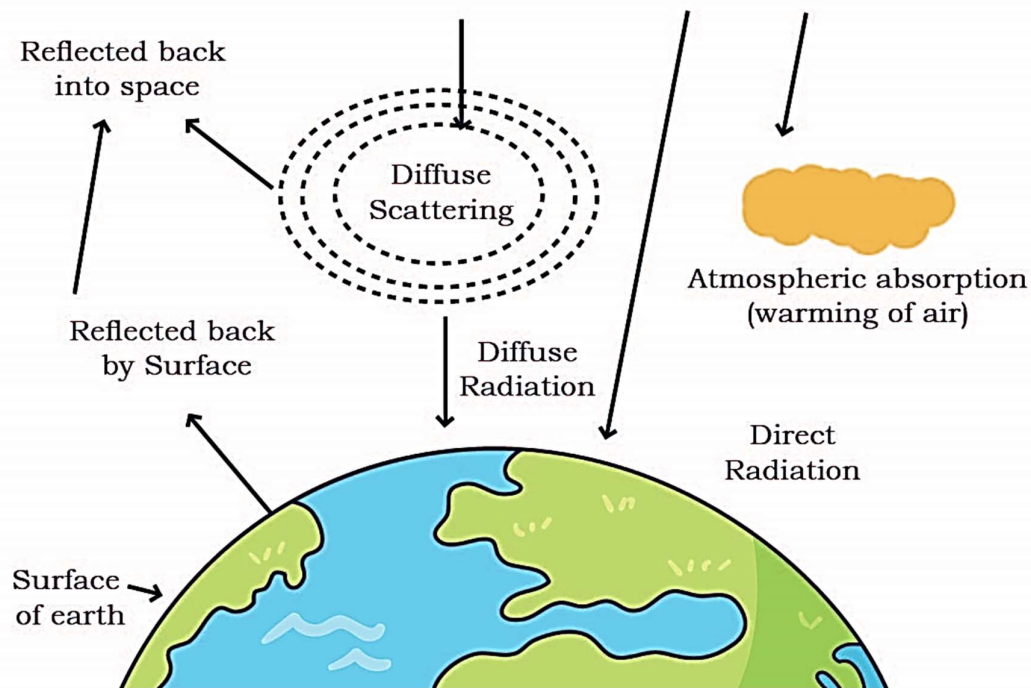


Fig. 3.1: Direct, diffuse and total radiation

The measurement of solar radiation is important due to the growing number of solar heating and cooling applications and the need for accurate solar irradiance data to predict performance. Experimental determination of the energy transferred to a surface by solar radiation required instruments that will measure the heating effect of direct solar radiation and diffuse solar radiation. Measurements are also made of beam radiation, which responds to solar radiation received from a very small portion of the circumsolar sky. A total radiation type of instrument may be used for measuring diffuse radiation alone by shading the sensing element from the sun's direct rays.

The following Two basic types of instruments are employed for solar radiation measurement:

1. **Pyrheliometer**-Pyrheliometer is an instrument that measures beam radiation.
1. **Pyranometer**-Pyranometer is an instrument that measures total or global radiation over a hemispherical field of view.

SOLAR RADIATION AND PRINCIPLES

For all practical purposes the sun can be assumed to be a hot gas with a surface temperature of 6000 °C. This temperature is maintained by nuclear fusion reactions in which hydrogen fuses into helium. The sun radiates in all directions and a small part of the radiation reaches the Earth. When designing and sizing a solar energy system, reliable solar data is required. The most relevant data is the average daily radiation (i.e. the total solar energy received per day per square meter) on a horizontal surface. Global radiation consists of the direct sun radiation and diffuse radiation of the sky. The strength of the radiation of the sun depends highly on the location of the Earth and is directly dependent on the hour of the day. The global radiation or the total radiation is the sum of three components, namely direct radiation, diffuse radiation and reflected radiation:

Direct Radiation

This component propagates in a straight line from the sun and casts shadows. Direct radiation comes in a straight beam and can be focused with a lens or mirrors. On a sunny day, most of the radiation is direct.

Diffuse Radiation

This is the radiation that has been scattered by clouds or dust particles in the atmosphere. Clouds and dust absorb and scatter radiation, reducing the amount that reaches the ground. On a cloudy day, up to 100% of the radiation is diffuse. Together, direct and diffuse radiations are known as global radiation.

Reflected Radiation

This is the radiation reflected by the ground and other physical surroundings. This distinction is very important, since some solar energy systems make use of all incoming light (e.g. PV panels), while others only use direct radiation (e.g. a solar heater with a parabolic dish). Apart from climate and the cloud cover, important factors determining global radiation are the latitude of the site, the time of the year and time of the day. The time of the year and the time of the day influence the length of the sun path through the atmosphere and thus the intensity of the direct sunlight. The intensity is highest when the sun is perpendicular above the solar collector. Knowledge of the sun path from day to day and season to season is also required to optimise the orientation and tilting of the device.

SOLAR ENERGY DATA

Solar Irradiance

Solar irradiance refers to the solar radiation actually striking a surface, or the power received per unit area from the sun. This is measured in watts or kilowatts per square metre.

Insolation

Insolation (incident solar radiation) is a measure of the solar energy received on a specific area over a specific period, normally an hour or a day. It is measured in kWh/m² /day or

MJ/m² /day. By knowing the insolation levels of a particular region we can determine the size of solar collector that is required. An area with poor insolation levels will need a larger collector than an area with high insolation levels.

MEASUREMENT OF SOLAR RADIATION

Solarimeter is a general term used to describe solar radiation measuring devices. Instruments, which measure global radiation, are called pyranometers and pyrliometer is used for measuring direct radiation. Sunshine recorders are used to record the sunshine hours.

HOW SOLAR CELLS CREATE SOLAR POWER

Solar cells are also called photovoltaic cells, which is why the panels that they create are generally called photovoltaics. Each solar cell is responsible for turning sunlight into electricity, and at the most basic level, it happens like this: Sunlight hits the solar cell. The photons in sunlight knock loose electrons in the solar cell, which causes them to move. The solar cell only allows electrons to move in one direction, which causes an electric current. That is called photovoltaic effect

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. The process by which solar cells convert sunlight directly into electricity is known as:
 - a) Solar fusion
 - b) Photovoltaic effect
 - c) Solar conduction
 - d) Radiative conversion

2. Which instrument is used to measure beam (direct) solar radiation?
 - a) Pyranometer
 - b) Pyrliometer
 - c) Solarimeter
 - d) Sunshine recorder

3. The total solar radiation received on a unit area on the Earth's surface is called:
 - a) Insolation
 - b) Reflection
 - c) Diffuse radiation
 - d) Radiative energy

4. On a cloudy day, most of the solar radiation reaching the Earth's surface is:

- a) Direct radiation
- b) Reflected radiation
- c) Diffuse radiation
- d) Concentrated radiation

B. Fill in the Blanks

1. Solar energy comes from the _____ and is a renewable and abundant energy source.
2. The instrument used to measure total or global solar radiation is called a _____.
3. The Sun's surface temperature is approximately _____ degrees Celsius.
4. The measure of solar energy received on a specific area over a specific time period is called _____.

C. Answer the following Questions

1. Explain the different types of solar radiation received on Earth's surface.
2. Describe the measurement of solar radiation and list the instruments used.
3. What is the Photovoltaic Effect, and how do solar cells convert sunlight into electricity?
4. Explain the importance and potential of solar energy as a renewable source.

SESSION 2: FUNDAMENTALS OF ELECTRICITY

Electricity is a natural force that comes into existence whenever there is a flow of electric charge between two components. When working with circuits, there is need for the users to be aware about some of the basic concepts of electricity, otherwise an incorrect connection in a circuit may cause high damage to people and the circuit components.

The main terms associated with electricity are as follows:

- Current
- Voltage
- Power
- Energy

Current

Electric current is the flow of electric charge. We measure it by how much charge moves through a specific area in a certain amount of time.

How does an electrical appliance use current? A switch connects the cell to the appliance, like an LED lamp. This connection creates a complete path for the electric current, known as an electric circuit. If the circuit is broken or if the switch is turned off, the current stops, and the LED will not light up.

We measure electric current in units called amperes (A). To measure the current in a circuit, we use a device called an ammeter, which we connect in series to the circuit we are measuring.

The electric current flows in the circuit from the positive terminal of the cell to the negative terminal, passing through the bulb and the ammeter.

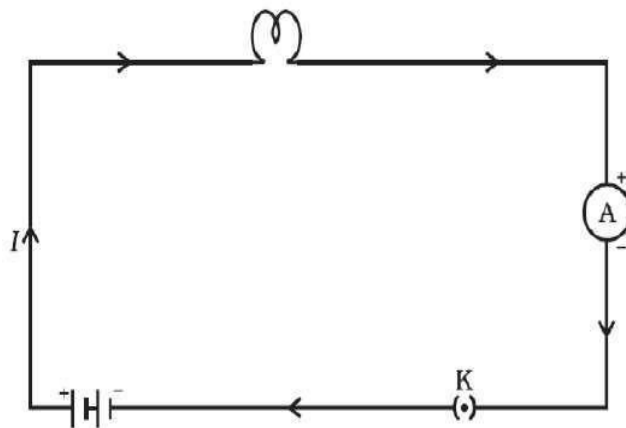


Fig. 3.2: Shows a Simple Electric Circuit that includes a Cell, an LED Bulb, an Ammeter, and a Plug Key.

Direct Current (DC) and Alternating Current (AC)

AC is defined by its frequency. In India, the frequency of Alternating Current (AC) is 50 Hertz, meaning it completes 50 cycles every second. In countries like the USA and Canada, the AC frequency is 60 Hertz.

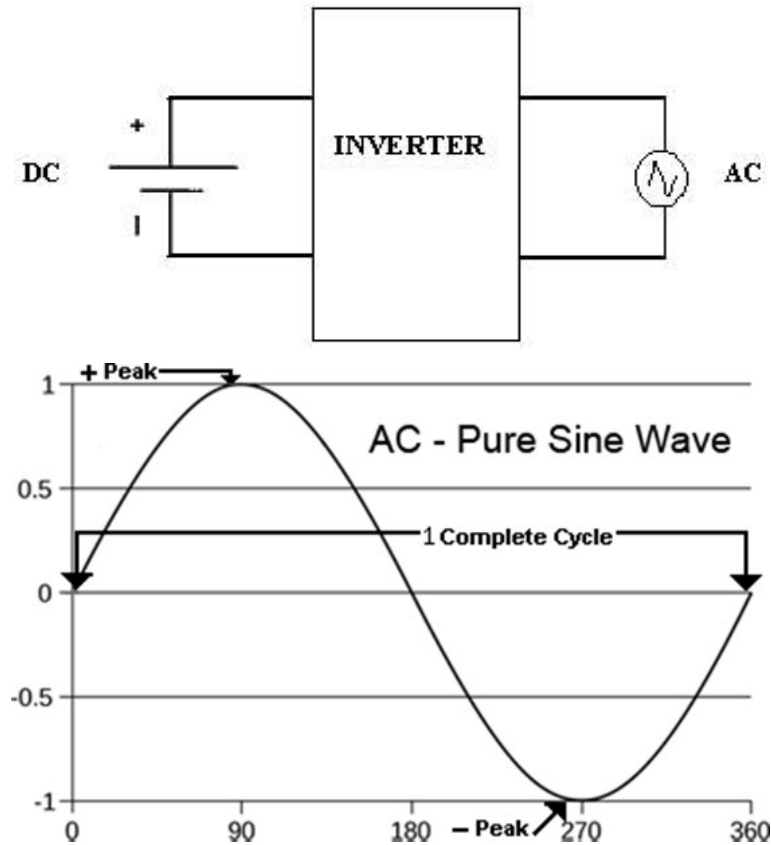


Fig. 3.3: Shows the waveforms and circuits for Alternating Current and Direct Current.

Voltage

What causes electric charge to flow?

In a metal wire, electrons move when there is a difference in electric pressure, known as potential difference, along the wire. This potential difference often comes from a battery, which may have one or more electric cells. We also call potential difference "voltage."

We define the electric potential difference between two points in a circuit with current as the work needed to move one unit of charge from one point to the other. The unit of electric potential difference is the volt (V).

To measure this potential difference, we use a device called a voltmeter. The voltmeter connects in parallel across the two points where we want to measure the difference.

Single Phase and Three Phase Voltage

As mentioned, current flows because of the voltage difference between two points. If the voltage source creates direct current (DC), it is called DC voltage. If the source creates alternating current (AC), it is called AC voltage. AC became more popular in the late 19th century because it was a more cost-effective option compared to DC.

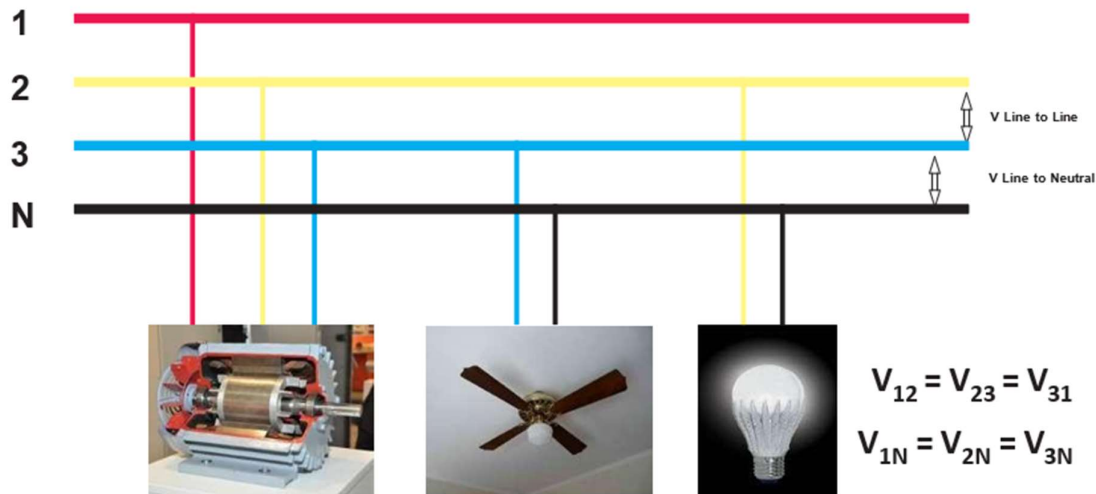


Fig. 3.4: Connection of load to a three-phase supply (Three-phase, four-wire system)

An inverter is a device that converts DC electricity to AC electricity. This conversion is important for using solar energy voltage so it can be fed into the electrical grid.

1. Countries across the world maintain a uniform frequency which is either 50 Hz or 60 Hz. In India, the frequency of AC is 50 Hz.
2. Typical values of Supply Voltage at the final Load points:
3. In the case of three phase supply, the total load connected should be equally distributed between the three phases for a balanced power system. Overloading of one phase may cause under-voltage in the other phases and damage the functioning of connected equipment.
4. Using a 3 Phase power arrangement saves on electrical construction costs by reducing the current requirements, the required wire size, and the size of associated electrical devices. It also reduces energy costs because the lower current reduces the amount of electrical energy lost to resistance (converted to heat).
5. As a matter of fact, the electricity voltage supply we get at homes is AC Supply. All appliances like LED lamps, Fans, Air Conditioners, Heaters and all electrical points draw current (or energy) from AC Voltage supply.

Power

When electricity flows in an electrical circuit, it results in some work done. For example, when electricity flows in a fan, the blades of the fan rotate and when the electricity flows in a refrigerator, it cools things inside. Thus, when electricity flows through an appliance, it results in some work done.

Electrical power is the rate at which an electric circuit transfers electrical energy. Electrical power is similar to mechanical power and can be considered as the rate at which electrical work is done. It is measured in watts (one joule per second) and represented as P. Electric power in watts is also called wattage. Consider the formula:

$$P = \text{work done per unit time} = VQ/t = VI$$

Where P is the electric power in watts determined when an electric current represented by I in amperes with a charge Q in coulombs passes through an electrical potential difference denoted by V in time t seconds. Electric power is produced by electric generators in an electric power generation unit called a grid. This power is further supplied to residential and commercial location. It can also be produced by other sources such as electric batteries. The energy delivered and consumed by electric utilities is measured using an electricity meter.

Energy

If the electrical power is the rate or speed of work done, then electrical energy is the total amount of work done in a given time period. It is product of power of electrical appliance and duration of its usage. Consider the following equation to determine electrical energy:

$$\begin{aligned} \text{Electrical Energy (E)} &= \text{Power (P)} \times \text{Duration of Energy usage (T)} \\ &= \text{Power (Watt)} \times \text{Time (hour)} \end{aligned}$$

$$E \text{ (Wh)} = P \text{ (W)} \times T \text{ (h)}$$

$$\text{Power} = \text{Energy} / \text{Time}$$

Energy and Its Units

Energy as quantity can be represented in many units like calories, Horsepower, Kilowatt-hour (kWh), and Electron volts (eV), one of the basic units of energy is called joule (J).

One joule of energy is equal to work done by applying a force of 1Newton through a distance of one meter. In terms of electrical energy is equal to energy using up to 1 watt of power running for 1 second.

$$1 \text{ watt (W)} = 1 \text{ joule/second (J/s)}$$

For instance, energy consumes by a 10-watt bulb in one hour is 36000 joules.

Unit conversion:

Different energy units are related to each other through different constant below table gives the relationship between different energy units.

$$1\text{KJ (Kilo Joule)} = 1000\text{J}$$

$$1\text{MJ (Mega Joule)} = 1000\text{KJ} = 1000000\text{J}$$

$$1\text{GJ (Giga Joule)} = 1000\text{MJ} = 1000000000\text{J}$$

Various units of electrical energy:

In this manual, we are mainly concerned with electrical energy.

$$\text{Energy (Joule)} = \text{Power (Watt)} \times \text{Time (Second)}$$

$$1 \text{ Joule} = 1\text{W} \times 1\text{s}$$

$$1\text{KW} = 1000 \text{ Watt}$$

$$1\text{hour (h)} = 3600 \text{ seconds (sec)}$$

Thus,

$$1 \text{ Kw} \times \text{h} = 1000\text{W} \times 3600\text{sec} = 3600000\text{Ws} = 3600000\text{J} = 3600\text{KJ}$$

$$1 \text{ KWh Energy} = 1 \text{ Unit of electricity}$$

ENERGY UNITS AND THEIR CONVERSION

ENERGY UNIT	EQUIVALENT ENERGY UNIT
1 JOULE (J)	1 Ws (watt second)
1 watt-hour (Wh)	3600 Ws = 3600 J
1 kilo watt hour (KWH)	3600 KJ = 3600000 J
1 kilo Joule (KJ)	1000 J
1 mega Joule (MJ)	278 KWh
1 Giga Joule (GJ)	1000 MJ

Ohm's Law

The relationship between voltage and current can be simply explained by Ohm's Law.

Activity:

1. Set up a circuit as shown in figure, consisting of a nichrome wire XY of length, say 0.5 m, an ammeter, a voltmeter and four cells of 1.5 V each. (Nichrome is an alloy of nickel, chromium, manganese, and iron metals.)

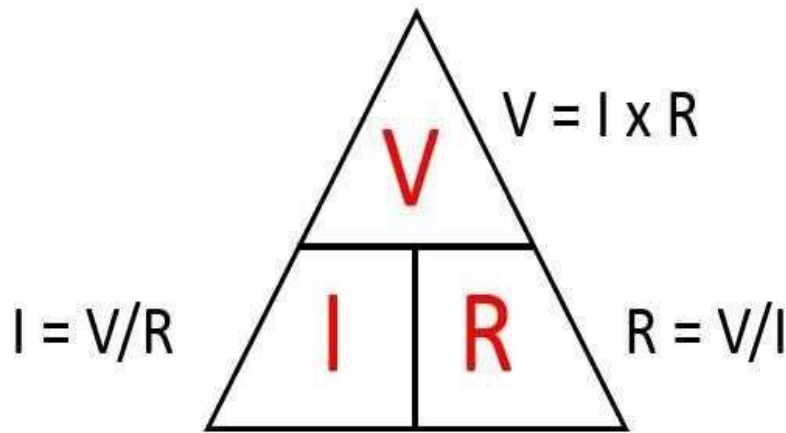


Fig. 3.5: Ohm's triangle

Table 3.1 Observation Table to calculate V-I Ratio

S.No.	Number of cells used in the circuit	Current through the Nichrome wire, I (ampere)	Potential difference across the nichrome wire, V (volt)	V/I (Voltage/Ampere)
1.				
2.				
3.				

- First use only one cell as the source in the circuit. Note the reading in the ammeter I, for the current and reading of the voltmeter V for the potential difference across the nichrome wire XY in the circuit. Tabulate them in the Table given.
- Next connect two cells in the circuit and note the respective readings of the ammeter and voltmeter for the values of current through the nichrome wire and potential difference across the nichrome wire.
- Repeat the above steps using three cells and then four cells in the circuit separately.
- Calculate the ratio of V to I for each pair of potential difference V and current I.
- Plot a graph between V and I, and observe the nature of the graph.

It is found that approximately the same value for V/I is obtained in each case. Thus the V-I graph is a straight line that passes through the origin of the graph, as shown in figure above. Thus, V/I is a constant ratio.

The potential difference, V, across the ends of a given metallic wire in an electric circuit is directly proportional to the current flowing through it, provided its temperature remains the same. This is called Ohm's law.

R is a constant for the given metallic wire at a given temperature and is called its resistance. Ohm's triangle can be used to calculate voltage, current or resistance in a circuit for standard conditions.

Resistance

Resistance is the property of a conductor to resist the flow of charges through it. Its SI unit is ohm, represented by the Greek letter ' Ω '.

According to Ohm's Law, $R=V/I$ and conversely, $I=V/R$

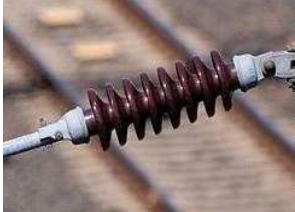
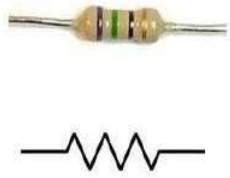
It can be observed that the current through a resistor is inversely proportional to its resistance. If the resistance is doubled the current gets halved. In many practical cases it is necessary to increase or decrease the current in an electric circuit. A component used to regulate current without changing the voltage source is called variable resistance. In an electric circuit, a device called rheostat is often used to change the resistance in the circuit.

Certain components offer an easy path for the flow of electric current while the others resist the flow.

The motion of electrons in an electric circuit constitutes an electric current. The electrons, however, are not completely free to move within a conductor. They are restrained by the attraction of the atoms among which they move. Thus, motion of electrons through a conductor is retarded by its resistance.

- A component of a given size that offers a low resistance is a good conductor.
- A conductor having some appreciable resistance is called a resistor.
- A component of identical size that offers a higher resistance is a poor conductor.

An insulator of the same size offers even higher resistance.

		
Fig. 3.6: Good conductor - copper wire	Fig. 3.7: Insulator - ceramic	Fig. 3.8: Resistor (with symbol)

Connection in Series and Parallel

Combination of Resistors

In various electrical gadgets, we often use resistors in various combinations. We now therefore intend to see how Ohm's law can be applied to combinations of resistors. There are two methods of joining the resistors together – Series and Parallel.

Table Voltage across and current flowing through a system of resistors

For 'n' Lamps connected across a Source	Series	Parallel
Voltage	Divided as per Resistance of Individual Loads	Same across all Loads
Current	Same flowing through all Loads	Divided as per Resistance of Individual Loads

Series

In a series combination of resistors, the current is the same in every part of the circuit or the same current through each resistor.

Secondly, the total potential difference across a combination of resistors in series is equal to the sum of potential differences across the individual resistors.

The individual voltages can be calculated as follows:

- Calculate Total/Effective resistance

$$R_t = R_1 + R_2 + R_3 + \dots + R_n$$

- Calculate the Current flowing through circuit

$$I_t = \frac{V_s}{R_t}$$

$$\text{Also, } I_t = I_1 = I_2 = I_3 = \dots = I_n$$

- Calculate Voltage through each element/LED lamp:

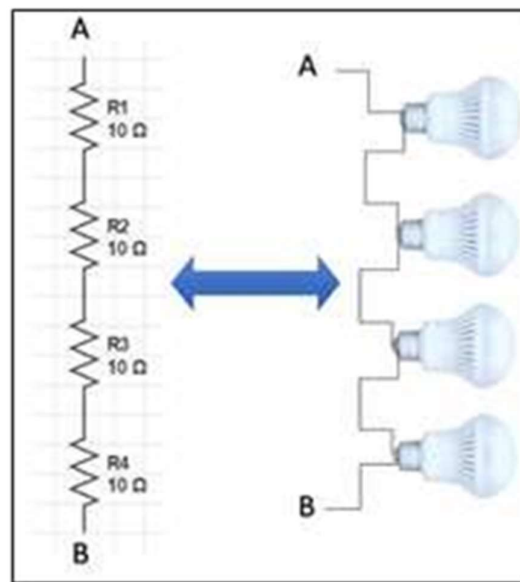


Fig. 3.9: Series connected LED lamps

$$V_n = I_n \times R_n$$

Table 3.3 Voltage and Current for elements connected in series

Voltage is added in a series branch	$V_t = V_1 + V_2 + V_3 + \dots + V_n$
Current remains same across the series branch	$I_t = I_1 = I_2 = I_3 = \dots = I_n$

PARALLEL

Now, let us consider the arrangement of three resistors joined in parallel with a combination of cells (or a battery).

It is observed that the total current I is equal to the sum of the separate currents through each branch of the combination.

The individual current through elements can be calculated as follows:

- Calculate Total/Effective resistance

$$1/R_t = 1/R_1 + 1/R_2 + 1/R_3 + \dots + 1/R_n$$

- Voltage remains the same as Source V_s (across terminals A-B),

$$V_s = V_1 = V_2 = V_3 = \dots = V_n$$

- Calculate current through individual element as follows:

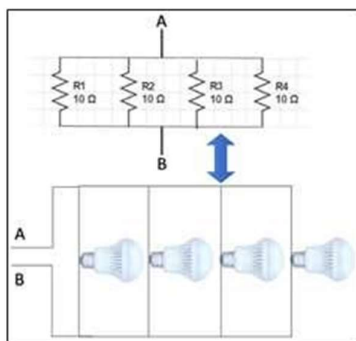


Fig. 3.10: Parallel connected LED lamps

$$I_n = V_s / R_n$$

Table 3.4 Voltage and Current for elements connected in Parallel

Current is added in a parallel branch	$V_t = V_1 = V_2 = V_3 = \dots = V_n$
Voltage remains the same across the parallel branch	$I_t = I_1 + I_2 + I_3 + \dots + I_n$

- We have seen that in a series circuit, the current is constant throughout the electric circuit. Thus, it is obviously impracticable to connect an electric bulb and an electric heater in series, because they need currents of widely different values to

operate properly.

2. Another major disadvantage of a series circuit is that when one component fails the circuit is broken and none of the components works.
3. On the other hand, a parallel circuit divides the current through the electrical gadgets. The total resistance in a parallel circuit is decreased. This is helpful particularly when each gadget has different resistance and requires different current to operate properly.
4. All household circuits and appliances are connected in Parallel. Hence, they all operate at the same voltage. The total current requirement of a house is addition of individual current required for each appliance.

Activity

1. Set up a simple circuit with a battery, bulb, switch, and ammeter.
2. Observe the current flow when the switch is on and off.
3. Draw the circuit diagram and label each component.
4. Measure and record current and voltage readings.

Check Your Progress

A. Multiple Choice Questions (MCQs)

1. The unit of electric current is:
 - a) Volt (V)
 - b) Ohm (Ω)
 - c) Ampere (A)
 - d) Watt (W)
2. Which device is used to measure voltage in a circuit?
 - a) Ammeter
 - b) Rheostat
 - c) Voltmeter
 - d) Galvanometer
3. In India, the frequency of alternating current (AC) is:
 - a) 40 Hz
 - b) 50 Hz
 - c) 60 Hz
 - d) 100 Hz
4. The relationship between voltage, current, and resistance is given by:
 - a) $P = V/I$
 - b) $R = V/I$

c) $V = IR^2$

d) $I = P/V$

5. The electricity we receive at home is:

- a) DC Supply
- b) AC Supply
- c) Mixed Supply
- d) Constant Voltage Supply

B. Fill in the Blanks

1. The flow of electric charge is known as _____.
2. Electric potential difference is also known as _____.
3. The SI unit of resistance is _____.
4. 1 kilowatt-hour (kWh) of energy is equal to _____ joules.
5. The device used to convert DC to AC is called an _____.

C. Answer the following Questions

1. What is the difference between AC and DC current?
2. Define Ohm's Law and write its formula.
3. What is resistance? On what factors does it depend?
4. Write the formula for electrical power and its unit.
5. Explain the relationship between Voltage, Current, and Resistance with the help of Ohm's Law experiment.
6. Differentiate between Series and Parallel connections of resistors.
7. Define Electrical Energy and derive the formula for 1 kWh.
8. Explain the advantages of using a 3-phase power supply.

SESSION 3: TERMINOLOGY AND DEFINITIONS EXPLAINED

1. **Irradiance (W/m^2):** Irradiance is the solar energy that reaches the Earth's surface per unit area.
2. **Insolation or Irradiation (Wh/m^2):** Insolation or irradiation is the total solar energy received by the Earth's surface over a specific time period.
3. **Solar Constant:** The solar constant is the amount of energy that hits a 1 m^2 area of the Earth's atmosphere each second, when the Earth is at its average distance from the sun. This value is $1367 \text{ W}/\text{m}^2$.
4. **Direct Normal Irradiance (W/m^2):** This is the solar radiation that reaches the Earth's surface without being absorbed or scattered.
5. **Beam Radiation (W/m^2):** This is the cosine component of the Direct Normal Irradiance.

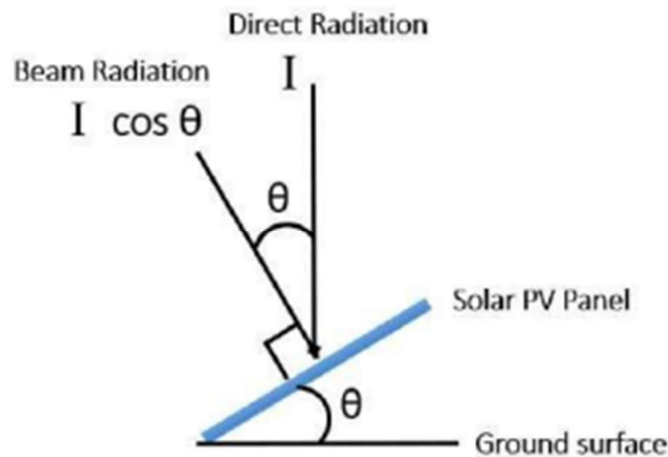


Fig. 3.11: The cosine component of direct radiation is called 'Beam Radiation'

6. **Diffused horizontal irradiance (w/m^2):** This is the total amount of scattered radiation.
7. **Albedo radiation (w/m^2):** This is the part of diffused and direct radiation that gets reflected by the Earth and other objects.
8. **Global horizontal irradiance (w/m^2):** This is the total of diffused radiation, direct radiation, and albedo radiation.

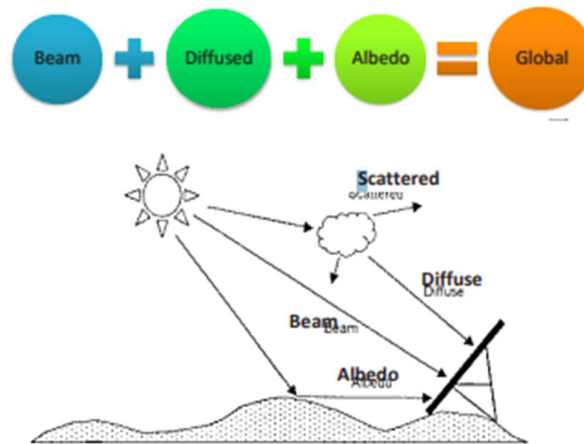


Fig. 3.12: Global horizontal radiance is the total of all radiation (beam, diffuse and albedo) falling on the solar PV panel

9. **Irradiance at tilted surface (W/m^2):** It is defined as the radiation falling on any tilted surface.
10. **Air mass:** The Air Mass is the path length that light takes through the atmosphere, normalised to the shortest possible path length (that is, when the sun is directly overhead). The Air Mass measures the reduction in the power of light as it passes through the atmosphere and is absorbed by air and dust. In simple terms, it is defined as the distance travelled by solar radiation in Earth's atmosphere.

$$AM = 1 / \cos \theta$$

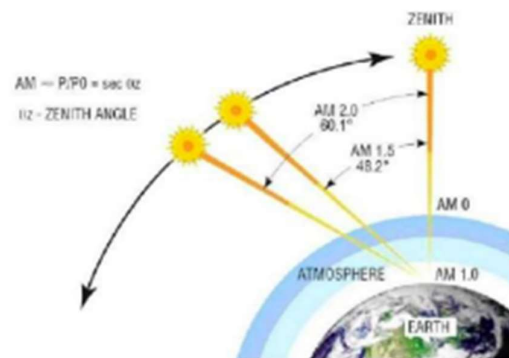


Fig. 3.13: Air Mass

11. **Latitude angle (or angle of latitude):** It is defined as the angle drawn between the lines joining the centre of Earth to the site with its projection on the equatorial plane. For India, it is considered to be positive. It is denoted by ' ϕ '.
12. **Solar hour angle:** It is defined as the angular measurement of time. Conventionally, it is taken as positive in the morning and negative in the afternoon. It is denoted by ' ω '.
13. **Declination angle:** It is defined as the angle drawn between the lines joining the

centre of earth to the centre of sun having its projection on the equatorial plane of the earth. It is denoted by ' δ '.

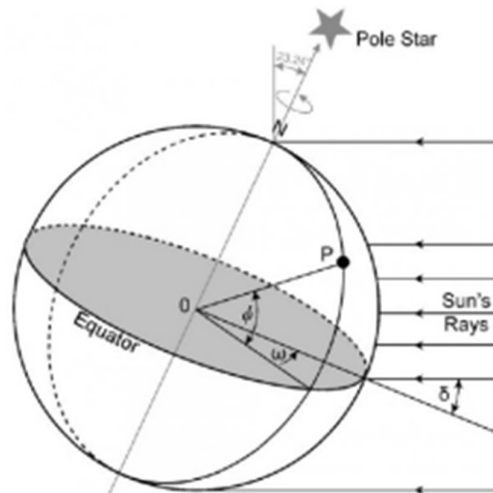


Fig. 3.14: Declination angle

14. **Equinox:** Literally "equal night", a day when the number of hours of daylight equals the number of hours of night. The vernal equinox, usually March 21, signals the onset of spring, while the autumnal equinox, usually September 21, signals the onset of autumn.
15. **Solstice:** A day when the sun is at the highest point in the sky (summer solstice, 21 June) or at the lowest point in the sky (winter solstice, 22 December).
16. **Azimuth angle:** It is defined as the angle between the sun's rays and true South. A positive solar azimuth angle indicates a position East of South, and a negative azimuth angle indicates West of South.

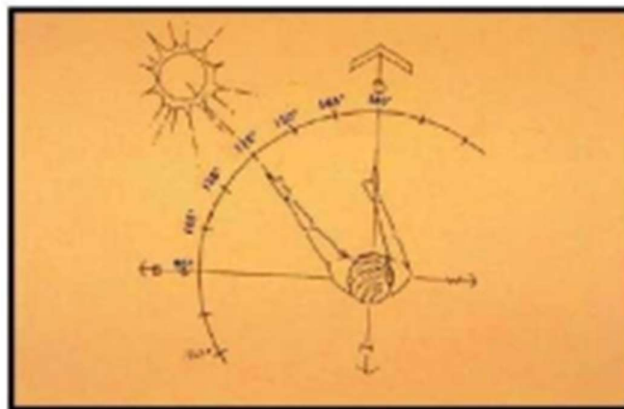


Fig. 3.15: Sun azimuth

17. **Zenith angle:** It is defined as the angle drawn between the sun and the vertical.

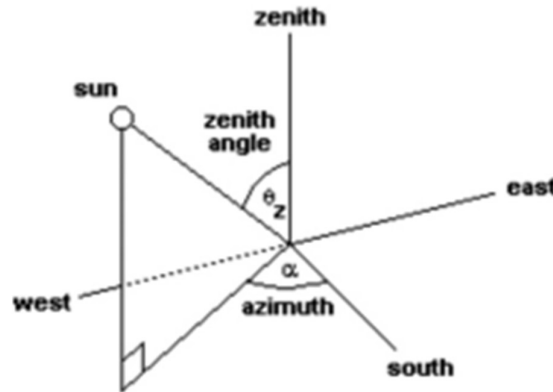


Fig. 3.16: Zenith angle and azimuth angle

Solar Radiation and Sun Path Diagram

The path followed by the sun across the sky from sunrise to sunset can be drawn for any situation. It depends on:

1. The location of observation on earth; and
2. The time of the year

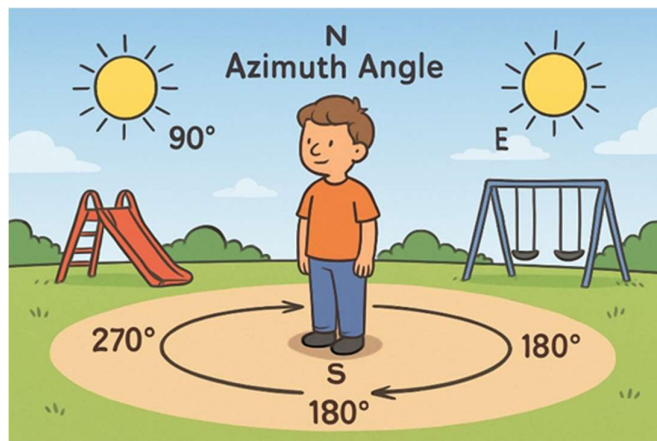
Imagine the sun is playing a game of hide and seek in the sky every day. It rises from one side, climbs up, travels across the sky, and then goes down on the other side. But here's the twist — it never takes the same path every day! The path changes with the seasons.

So, how do we keep track of where the sun will be at any time? That's where the Sun Path Diagram comes in — it's like a treasure map of the sky!

Let's break it down:

1. Azimuth Angle – The Sun's Direction

Think of standing in a playground, facing north. Now, imagine turning in a full circle like a compass. The Azimuth angle tells you which direction to look to find the sun — east, south, west, etc.



- If the Azimuth angle is 90°, the sun is in the east.
- If it's 180°, it's directly south.
- If it's 270°, the sun is in the west.

It's like asking: "Which way should I turn to see the sun?"

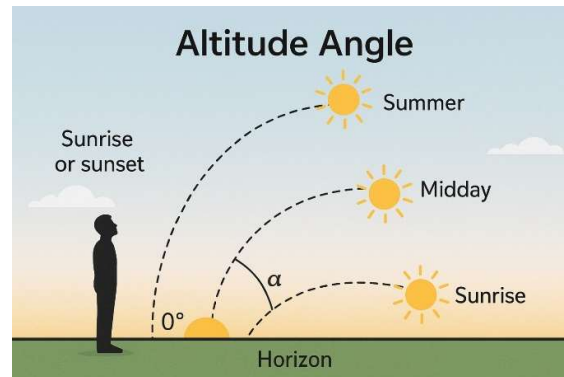
2. Sun Height – How High is the Sun?

Now that you know which direction to look, the next question is: how high up in the sky is the sun?

That's where Sun Height (also called Altitude Angle) comes in. It tells you how far above the horizon the sun is.

- At sunrise or sunset, the sun is low (almost 0°).
- At midday, it's higher up.
- In summer, it goes much higher than in winter.

It's like asking: "Do I look straight ahead, or do I tilt my head up to see the sun?"

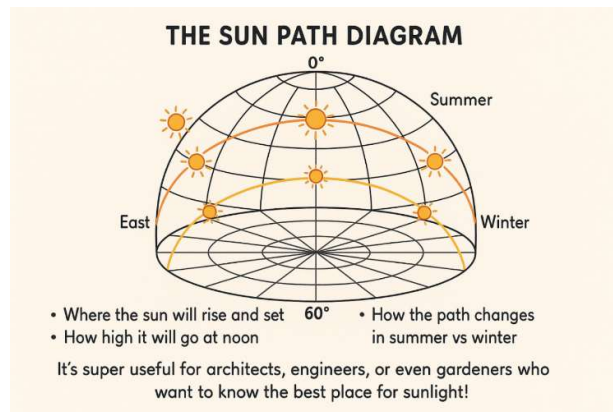


The Sun Path Diagram

The Sun Path Diagram is a special drawing that shows the sun's journey through the sky for every day of the year. You can find out:

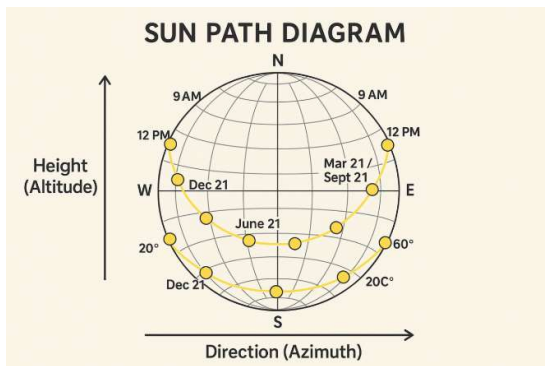
- Where the sun will rise and set
- How high it will go at noon
- How the path changes in summer vs winter

It's super useful for architects, engineers, or even gardeners who want to know the best place for sunlight!



Think of it like this:

The Sun Path Diagram is the GPS for the sun; it tells us where the sun will be at any time of day, any day of the year, using just two clues:



🌐 Direction (Azimuth) and ▲ Height (Altitude).

Tilt Angle and the Cosine Effect

Imagine you are standing outside on a sunny day holding an **umbrella**.

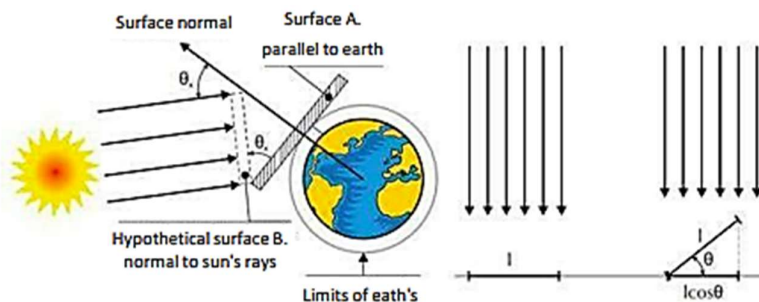
If you hold the umbrella straight up (flat, horizontal), the sunlight falls directly on it when the sun is high in the sky. The umbrella collects maximum sunlight. But if you tilt the umbrella, the sunlight starts hitting at an angle. Now the same amount of sunlight is spread over a larger area, so it feels weaker.

This is exactly what happens with solar panels. When the sun is directly overhead, the sunlight falls straight on the panel, and we get the maximum solar power. But when the sun is lower in the sky, the sunlight hits at an angle. The effective sunlight on the panel becomes less. This is called the cosine effect, because the strength of sunlight depends on the cosine of the angle between the sunlight and the panel's surface.

The Role of Tilt Angle

To get the best energy output, we don't keep solar panels flat all the time. Instead, we tilt them so that they can face the sun more directly during the year.

- As a rule of thumb, the best tilt angle $\approx$ Latitude of your location. (For example, if your city is at 25° latitude, tilt your solar panel at about 25°).
- However, for perfect results, engineers use computer software like PVsyst or PVSOL. These tools calculate the exact optimal tilt by considering seasons, weather, and shading



Tilt Angle and the Cosine Effect



Fig. 3.17: Optimal Tilt Angle

To illustrate, India lies between the latitudes: $8^{\circ}0'0''$ N to $36^{\circ}0'0''$ N For example, as Delhi's latitude is 28.60° N , the tilt angle of the solar panel will be:

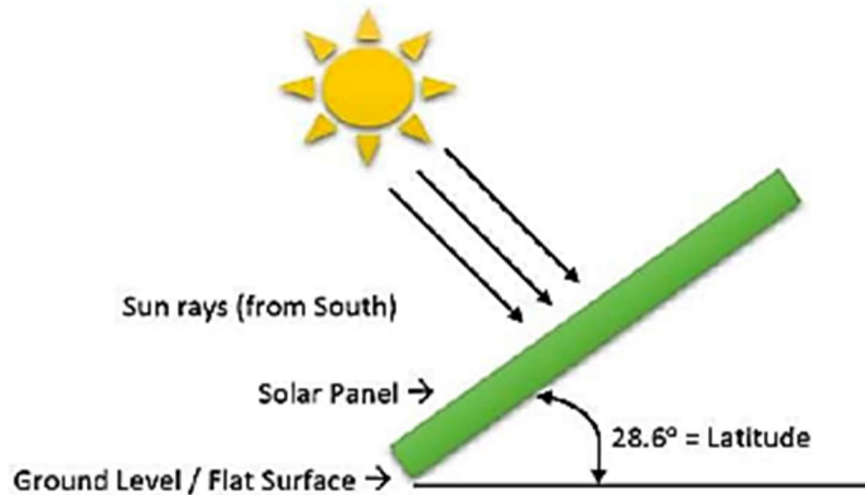


Fig. 3.17: Latitude angle

Know Your Progress

A. Multiple Choice Questions

1. The total solar energy received by the Earth's surface over a period of time is called:
 - a) Irradiance
 - b) Insolation
 - c) Albedo radiation
 - d) Air mass
2. The Air Mass (AM) of sunlight when the sun is directly overhead is:
 - a) AM 0
 - b) AM 1
 - c) AM 2
 - d) AM ∞
3. The angle between the sun's rays and the vertical is called:
 - a) Latitude angle
 - b) Declination angle
 - c) Zenith angle

d) Azimuth angle

4. The day when the sun is at its highest point in the sky is called:

- a) Winter solstice
- b) Equinox
- c) Summer solstice
- d) Declination

B. Fill in the Blanks

- 1. The amount of solar energy received per unit area is called _____.
- 2. The solar constant is approximately _____ W/m^2 .
- 3. The azimuth angle is measured with respect to _____ direction.
- 4. The tilt angle of a solar panel is generally equal to the _____ of the location.

C. Short Answer Type Questions

- 1. Define "Direct Normal Irradiance" and "Diffuse Horizontal Irradiance."
- 2. What is the difference between Equinox and Solstice?
- 3. What is the cosine effect in solar energy?
- 4. Explain the term "Air Mass."
- 5. Define and explain the following solar radiation terms:
 - i. Irradiance
 - ii. Insolation
 - iii. Albedo Radiation
 - iv. Global Horizontal Irradiance
- 6. Explain the importance of Tilt Angle and how it affects solar power generation.
- 7. Describe the Sun Path Diagram and its applications.
- 8. Differentiate between Azimuth Angle and Zenith Angle with examples.

MODULE 4: SITE SURVEY FOR INSTALLATION OF SOLAR PV SYSTEM

Before installing a Solar PV (Photovoltaic) System, it is very important to check whether the location is suitable for solar power generation or not. This careful study of the site is known as a Site Survey. Just like a doctor examines a patient before giving treatment, engineers or technicians must survey the site before setting up solar panels. During a site survey, they observe and record important details such as how much sunlight the area receives, whether there are any shadows from trees or nearby buildings, the direction and tilt of the roof, the strength of the structure, and where other components like the inverter and batteries can be safely placed.

A proper site survey ensures that the solar system produces maximum electricity, operates safely, and lasts for a long time. Without it, panels might be installed in shaded areas or on weak roofs, reducing the system's efficiency and safety. Therefore, the site survey is considered the first and most essential step in any solar installation project.

In this module, you will learn how to observe and measure sunlight availability, identify obstacles causing shading, check the strength and direction of the roof or ground, and collect the necessary data for designing a solar PV system.

Session 1: Understanding Customer Needs in Solar PV Installation

Imagine you are a Solar Detective, and your mission is to make the customer happy by giving them the perfect solar system. To do that, you need to truly understand what they need. When it comes to a PV system, every customer has three main questions hiding behind their needs:

1. How much power do their devices need?
 - This is like counting how many bulbs, fans, and gadgets they use. You need to know their “energy appetite” so the system can feed all their devices without any hiccups.
2. How much backup energy is needed?
 - Imagine a blackout. Will their fridge, lights, or TV keep running? Backup energy ensures the lights stay on when the grid goes off. Think of it as having a solar safety net.
3. Where can the solar system fit?
 - You need to scout the building for the best spot: rooftop, balcony, or open yard. The goal is maximum sunlight for maximum energy!

To answer these questions, solar installers use smart methods:

- Interviews & Questions: Talk to the customer about their daily electricity use and expectations.
- Observation: Walk around their space to check rooftops, shading, and orientation.
- Data Analysis: Check past electricity bills to understand their actual consumption.

By combining these methods, you uncover the full picture and design a system that fits the customer perfectly.

Importance of Assessing Site Conditions for Safe Solar PV Installation

Before we install a solar PV system, it is not just about putting panels on a roof or ground. We must carefully check the site conditions. This ensures the system works well, lasts long, and is completely safe.

Imagine you are about to build your dream solar PV system. Sounds exciting, right? But before we start fixing shiny panels on a roof or the ground, we need to pause and look closely at the site because the success and safety of the whole system depend on it.

First, think of the roof or ground as the backbone. If it's weak, cracked, or damaged, it may not handle the weight of panels, mounts, and even strong winds. A shaky base could mean leaks, collapses, or expensive repairs later so checking strength is step one. Next comes the sunlight factor. Solar panels love the sun, but shadows from trees, poles, or nearby buildings are like bullies that steal away power. A good site check ensures the panels soak up maximum sunlight and give maximum electricity.

Then there's the tilt and orientation like adjusting your chair to face the teacher. If the panels face the right direction (usually south in India) and are tilted at the right angle, they "listen" to the sun all year long. But nature has its own tests. Strong winds and heavy rain can threaten the panels. That's why engineers use sturdy mounts, clamps, and fasteners, so the panels don't go flying like kites in a storm.

We also need to think about safety and access. Imagine installing panels without enough space to clean them, check wiring, or fix a fault it would be a nightmare. Proper spacing avoids overheating and keeps both people and panels safe. For systems on the ground, the soil matters too. If it's too soft or sandy, the mounting structures might sink or tilt. Soil testing makes sure the foundation is strong and stable.

Finally, electrical safety is a must. Space should be planned for neat cabling, earthing, and inverter placement. A messy setup could cause overheating, shocks, or even fires. So, assessing site conditions is like a health check-up for solar systems. It keeps the panels safe, the electricity flowing, and ensures the sun's gift is used to its fullest.

Identifying and Listing the Load for a Solar PV System

Before we set up a solar PV system, the first big question is: *What do we actually want to run on solar power?* This step is called identifying the load, and it's like making a shopping

list before going to the market. If we don't know what appliances we need, we can't decide how big our solar system should be.

The process is simple. First, make a list of all the appliances you want to connect—like lights, fans, TV, or maybe even an air conditioner. Next, check their power rating (written on the back label in watts). Then, estimate how many hours a day each one will run. Finally, multiply power (W) $\times$ hours (h) to get the energy used per day (Wh). Adding them all up gives the total energy demand.

3. Example Load List (for a small home system)

Appliance	Power (W)	Hours per day	Energy (Wh/day)
4 LED Bulbs	$10 \times 4 = 40$ W	5 h	200 Wh
2 Ceiling Fans	$60 \times 2 = 120$ W	6 h	720 Wh
1 TV	100 W	4 h	400 Wh
1 Laptop	50 W	3 h	150 Wh
1 Mobile Charger	10 W	4 h	40 Wh
Total			1,510 Wh $\approx$ 1.5 kWh/day

This step is super important because it tells us:

- How many solar panels we need.
- How big should the battery be for backup?
- What size of inverter is safe to handle the load.
- And most importantly, it prevents overloading, making sure the system runs smoothly and lasts longer.

So, identifying and listing loads is like creating a blueprint of your solar lifestyle it ensures the sun's energy is used wisely and efficiently

What is a Load Profile?

A load profile is like a graph or record that shows how much electricity is used in a home, building, or industry at different times of the day.

Think of a load profile as the daily “story” of how we use electricity. It's like a diary or a graph that shows *when* and *how much* electricity a home, building, or industry consumes at different times of the day.

For example, in a typical home:

- **Morning (6–9 AM):** The demand shoots up because people switch on lights, fans, geysers, mixers, and TVs.
- **Afternoon (10 AM–4 PM):** The house is quieter, and only essentials like the fridge and maybe a fan are running, so the demand drops.
- **Evening (6–10 PM):** Once everyone is back, demand rises again with lights, fans, TV, and kitchen appliances.
- **Night (after 11 PM):** The load becomes very low—usually just the fridge or a few devices left on.

If we plot this information on a graph (time on the x-axis and power on the y-axis), the curve we get is called the load profile. It's basically the *pattern of electricity use* over time whether hourly, daily, monthly, or even yearly.

But why does this matter for solar PV systems? Because knowing the load profile helps us design the system better:

1. We can size the number of solar panels and batteries correctly.
2. We can match solar energy production with the times when demand is highest.
3. We save money by avoiding systems that are too small (causing shortages) or too big (wasting resources).
4. We make sure important appliances—like lights, fans, or even medical equipment—always get reliable power.

So, a load profile is like the fingerprint of electricity usage. Once we know it, we can plan a solar PV system that perfectly fits our lifestyle.

Importance of Engaging with Customers in Energy Solutions

When we talk about installing solar PV systems or innovative energy solutions, one very important step is to talk to the customer and understand their needs and budget.

When we plan to install a solar PV system or introduce any innovative energy solution, the first step is not fixing panels or wiring—it's actually talking to the customer. Why? Because every customer has different needs and a different budget. Some may only want solar for lights and fans, while others may dream of running an entire office or factory on solar. By listening carefully, we understand what they want, what they can afford, and then design the system that fits best. This is called customer engagement, and it builds both satisfaction and trust.

Now, here's where innovative solutions open exciting opportunities. Not all customers can afford heavy construction or complex installations. In such cases, we can suggest:

- **Plug and Play Solutions** – Think of these like ready-to-use solar kits. They are simple, portable, and perfect for basic needs like lighting and charging mobiles. No big construction—just unpack, connect, and use.
- **Behind the Meter Solutions** – These are installed on the customer's side of the electricity meter. For example, rooftop solar panels that directly reduce the home's electricity bill. They are flexible, don't need massive civil work, and are easier to adopt.

Why does all this matter? Because it allows solar to reach more people—even those with limited budgets or space. It makes renewable energy affordable, user-friendly, and less disruptive to daily life. And most importantly, it helps us move faster towards a clean, green future while keeping customers happy.

SYSTEM SIZING

System sizing is one of the most important steps in designing a solar PV system. It means deciding the correct size of solar panels, inverter, and batteries so that the system can meet the energy demand of a customer without being too small (which causes power shortages) or too large (which wastes money). Proper system sizing ensures efficiency, reliability, safety, and long life of the system.

To calculate system size, we use some **basic mathematical tools**. The steps are:

1. **Find total daily energy demand (E):**
2. Add up the energy used by all appliances.

Formula:

$$E = \text{Power (W)} \times \text{Hours of use (h)}$$

Example: If 4 LED bulbs of 10 W each run for 5 hours,

$$E = 40 \text{ W} \times 5 \text{ h} = 200 \text{ Wh}$$

3. **Add up all loads:** Suppose a small house uses 200 Wh (LED bulbs) + 720 Wh (fans) + 400 Wh (TV) + 150 Wh (laptop) + 40 Wh (mobile) = **1,510 Wh $\approx$ 1.5 kWh/day**.
4. **Size the solar panels:** If one solar panel generates about 250 Wh/day (depending on sun hours), then

$$\text{Number of panels} = 1,510 / 250 = 6$$
5. **Battery sizing:** If backup is needed for 1 day, battery storage should be about 1.5 kWh. With a 12 V battery, the capacity required is:

$$\text{Ah} = 1500 / 12 \approx 125 \text{ Ah}$$

6. **Inverter sizing:** The inverter must handle the peak load (sum of all appliances running together). For example, if the maximum demand is 1,000 W at a time, choose an inverter slightly above this, say **1.2 kW**.

How to Prepare a Site Map for Solar PV Installation

A **site map** is a simple drawing or plan of the place where the solar system will be installed. It helps engineers and technicians understand the space, orientation, shading, and placement of solar panels, inverters, and other components.

Steps to prepare a site map:

1. **Visit the Site (Survey):** Walk around the location (roof or ground) and note the available space.
2. **Draw the Boundaries:** Sketch the outline of the roof, terrace, or ground area on paper. Mark walls, fences, or building edges.
3. **Show Directions:** Always mark the **North (N)** direction on the map. This helps in deciding the tilt and orientation of panels.
4. **Identify Obstacles:** Draw any objects that may cause shading—like water tanks, trees, poles, chimneys, or nearby tall buildings.
5. **Mark Available Area for Panels:** Highlight the usable roof/ground area where panels can be placed.
6. **Add Access Points:** Show stairs, pathways, or safe entry points for installation and future maintenance.
7. **Space for Equipment:** Mark a place for the inverter, batteries, and cabling routes (close to load centre if possible).
8. **Final Layout:** Use simple symbols to show panel rows, inverters, and cables. This becomes the working plan for installation.

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. What is the main purpose of conducting a site survey before installing a solar PV system?
 - A) To find cheaper panels
 - B) To check if the location is suitable for solar power generation
 - C) To calculate the customer's monthly electricity bill
 - D) To test the inverter efficiency

2. The direction solar panels should face in India for maximum sunlight is:
 - A) North
 - B) East
 - C) South
 - D) West
3. What is the formula for calculating the energy used per day by an appliance?
 - A) Power (W) + Hours (h)
 - B) Power (W) $\times$ Hours (h)
 - C) Power (W) $\div$ Hours (h)
 - D) Power (W) – Hours (h)
4. What is the purpose of a site map in solar PV installation?
 - A) To calculate electricity bills
 - B) To show the placement of panels, inverters, and other components
 - C) To track weather changes
 - D) To design the customer's roof

B. Fill in the Blanks

1. A careful study of the location before installing a solar PV system is called a _____.
2. Identifying and listing all appliances that will use solar power is known as finding the system's _____.
3. A _____ shows how much electricity is used at different times of the day.
4. Proper system _____ ensures efficiency, reliability, safety, and long life of the solar system.

C. Short Answer Questions

1. Why is a site survey considered the first and most essential step in a solar PV installation project?
2. What are the three main questions a customer usually has before installing a solar PV system?
3. Write any two factors checked during assessment of site conditions for solar installation.
4. What important details should be shown on a site map for solar installation?

Session 2: Key Methods for Gathering Customer Requirements

As a solar installer, it's essential to prioritize customer needs while providing photovoltaic (PV) systems. The primary objective is to address customer issues effectively and ensure their satisfaction with the solution offered.

To accurately gauge a customer's requirements for a PV system, you should focus on three fundamental questions:

- How to gather information?

To gather this information, a combination of methods and corresponding specific questions can be employed:

1. **Assessment by Phone:** This approach aims to understand whether solar PV is a viable option for the customer by asking:
 - What are the customer's expectations regarding a solar system?
 - What devices are commonly used?
 - How often do power outages occur?
2. **Assessment by Walkthrough:** Conducting a physical walkthrough allows for a detailed analysis of both load and site conditions. Key questions to consider include:
 - What devices are present and what are their power ratings?
 - How much space is available for the installation?
 - Are there any potential risks or obstacles on-site?
3. **Reading Electricity Bills:** Reviewing the customer's electricity bills helps determine:
 - The total units of electricity consumed.
 - The customer's current electricity expenditures.
4. **Predicting Shadows on the Space:** It's also crucial to assess whether the designated installation area will be free from shading throughout the year.

The phone assessment should yield vital information to help identify if solar PV is appropriate for the customer. Sample questions include:

1. What devices do they typically use?
2. Are any heavy-load devices in use, such as air conditioners or pumps?
3. Do they require power for all or just part of their loads?
4. What is their estimated load size?
5. How many hours do they experience power outages?
6. How many hours of backup power do they require?
7. During which times of day and months do they most frequently encounter power outages?

By combining these assessment methods and questions, solar installers can gain a comprehensive understanding of a customer's specific needs regarding their PV system, the customer's power and energy requirements.

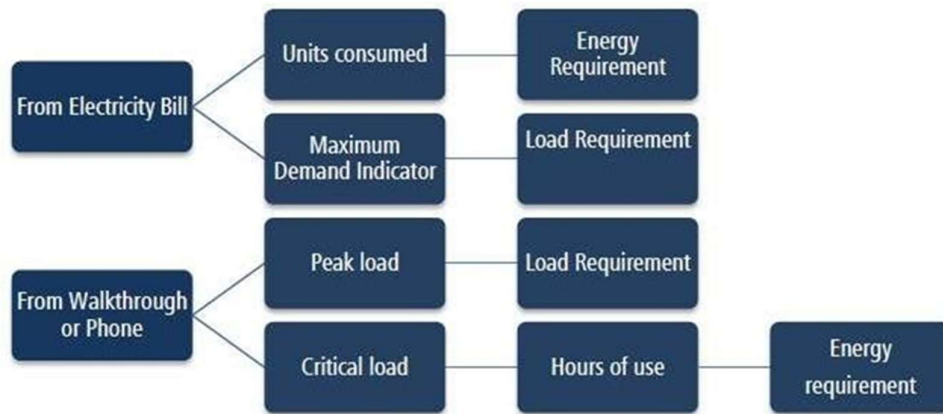


Fig. 4.1: Summary of methods to do load and site assessment

- Critical load – Loads that are essential to work during an outage
- Peak load – The maximum load that can occur when all devices are operated
- Units consumed – The kilowatt-hours of energy consumed by devices

Site Assessment: Understanding Shadow Analysis and Its Significance

The angle of sunlight varies throughout the day and across seasons, influencing the amount of solar energy received at any given location. The concept of the sun path encompasses these seasonal and hourly changes, as well as variations in daylight duration resulting from the Earth's rotation and its orbit around the sun. The sun's relative position plays a crucial role in the effectiveness of solar energy systems. Therefore, employing specialised techniques to assess potential shading on a rooftop is essential, as shadows vary with seasonal changes.

By conducting a thorough shading analysis, you can provide accurate assessments to your design team. This information will enable them to create a tailored solar energy system that fits your client's specific location. Ultimately, this customised design approach is aimed at ensuring the solution is both effective and cost-efficient.

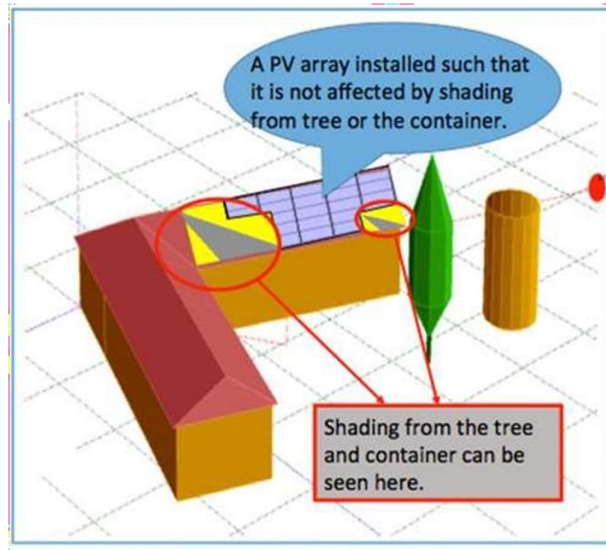


Fig. 4.2: Placement of PV array to avoid shading from surrounding objects

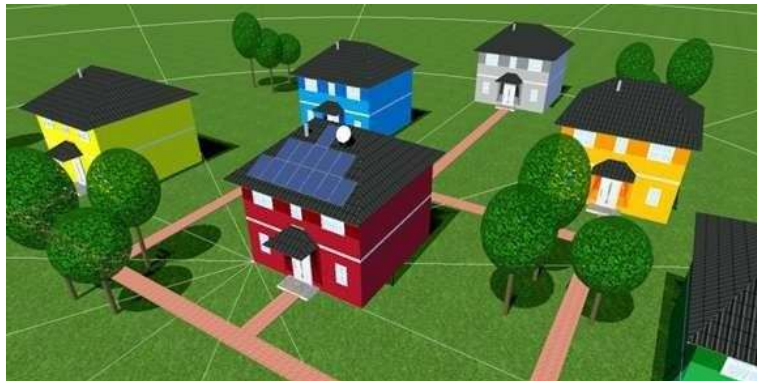


Fig. 4.3: PV array installations must be carried out after thorough consideration of possible shading objects surrounding the location

Benefits of Conducting a Site Survey

For photovoltaic (PV) installers, it is essential to ensure that the solar energy system installed aligns with the unique requirements of the customer as effectively as possible. Conducting load and site assessments serves as the primary method for achieving this objective.

A solar PV system is designed to power electrical loads and recharge batteries, making it critical to accurately determine the customer's load size and energy storage needs. This process is referred to as load assessment.

Additionally, it is important to remember that a PV system requires physical space within a customer's property, and most customers may not have infinite space to accommodate these systems. After establishing the load and energy requirements, the next step is to

evaluate whether there is sufficient space to fulfill these needs. It is also crucial to ascertain if the available space is suitable for the installation of a solar PV system. This evaluation process is known as site assessment.

The ultimate benefits of conducting thorough load and site assessments are highlighted below:

Table 4.1: Outcome expected on completion of site survey activities

Site Survey Activities	Some benefits of doing an accurate assessment
Load Assessment	• Solar array and batteries are sized according to need • Critical loads are backed up • The customer's gets maximum value for money
Site Assessment	• Components are placed in proper locations where they function without hindrance • Shadows do not fall on the arrays, maximising output • The area remains safe for humans and equipment

Steps for Conducting a Load Assessment

Gather Load Information

Assume you are at a customer site and about to start load assessment. We will now follow a step-by-step procedure to perform a load and site assessment for any customer

Step 1: Collect Essential Customer Information

The decisions regarding the type of systems to be installed are heavily influenced by the customer's profile. To ensure the best fit for their needs, utilise the following form to gather important details about the customer.

Table 4.2: Sample form for gathering customer information

	Question	Answer
1.	Name and Address of customer	
2.	Types of Customer	Residential/commercial/ Institutional
3.	Type of locality	City/Town/Village
4.	Current sources of power used	Electricity Grid/Diesel Generator/DC solar devices
5.	• Current back-up sources used • Battery backup size, if any (in Ampere)	• Yes/ No • Battery Back Up
6.	If the grid is available, the hours of power	

	cuts experienced	
--	------------------	--

Step 2: Identify Devices and Their Ratings

To estimate the maximum power needed, identify all the main electrical devices and note their power ratings. This rating represents the highest load the solar system will have to support, assuming the customer has enough space and budget. However, most customers only want to back up specific essential devices with solar energy.

Walk through the building and create a table to list the devices and their power ratings.

Table 4.3: Identifying electrical loads in the building

Type of Load	Power	Total Number	Critical loads	Hours of Use
TV	60 W	1	1	3
Fan	60 W	5	2	6
Lamp	60 W	3	0	6
CFL	20 W	12	6	6
Desktop Computer	270 W	2	1	4
Laptop	50 W	2	0	2
Laser Printer	375 W	1	0	
Refrigerator	380 W	1	0	12
DC Loads				
Phone Charger	4 W	1	1	5
LED	5W	5	3	7

Tips

- You can usually find the wattage of most appliances on the bottom or back of the appliance, or on its nameplate.
- If the wattage is not listed, you can estimate it by finding the current draw in amperes and multiplying that by the voltage used by the appliance. Most appliances in India use 240 volts.
- The amperes may be stamped on the unit instead of the wattage. If not, you can use a clamp-on ammeter, which is a tool that clamps around one of the appliance's wires, to measure the current. Take a reading while the device is running to see the actual amount of current being used at that moment.
- If you are measuring the current for a motor, be aware that it will show about three times more current when the motor starts than when it is running smoothly.
- It's important to gather all necessary information without making assumptions about the type of solution the customer will need, such as AC or DC, grid-tied or off-grid systems, etc.

Step 3: Read the Electricity Bill

- Capture the electricity bills from at least the last three months.
- Record the number of units used each month.
- Write down the electricity charges listed on the bill.
- Also, note any extra fees charged by the distribution company. This information will help explain the payment details to the consumer later.

Extract and record information as shown in the sample table below.

Table 4.4: Information recorded from the electricity bill

Month	Units Consumed	Unit Rate Applied	Surcharges

Meter Details in Annexure

Billing Details Current Period Charges (01-09-2014 to 30-09-2014)

Fixed Charges (A)	Slab-wise Energy Charges			Slab-wise FPA/PFA		T O D		Surcharge 8% on (E) (A+B+D+G)	Electricity Tax @ 5% (F)	Total Amount Payable (A+B+C+D+E+F+G)
	Cont. Moored During	Billed Units	Unit Rate	Amount (H)	PPAC % on B	Amount (C)	TOD % on B			
6785.00 (1.00 Mths)	NORMAL(S)	772.00	8.50	6562.00					1653.65	23074.07
	OFFPEAK(S)	48.00	8.50	408.00			(25.00)	(102.00)		
	PEAK(S)	688.00	8.50	5848.00			20.00	1169.60		
PPAC on Fix Chg. 0.00										
TOTAL ~		1508		12818.00		.00		1067.60		

Past Dues / Refunds / Subsidy		Late Payment Surcharge (LPSC)	Other Charges, if any *	Total Charges Payable	Rebate(R) / Subsidy *	Net Amount Payable
Amount	Period to which it relates					
0.00		0.00	3.31	23077.38	0.00/0.00	23077.38

net avail. Rs. 0.00 Reason

Amount not immediately payable, if any.

Security Deposit with DISCOM	Rs.
Interest accrued for FY already adjusted in bill No. (generated for the period to).	Rs.
Interest for FY will be adjusted in your first bill to be generated in FY	

Bill Amount Payable

Rs. 23070.00

Due Date of Payment
20-10-2014
 If payment is made after the due date, LPSC for the delay, shall be charged in the next bill.

Last payment Rs. 19020.00 received on 11-09-2014. Payment Accounted upto 28-09-2014.
 The connection shall be liable for disconnection on non payment of all dues (including arrears of previous bill(s)) by due date, after notice as per Section 50(1) of the Electricity Act, 2003.

Switch off lights and appliances from mains when not in use. This will conserve energy and reduce your electricity bill. ELCB is a safeguard against faulty internal wiring and prevents shock, fire and electrical accidents. Install ELCB for all loads. Installation is mandatory for load of 5 KW and above. **ENERGY SAVED IS ENERGY PRODUCED.**

Fig. 4.4 Customer Bill

Step 4: Assess Building Wiring

Branch Circuits

As a site surveyor, it is very important to gather all the details about home wiring. Knowing how each branch circuit works is essential for any home wiring project. A branch circuit is an area of the home where the panel board sends out electrical currents. Miniature Circuit Breakers (MCBs) are used to manage these circuits. This allows you to turn off the power to one room while keeping the rest of the house powered. We should identify and record all the normal and power loads.

In your home wiring layout, number each MCB installed at the site and specify the loads they control. This information can be organised in a table. It is very useful when designing the photovoltaic (PV) system for the location.

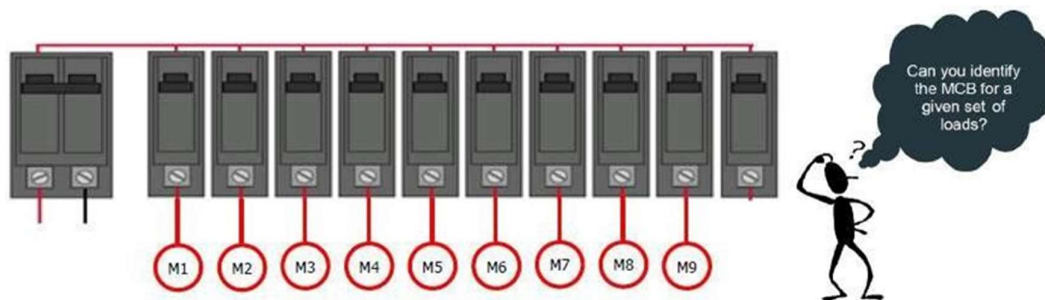


Fig. 4.5: Identify all the MCBs and their respective loads and present the data in a table format.

Table 4.5: Representation of MCBs and their respective loads.

MCB	Remarks	Electrical Load	Power Socket
M1	DR	TV, Incandescent Light Bulb	Yes (2)
M2	BR1		Yes (1)
M3	BR2	TV	Yes (1)
M4	Kitchen	Tube light, Fan, Laptops	Yes (3)
M5	Terrace	Light	Yes (1)

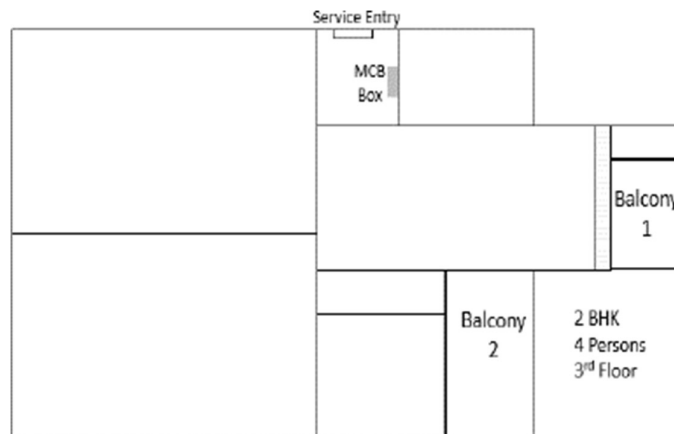


Fig. 4.6: Identify the Service Entry, and draw a basic layout of home wiring, marking locations such as the Service Entry, Panel

You have now captured enough information to later perform a load analysis.

Steps for Conducting a Site Assessment

Step 1: Prepare the Layout of the Building

- Prepare a layout of the building with rooms
- Mark places available with shading for inverters and batteries

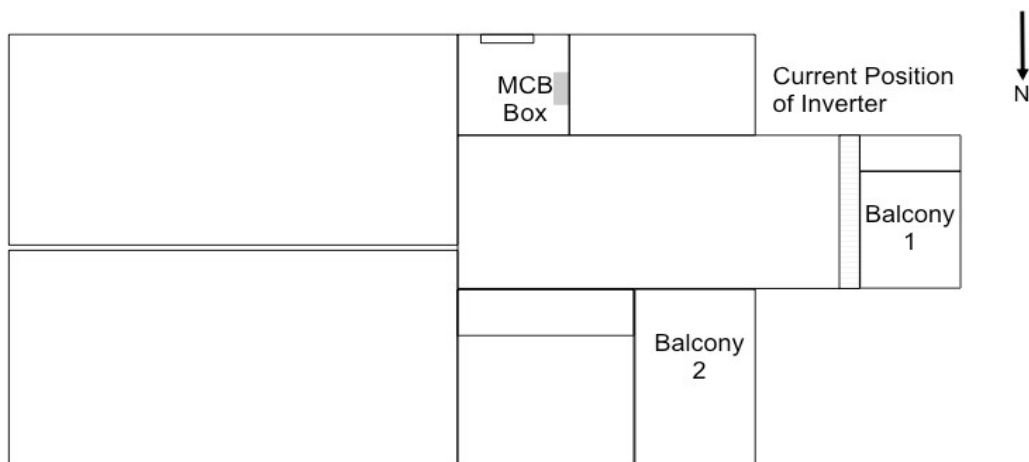


Fig. 4.7: Site assessment

Step 2: Prepare Layout of Roof; Take Pictures;

- Mark Dimensions
- Marking site layout with dimensions on paper:
- Walk through the terrace and draw the layout
- Mark the dimensions and directions
- Mark the visible obstructions and measure their dimensions
- Enquire whether the obstructions can be moved or not

- Click multiple (from all angles) photographs of the roof
- Click and mark photographs of the most suited spot on the roof for installing PV array
- Take 2 or 3 of the most suitable available spots on the roof for installing PV array as a reference point, click photograph of obstacles in its North South East West directions.

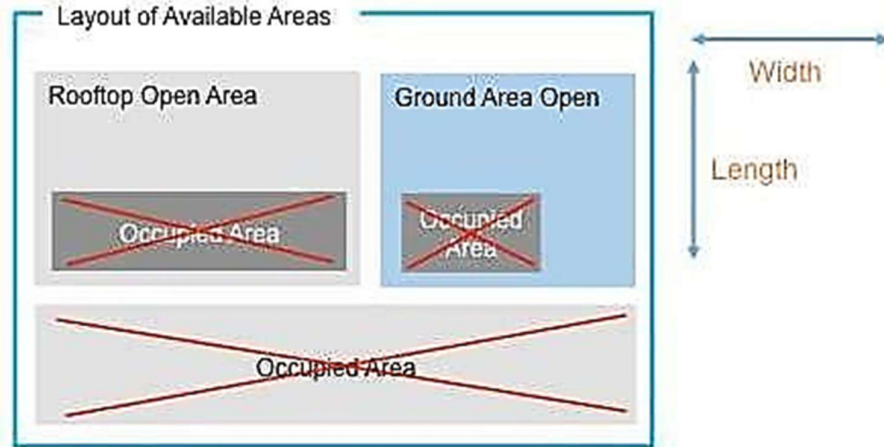


Fig. 4.8: Mark dimensions

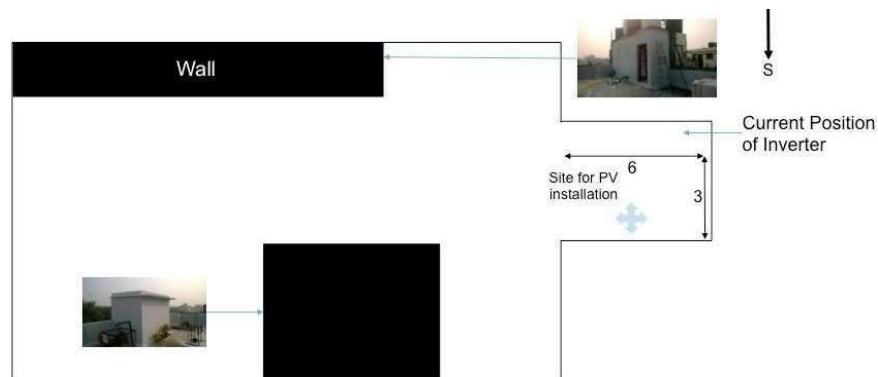


Fig. 4.9: Site layout (Roof)

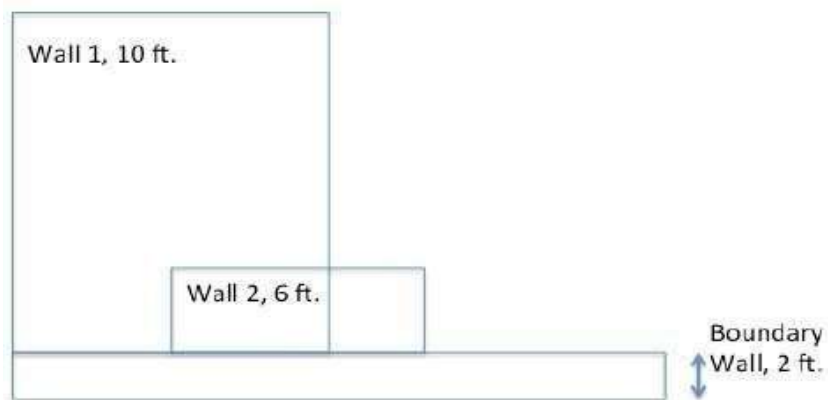


Fig. 4.10: Front view with height of walls photo

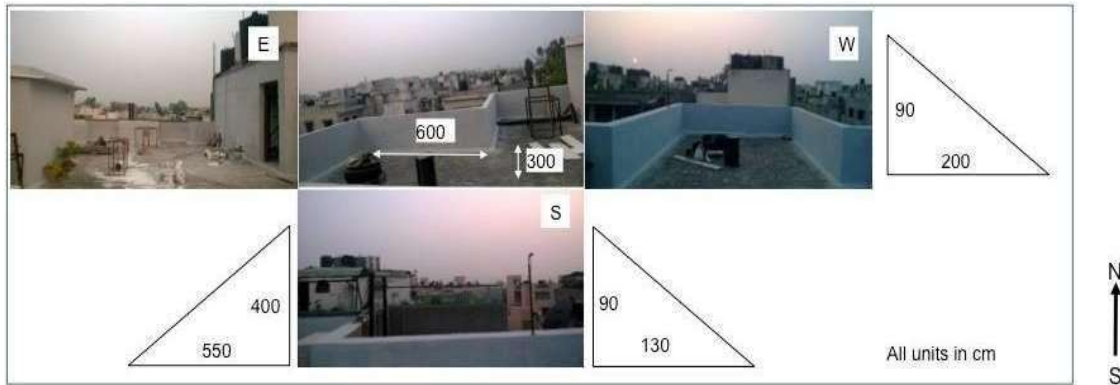


Fig. 4.11: Site photographs; Photo credit: Anthro Power Training Private Limited

- When marking locations for system components and cable routing, do keep the following in mind:
- Inverter should be located in a room or shelter protected from sun and rain.
- Batteries should be kept in a room or shelter in a rack and the room should be ventilated.
- If such space does not exist, you should enquire from the customer as to the possibility of constructing shelters for equipment,
- For cable routing, do keep in mind that the inverters should be kept as close as possible to the DC combiner box as DC side wire loss increases drastically with the length of the wire.
- Draw a rough sketch of how the cables will be routed and estimate the length of the wiring that may be required up to the switchboard.

Step 3: Choose Spots Suitable for Shading Analysis

Before doing a shading analysis on a spot, ensure that the area is suitable by other criteria: Is it possible to easily carry the panels to the area? Is it as close as possible to the location of the DC combiner box and inverter?

Assess area required for solar array, and identify shadow free locations on roof suitable for installation and nearest to the inverter wiring. Roughly 110 sq. ft. or 10 m² per kW of area is required. Make a layout of the rooftop on a sheet of paper.

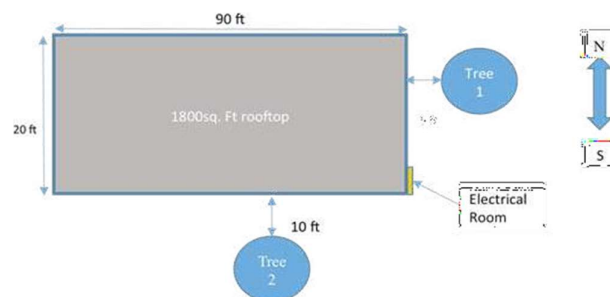


Fig. 4.12: Sample layout diagram of a rooftop

Step 4: Performing Shading Analysis

- Shading situations present a challenge for preparation of PV system implementation plans. Shading has an effect on system yield.
- Shading analysis tells us how many hours of sunlight a selected location will receive in a given month of the year
- Simulation programs are available, which generally stimulate shading effects using horizon photographs of shade-generating objects based on 3D simulation. There are various ways tools for doing shading analysis, such as Solar Pathfinder, Sun Eye and paper tools. There are software simulation tools like PVSOL and PVsyst, which are also used for doing shadow analysis and annual energy generation projections. Even the result from solar pathfinder and other instruments is used as an input in the above solar simulation software for energy generation projections. Some of these tools are described below.

Table 4.6 : PV system type with customer requirement

Customer Requirement	PV System Type
Lighting, mobile charging, small DC devices such as DC fans	DC off-grid system
AC loads such as fans, CFLs, TV and Refrigerators Very erratic or no grid supply. So backup requirement is high	AC off-grid system (stand-alone system)
Grid is available with very little or no power cuts	Grid-tied system

ACTIVITY**Activity: Mini Site Assessment and Shadow Analysis****Objective:**

To make students understand the importance of site mapping, shading analysis, and suitable placement of solar PV panels.

Materials Required:

- Graph paper or plain drawing sheets
- Scale and pencil
- Compass or smartphone compass app

- A small model of a rooftop or use the classroom/terrace
- Small cardboard objects to represent obstacles (walls, tanks, etc.)
- Sunlight or flashlight for simulation

Procedure:

1. Take students outside (terrace/open area) or use a model setup.
2. Ask them to draw a rough layout of the roof, marking:
 - North direction
 - Dimensions (approximate)
 - Locations of obstacles (walls, trees, poles, etc.)
3. Using a flashlight or by observing shadows, identify shadow-free zones suitable for PV panels.
4. Students mark *proposed PV array locations*, inverter placement, and cable routing paths on their layout.
5. Each group explains why they chose specific spots and how they avoided shading.

Expected Outcome:

Students will understand:

- How to evaluate a site physically.
- How to mark and choose suitable, shadow-free installation areas.
- The connection between site survey and final system design.

CHECK YOUR PROGRESS**A. Multiple Choice Questions (MCQs)**

1. Which of the following methods helps determine if solar PV is a suitable option for a customer before a site visit?

- A) Shading analysis
- B) Walkthrough assessment
- C) Assessment by phone
- D) Reading the electricity bill

2. During a walkthrough assessment, what key aspect is **not** typically checked?

- A) Available installation space

- B) Power ratings of devices
- C) Customer's billing history
- D) Possible risks or obstacles on-site

3. Why is **shadow analysis** important in site assessment for PV installation?

- A) It reduces the cost of installation
- B) It helps identify areas that receive sunlight throughout the year
- C) It predicts the lifespan of solar panels
- D) It improves the appearance of the system

4. What is the main benefit of conducting an accurate **load assessment**?

- A) Reducing panel cleaning cost
- B) Proper sizing of solar arrays and batteries as per need
- C) Ensuring inverter placement near the DC box
- D) Avoiding wiring and cabling

B. Fill in the Blanks

1. The first step in understanding a customer's solar energy needs is known as _____ assessment.
2. A _____ assessment helps analyse the actual load and site conditions during a physical visit.
3. _____ the electricity bill can find the total number of electricity units consumed by a customer.
4. The position of the sun and seasonal shadows are studied during a _____ analysis.

C. Short Answer Questions

1. What are the three key methods used to gather customer requirements for a PV system?
2. Why should a solar installer conduct a phone assessment before visiting the site?
3. What information can be obtained by reading the customer's electricity bill?
4. Mention two benefits of conducting a thorough site assessment.

MODULE 5: BASICS OF SOLAR PHOTOVOLTAIC SYSTEMS AND ITS COMPONENTS

A solar power system, also known as a PV system or photovoltaic system, is an electric power system designed to supply usable solar power by means of photovoltaics. It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity, a solar inverter to convert the output from direct current to alternating current, as well as mounting, cabling, and other electrical accessories to set up a working solar power system. It may also use a solar tracking system to improve the system's overall performance and include an integrated battery.

SESSION 1: SOLAR POWER SYSTEM AND ITS COMPONENTS

PV systems convert light directly into electricity and are not to be confused with other solar technologies, such as concentrated solar power or solar thermal, used for heating and cooling. A solar array only encompasses the ensemble of solar panels, the visible part of the PV system, and does not include all the other hardware, often summarised as balance of system (BOS). PV systems range from small, rooftop-mounted or building-integrated systems with capacities from a few to several tens of kilowatts, to large utility-scale power stations of hundreds of megawatts. Nowadays, most PV systems are grid-connected, while off-grid or stand-alone systems account for a small portion of the market.

Solar energy is used for generating electricity through the help of solar photovoltaic (PV) cells, which is also known as solar PV. Solar energy is a cheap source of energy and requires little maintenance. Solar light and solar power can be used most effectively where there is no power supply in a remote area as well as village level. Solar energy power is used for lighting, cooking as well as storage of power, and lifting the water from the underground level for drinking water as well as irrigation purposes.

The solar ON-grid is mostly used in rural and urban areas for electricity generation and irrigation purposes. In this session, we are going to discuss about major components and equipment used in solar power system/ solar PV System installation and their characteristics.

SOLAR PV SYSTEM (SOLAR POWER SYSTEM)

All solar power systems work on the same basic principles. Solar panels first convert solar energy (sunlight) into DC power. The photovoltaic effect is a technique that solar panels use to transform solar energy (sunlight) into DC power. The DC power can then be stored in a battery or converted by a solar inverter into AC power which can be used to run home appliances. Depending on the type of system, excess solar energy can either be fed into the electricity grid for credits, or stored in a variety of different battery storage systems.

Main Components of a Solar PV System

1. Solar Panels

Most modern solar panels are made up of many silicon-based photovoltaic cells (PV cells) which generate direct current (DC) electricity from sunlight. The PV cells are linked together within the solar panel and connected to adjacent panels using cables.

2. Solar Inverter

Solar panels generate DC electricity which must be converted to alternating current (AC) electricity for use in our homes and businesses. This is primary the role of the solar inverter.

3. Solar Charge Controllers

A solar Charge Controller is an electronic device that manages the power going into the battery bank from the solar array. solar Charge Controller Protecting the batteries from overcharge and over-discharge conditions.

4. Maximum Power Point Tracker (MPPT)

Maximum power point tracking is a technique used with variable power sources to maximize energy extraction as conditions. The technique is most commonly used with photovoltaic (PV) solar systems. Many times, the inverter and charge controller performs the function of maximum power point tracker.

5. Battery

The battery is a device that stores electrical energy. Battery capacity is generally measured as either Amp hours (Ah) for lead-acid, or kilowatt hours (kWh) for lithium-ion. Battery capacity is measured in either Amp Hours (Ah) or kilowatt hours (kWh). The amount of energy used, known as the depth-of-discharge or DOD is taken as a percentage % of total battery capacity.

A PV system can be several types it is depending on the way of energy used and generated. Broadly, PV system is divided into three categories

The Three main types of solar power systems

1. On-grid - also known as a grid-tie or grid-feed solar system
2. Off-grid - also known as a stand-alone power system (SAPS)
3. Hybrid - grid-connected solar system with battery storage

ON-GRID SOLAR SYSTEM

On-grid or grid-tie solar systems are by far the most common and widely used by homes and businesses. These systems do not need batteries and use either solar inverters or micro-inverters and are connected to the public electricity grid. Any excess solar power that you generate is exported to the electricity grid and you usually get paid a feed-in-tariff (FiT) or credits for the energy you export.

Unlike hybrid systems, on-grid solar systems are not able to function or generate electricity during a blackout due to safety reasons. Since blackouts usually occur when the electricity grid is damaged; if the solar inverter was still feeding electricity into a damaged grid it would risk the safety of the people repairing the fault/s in the network. Most hybrid solar systems with battery storage can automatically isolate from the grid (known as islanding) and continue to supply some power during a blackout.

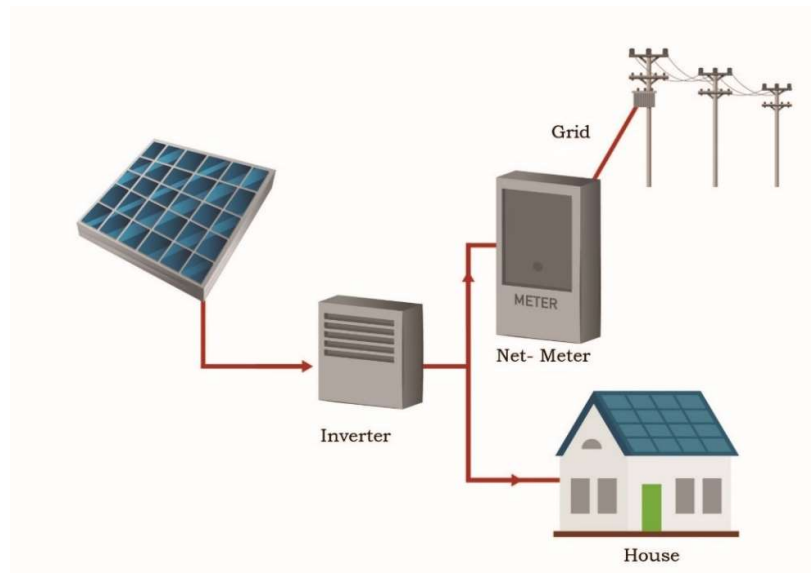


Fig. 5.1: In an on-grid system,

Excess solar energy runs through the meter, which calculates how much power you are either exporting or importing (purchasing). The electricity that is sent to the grid from your solar system can then be used by other consumers on the grid (your neighbours). When your solar system is not operating, or you are using more electricity than your system is producing, you will start importing or consuming electricity from the grid.

Advantages of a Grid-Tied Solar System:

- Grid-tied systems tend to be the less expensive option, due to not needing batteries and other equipment
- This type of system is great for those who don't have the room or financing to install a solar system big enough to cover 100% of their energy usage. You can continue to pull electricity from the grid if needed.
- Net Metering allows the electricity generated by a solar system to

Offset the electricity used from the grid during the night or cloudy days

- The grid becomes your cost-effective, reliable storage solution
- In some regions, Solar Renewable Energy Credits (SRECs) allows owners of a grid-tied system to receive extra income by selling the SRECs their system produces.

Disadvantages of a Grid-Tied Solar System:

- If the grid goes down your system will shut off, leaving you without power. This is required to prevent energy from back feeding into the grid to keep utility workers safe. Your grid-tied system will automatically shut off when the grid goes down, and will also automatically turn back on when power is restored.
- You're not completely independent from the grid.

OFF-GRID SOLAR SYSTEM

An off-grid system is not connected to the electricity grid and therefore requires battery storage. Off-grid solar systems must be designed appropriately so that they will generate enough power throughout the year and have enough battery capacity to meet the home's requirements, even in the depths of winter when there is generally much less sunlight.

The high cost of batteries and off-grid inverters means off-grid systems are much more expensive than on-grid systems and so are usually only needed in more remote areas that are far from the electricity grid. However, battery costs are reducing rapidly, so there is now a growing market for off-grid solar battery systems even in cities and towns. AC-coupled off-grid solar systems use a solar inverter together with a multi-mode battery inverter. Simple, affordable, small-scale DC-coupled off-grid solar power systems uses solar charge controllers to manage the battery charging, plus a simple inverter to supply AC power.

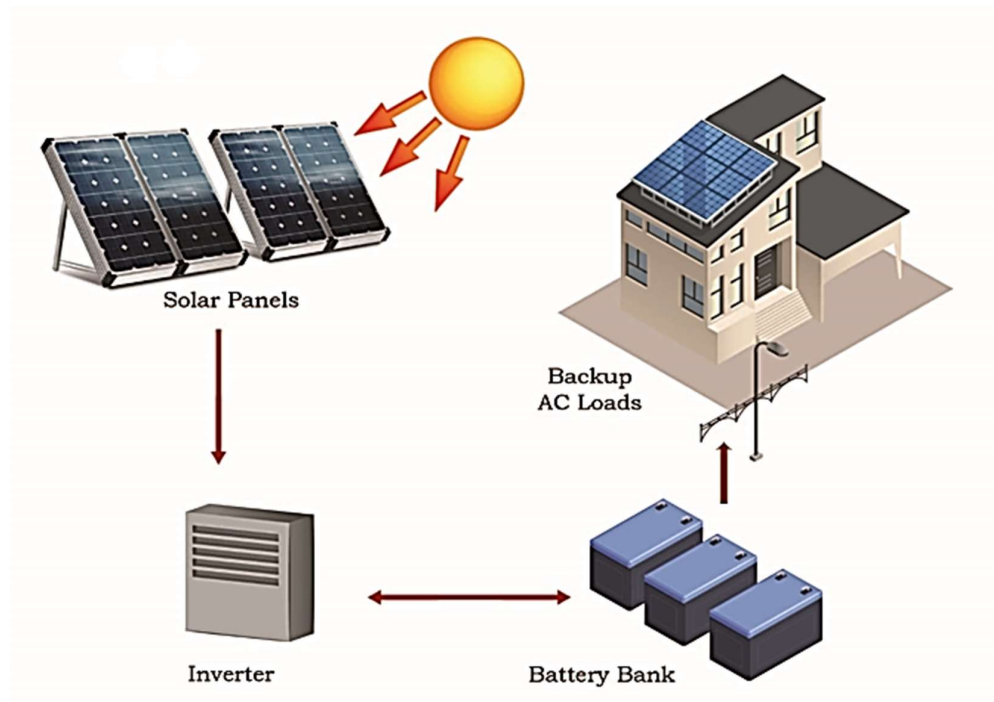


Fig. 5.2: Off-Grid Solar System

AC-coupled off-grid solar systems use a solar inverter together with a multi-mode battery inverter.

Simple, affordable, small-scale DC-coupled off-grid solar power systems uses solar charge controllers to manage the battery charging, plus a simple inverter to supply AC power.

The battery banks: In an off-grid system there is no public electricity grid. Once solar power is used by the appliances in your property, any excess power will be sent to your battery bank. Once the battery is full it will stop receiving power from the solar system. When your solar system is not working (nighttime or cloudy days), your appliances will draw power from the batteries.

• **Backup Generator.** For times of the year when the batteries are low on charge and the weather is very cloudy, you will generally need a backup power source, such as a backup generator or gen-set. The size of the gen-set (measured in kVA) should to be adequate to supply your house and charge the batteries at the same time.

Advantages of an Off-Grid Solar System:

- Completely independent from the grid.
- A great solution for remote locations and underdeveloped Communities.

Disadvantages of an Off-Grid Solar System:

- They are costlier.
- Batteries are required to deliver electricity consistently throughout the day and night.
- It could require a lifestyle change to reduce energy consumption
- Surplus energy production could go to waste.
- Cannot rely on the grid at night or on cloudy days Batteries require maintenance, have a relatively short lifespan, and degrade rapidly.

Hybrid Solar System

Modern hybrid systems combine solar and battery storage in one and are now available in many different forms and configurations. Due to the decreasing cost of battery storage, systems that are already connected to the electricity grid can start taking advantage of battery storage as well. This means being able to store solar energy that is generated during the day and using it at night. When the stored energy is depleted, the grid is there as a back-up, allowing consumers to have the best of both worlds. Hybrid systems are also able to charge the batteries using cheap off-peak electricity (usually after midnight to 6 am).

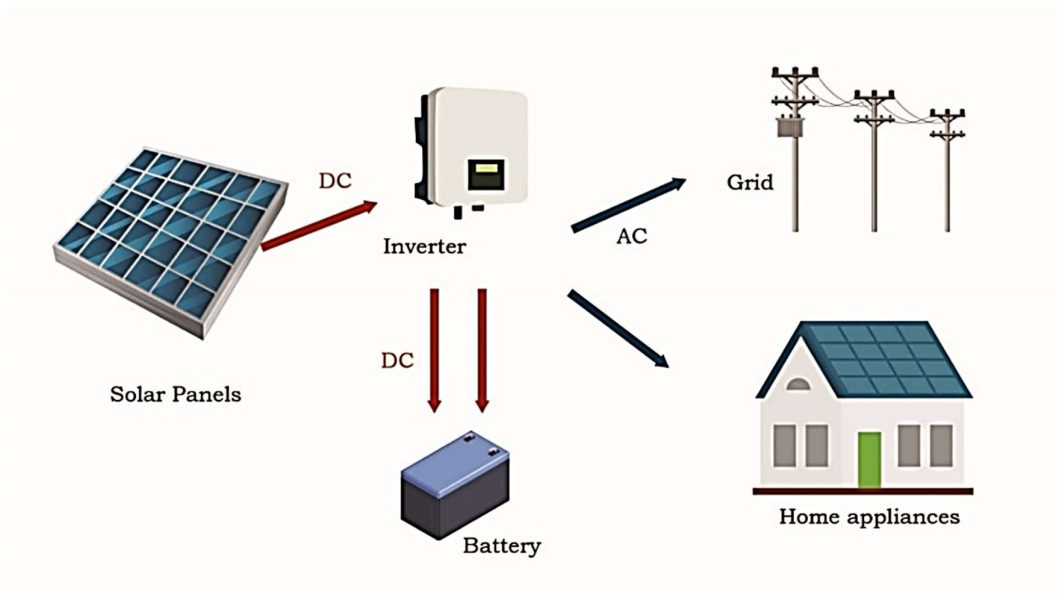


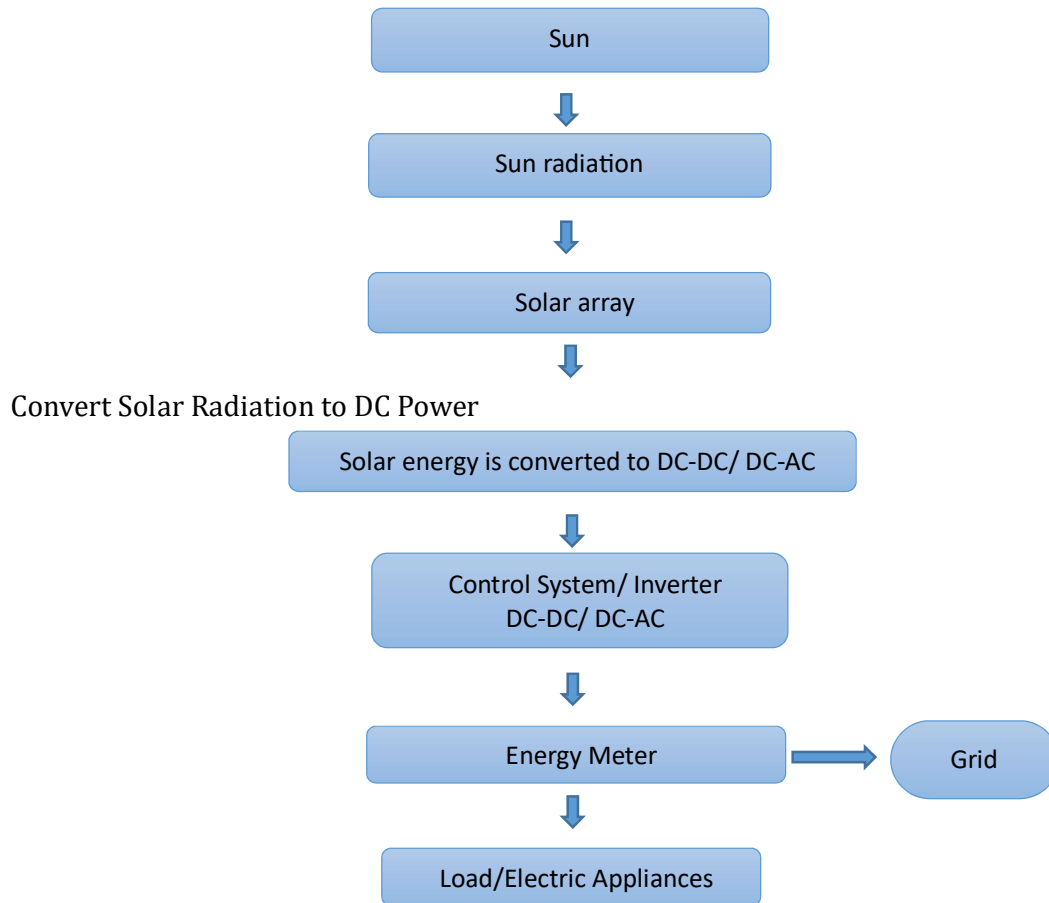
Fig. 5.3: Hybrid solar system

- The battery banks: In a hybrid system, once the solar power is used by the appliances in your property, any excess power will be sent to the battery bank. Once the battery bank is fully charged, it will stop receiving power from the solar system. The energy from the battery can then be discharged and used to power your home, usually during the peak evening period when the cost of electricity is typically at its highest.
- The meter and the electricity grid. Depending on how your hybrid system is set up and whether your utility allows it, once your batteries are fully charged, excess solar power not required by your appliances can be exported to the grid via your meter. When your solar system is not in use, and if you have drained the usable power in your batteries, your appliances will then start drawing power from the grid.

For most people, a grid-tied solar system is a solid investment that provides security and predictability for their business, farm or home. The payback for a grid-tied solar system is shorter and fewer components could need to be replaced in the future. An off-grid solar system is a good option for some cabins and more isolated areas; however, at this time, off-grid systems struggle to compete with the payback and ROI of a grid-tied system.

The solar power system consists of a solar panel, inverters, a solar charge controller, DCDB/ACDB, structure, earthing, a lightning arrester, and sometimes a solar battery.

When the sun rays fall on the solar panel or module, electricity is produced with the help of the solar PV module. The generated electricity is transferred to the grid or home appliances.

SOURCE OF ENERGY**Fig. 5.4: Principle of a solar power system****CHECK YOUR PROGRESS:****A. Multiple Choice Questions.**

1. Which of the following is not a function of pumps
 - a. For Power Generation
 - b. for irrigation
 - c. For drinking Facility
 - D. None of these
2. DC Pump Works on which Power.
 - a. HVAC
 - B. HVDC
 - C. DC power

D. AC power

3. For AC Pumps Which Type of inverters is used?

- a. Grid tie inverter
- b. Off-grid inverter
- c. Both
- d. None of these

4. DC Pump is _____

- a. High voltage operating pump
- b. Low-voltage operating pump
- c. Both
- d. None of these

B. Fill in the Blanks.

1. AC pumps are available at higher Hp varying from _____ Hp most suitable for irrigation purpose.
2. DC pump standard Capacity is _____ HP.
3. To operate 1HP Pump _____ Watt panel capacity required.
4. In AC Pump _____ type of charge Controller is used.

C. Short Answers Questions

1. Define the Pump and Its type.
2. What are the applications of Solar Powered Pumps?
3. Difference Between AC and DC Pumps?
4. Draw a line diagram of the AC and DC Solar Pumping systems.

D. Practical Exercise

1. Identify AC and DC pump their Connections and specification.
2. Draw a line diagram of a hybrid water pump

SESSION 2: THE SOLAR PANEL AND ITS COMPONENTS

A solar panel is a collection of solar cells, mainly connected in series. The combinations of solar cells provide higher power than a single solar cell. These solar panels are available in a power rating range from 1 watt to 700 watts. The proper connection of PV panels will lead to generating a large amount of solar power in the range of kilowatt (KW) or megawatt (MW) as per the requirement and design of the system. Various components are discussed below.

Photo Voltaic Cells (Solar Cell), Panels, PV array

Photovoltaic cells and panels are important components of a solar module.

Photovoltaic cells: Photovoltaic cells are semiconductors (semiconductors of a substance, such as silicon or germanium, with electrical conductivity intermediate between that of an insulator and a conductor) device that convert sun energy into direct current (Electrical energy). It is a fundamental unit of the solar module. A typical silicon solar cell produces only about volts.

There are a variety of semiconductor materials used in a photovoltaic cell. Silicon is the most available semiconductor and is mostly used in developing PV cells and other electronic chips. The crystalline structure of silicon makes the conversion process more efficient.

When light shines and falls on the photovoltaic cells, the photons in the sunlight transfer their energy to the electrons in the cells and these electrons start moving in the semiconductor material and produce electricity. This electricity supply is directly used in houses, hotels, agriculture, generators, etc.

The process was discovered as early as 1839, but the first solar cell was introduced by Bell executives in 1954. The first generation of solar cells was produced on silicon wafers either using monocrystalline or polycrystalline silicon crystals. The most recent and promising generation of solar cells consists of concentrated solar cells, polymer-based solar cells, dye-sensitized solar cells, nanocrystal-based solar cells, and perovskite-based solar cells.

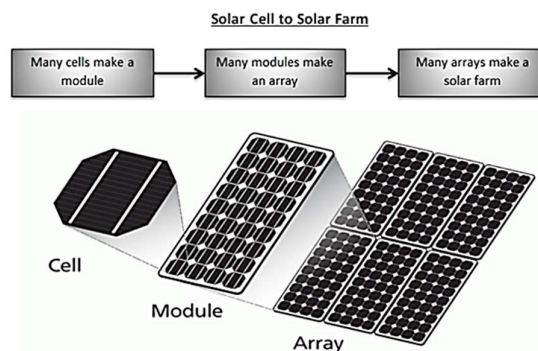


Fig. 5.5: PV Cell, Module, Array

Photovoltaic Panel/module: Photovoltaic Panel (shows in Fig. 5.5) is a collection of many photovoltaic cells connected in a grid to produce electricity. The current generated by each cell is combined and adds up enough to provide power to the household.

PV array: PV array, individual PV modules are connected in both series and parallel.

Types of solar panel

In the market various types of solar PV Panels are available. These panels are made of different materials; the name of the solar module depends on the name of the material used in the particular technology. The properties of materials of different types of modules are different. Hence different types of modules have different parameters like efficiency, voltage, and current.

The four types of photovoltaic technology are Bifacial, Monocrystalline, polycrystalline, and thin film. These four types of PV cells differ from each other with their size, efficiency, and cost which has been explained here.

Bifacial Solar PV Panel

A bifacial solar panel can capture sunlight from both the front and the back of the panel. Often the bifacial panels have a transparent back so sunlight can go through the panel, reflect off the ground, and back up towards the solar cells on the backside of the panel. This allows the panel to produce more electricity than a traditional solar panel.

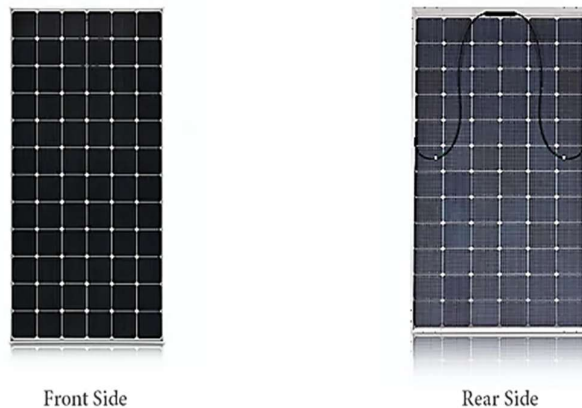


Fig. 5.6: Bifacial Solar PV Panel

Mono Crystalline Solar PV Panel

The cells used in these panels are produced from a single crystal of silicon. In appearance, it will have a smooth texture and black or iridescent blue in colour. These are the most expensive and their efficiency is also high as compared to other types of solar cells. These panels require less production compared with the amount of output they give.

Modules consisting of monocrystalline silicon PV cells reach commercial efficiencies between 15 and 20 %.

These panels are made of pure silicon and undergo a complex process of development and therefore are expensive. As shown in the figure below, the cells are produced by cutting long silicon rods into a slice of 0.2 to 0.4 mm thick discs or wafers and they are later wired into panels as shown in figure 5.7.

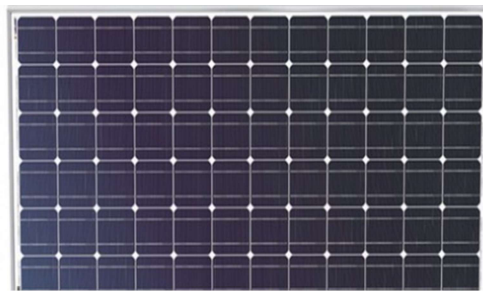


Fig. 5.7: Mono Crystalline Solar PV Panel

Poly Crystalline Solar PV Panels

As shown in the figure, the polycrystalline solar cells are made of the large number of small crystals and look like shattered glass-like appearance. These are much cheaper as their production cost is less as compared to mono-crystalline solar cells. However, these are less efficient than them. Their low-cost production makes them more popular. These cells are further wired together to form solar panels. Polycrystalline modules are leading in the market because they are the best value; they are half the cost of a monocrystalline module while offering efficiency levels close to 15%.



Fig. 5.8: Poly Crystalline Solar PV Panels

Thin Film PV (Amorphous) Panels: These panels are not made of silicon crystals fully. They are made by depositing a thin layer of silicon on some other material like glass or metal. These panels are very cheap but also compromise on the efficiency levels by great amounts as compared to mono and poly crystalline panels. As shown in the figure, these panels are made of combinations of materials. For example, thin hybrid silicon cells are a combination of amorphous and microcrystalline cells based on the different efficiency levels.



Fig. 5.9: Thin Film PV (Amorphous) Panels

SOLAR PANEL LAYERS

A Solar PV Panel consists of a multi-layered unit of the following items.

- **Aluminium frame:** To protect glass from cracks.
- **Cover:** A clear glass or plastic layer that provides outer protection from the elements. Transparent
- **Adhesive:** Holds the glass to the rest of the solar cell.
- **Anti-reflective Coating:** This substance is designed to prevent the light that strikes the cell from bouncing off so that the maximum energy is absorbed into the cell.
- **Front Contact:** Transmits the electric current.
- **N-Type Semiconductor Layer:** This is a thin layer of silicon that has been mixed (a process called doping) with phosphorous.
- **P-Type Semiconductor Layer:** This is a thin layer of silicon that has been mixed or doped with boron.
- **Back Contact:** Transmits the electric current.
- **Junction Box:** power collection junction from the solar cell.

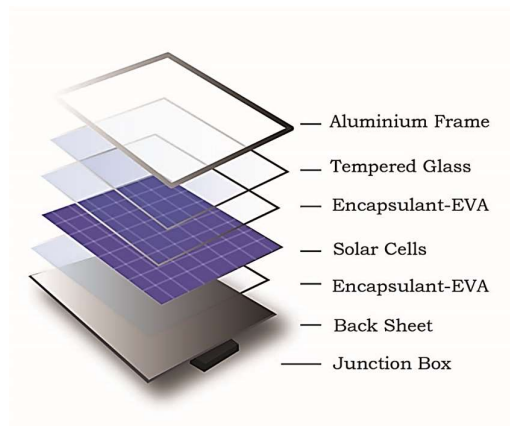


Fig. 5.10: Solar Photovoltaic cell layer

Panel Size and Efficiency

Overall panel efficiency can be affected by many factors, including temperature, irradiance level, cell type, and interconnection of the cells. Surprisingly, even the colour of the protective backsheet can affect efficiency. A black backsheet might look more aesthetically pleasing, but it absorbs more heat, resulting in higher cell temperature which increases resistance; this in turn slightly reduces total conversion efficiency.

Total Panel efficiency is measured under standard test conditions (STC), based on a cell temperature of 25°C, solar irradiance of 1000W/m², and Air Mass of 1.5. The efficiency (%) of a panel is calculated by the maximum power rating (W) at STC, divided by the total panel area in meters.

COMPARISON OF DIFFERENT TYPES OF PV MODULES

Table no. 5.1 Comparison of Different Types of PV Modules

TYPE OF PV Cell	Module efficiency	Surface area needed for 1 KW (Power)	Advantages	Disadvantages
Bifacial Solar PV Panel	20 Plus %	5-6m ²	-Less Area Required, -Highly Standardised,	Very Expensive
Monocrystalline silicon	15-19 %	7-9 m ²	- Most Efficient PV Modules	-Expensive
			- Easily Available On The Market	- Waste Of Silicon in the Production Process
Polycrystalline silicon	13-16 %	8-9 m ²	- Highly Standardised	
			- Less Energy and Time Needed for Production than for Monocrystalline Cells (Lower Costs)	-Slightly Less Efficient Than Monocrystalline Silicon Modules

			- Easily Available on the Market	
			- Highly Standardised	
Thin film:	10-12 %	9-11 m ²	- Higher Temperatures and Shading Have a Lower Impact On Performance	- More Space for The Same Output Needed
Copper Indium Diselenide (CIS)			- Lower Production Costs	
Thin film:	9-11 %	11-13 m ²	- Higher Temperatures and Shading Have a Lower Impact on Performance	- More Space for The Same Output Needed
Cadmium Telluride (CdTe)			- Highest Cost-Cutting Potential	
Thin film:(Amorphus Silicon (A-Si))	6-8 %	13-20 m ²	- Higher Temperatures and Shading Have a Lower Impact On Performance	- More Space for The Same Output Needed
			- Less silicon is needed for production	

Technical Parameters and Performance of Solar PV Panel

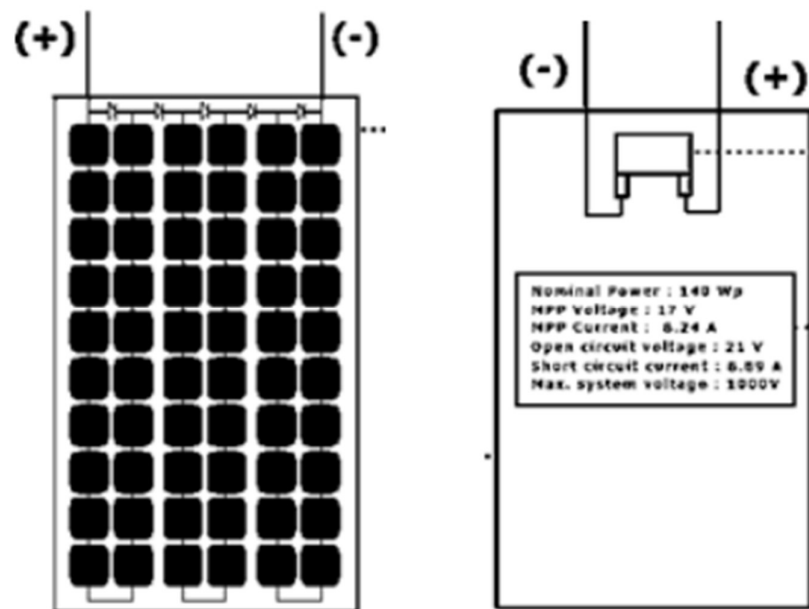


Fig. 5.11: Front Side and Back side of a PV Module: The Junction Box consisting of Positive and Negative Terminals is placed behind the module

A Solar PV Module is characterized by the following parameters:

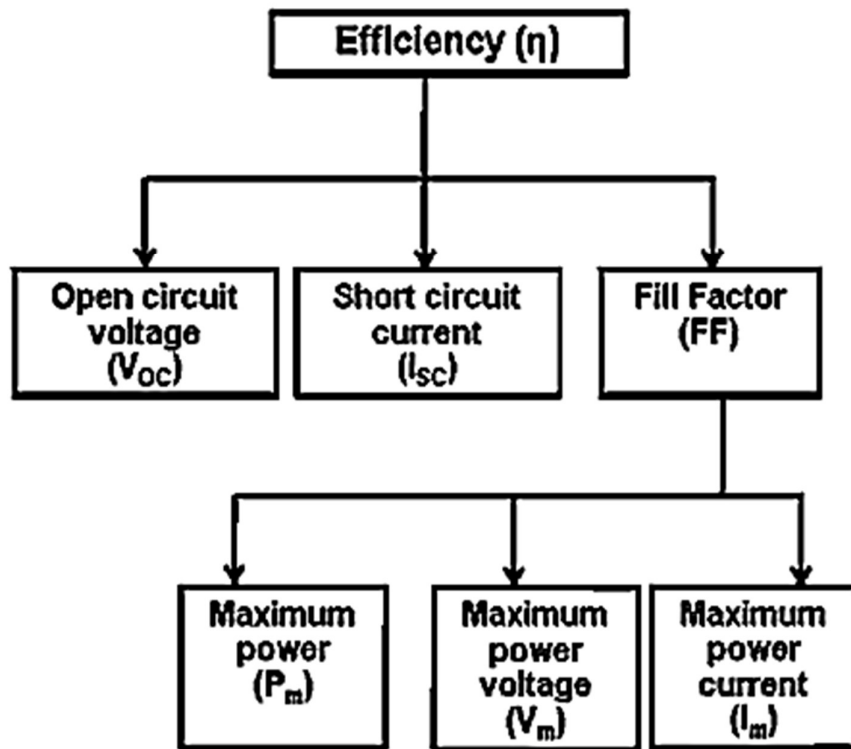


Fig. 5.12: Solar PV Module Characterisation

Table 5.2: Sample values of major Technical Specifications of a solar PV panel

Parameter	Value
Max Power Pmax (W)	100 W
Power Tolerance (+/-)	0.05%
Max Power Voltage Vmp (V)	18 V
Max Power Current Imp (A)	5.56 A
Open Circuit Voltage Voc (V)	22.3 V
Short Circuit Current I sc (A)	6.1 A
Max. System Voltage Vdc	1000/600

A. Short Circuit Current (I_{sc})

The short-circuit current is the current flowing through a solar cell when there is no voltage (when the solar cell is short-circuited). This current, known as I_{sc} , depends on how well the solar cell generates and collects light-based charges. It is the highest current that can be drawn from the solar cell.

B. Open Circuit Voltage (V_{oc})

The open-circuit voltage, V_{oc} , is the maximum voltage a solar cell can produce when no current is flowing. This voltage reflects the forward bias at the solar cell junction caused by light-generated current.

C. Maximum Power (P_{max})

Maximum power (P_{max}) is the highest output from a solar PV module. The maximum power voltage (V_{mp}) and maximum power current (I_{mp}) are the voltage and current values that achieve this maximum power output.

D. Fill Factor (FF)

The Fill Factor (FF) is the ratio of the maximum power from a solar cell to the product of V_{oc} and I_{sc} . FF measures how "square" the I-V curve is. A solar cell with a higher voltage can achieve a larger FF because the "rounded" part of the I-V curve occupies less area. A good FF indicates the quality of a solar cell, typically above 0.7, reaching up to 0.82 in some cases.

E. I-V Curve

The I-V curve represents all possible operating points (voltage and current combinations) of a solar panel under specific cell temperature and light intensity. Higher cell temperatures slightly increase current but significantly decrease voltage output. At a certain intensity, the output current and operating voltage of a solar panel depend on the load characteristics.

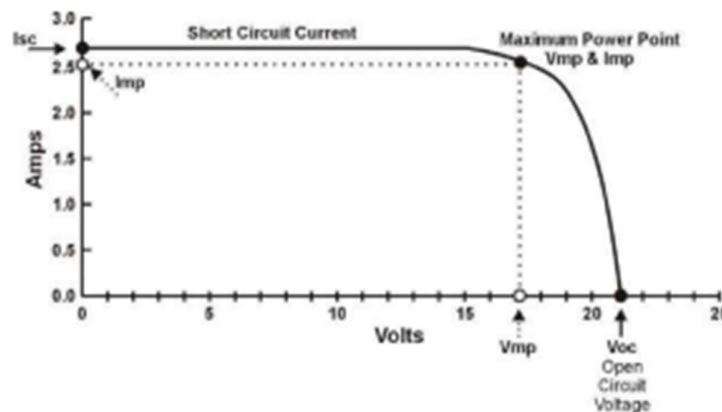


Fig. 5.13: Characteristics of a PV Cell with Operating Point (V_{mp}/I_{mp})

F. Efficiency

The efficiency of commercial solar PV modules usually ranges from 15% to 18%. This efficiency indicates the portion of sunlight converted into usable electricity. It, along with factors like latitude and climate, helps estimate the annual energy output of the system.

G. Standard Testing Conditions (STC)

Solar PV module performance is typically measured under Standard Testing Conditions (STC). This allows for fair comparisons of output among different solar PV modules. STC conditions include:

- a) Irradiance on the cell surface: 1000 W/m^2
- b) Air temperature: 25°C
- c) Air mass (AM): 1.5

H. Nominal Operating Cell Temperature (NOCT)

While PV modules are rated at STC (25°C , 1000 W/m^2 , AM 1.5), they generally operate at higher temperatures and lower sunlight levels in real conditions. To estimate the power output, it is important to know the module's expected operating temperature. The Nominal Operating Cell Temperature (NOCT) is the temperature of open-circuited cells under these conditions:

- a) Irradiance on cell surface: 800 W/m^2
- b) Air temperature: 20°C
- c) Wind velocity: 1 m/s
- d) Mounting: open back side

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. Solar Panel Generates power in –

- a. DC
- b. AC
- c. HVAC
- d. HVDC

2. Most Efficient Solar panel.

- a. Mono crystalline
- b. Polycrystalline
- c. None of this
- d. Thin Film

3. Solar Panel Rate in –

- a. Ampere
- b. Volt
- c. Watt

- d. Ohms
- 4. Solar PV Panel or Solar PV Cell made up of:
 - a. Silicon
 - b. Carbon
 - c. Metal
 - d. PVC

B. Fill in the Blanks.

1. Solar PV Module Works on _____ Principle.
2. _____ was least efficient Solar Panel.
3. Age of a Solar panel is _____ years.
4. Solar Panel use _____ for power generation.

C. Short answers Questions

1. A typical solar PV cell is a multi-layered unit consisting of?
2. How does a Solar PV Panel Works?
3. What is the Photovoltaic Principle explain.
4. Different types of solar Panels differentiate between them.

D. Practical Exercise:

1. Identify Different types of panels and measurements of these solar panel electrical parameters by using a Multimeter.

SESSION 3: EARTHING AND LIGHTNING PROTECTION

Lightning protection systems are designed to keep people safe from direct lightning strikes. If the photovoltaic (PV) system is located in an open area, it must have a proper lightning conductor. Lightning can cause voltage surges in the PV modules, the cables connected to them, and the main DC cable.

Here are some key points about overvoltage protection for PV systems:

- PV systems do not increase the chance of buildings being struck by lightning.
- If there is a lightning protection system, the PV generator must connect to it.
- It is advisable to use suitable surge arrestors on the DC side in the panel junction box.
- It is also wise to have overvoltage protection on the AC side.

External lightning protection includes all devices and measures used to catch lightning and direct it safely to the ground. This system typically consists of a lightning interception unit, a lightning wire, and an earthing system.

Internal lightning protection covers all equipment, like electronics and switching gear, designed to avoid lightning damage. All potentially conductive systems, such as AC units and heating appliances, must be connected to the earth or ground system.

Protection Methods

AC and DC side protection

To protect your solar panel system from surges, make sure to keep each string's positive and negative cables close together. This helps prevent short circuits. Use shielded individual cables if your system is at risk of lightning, ensuring the shield meets minimum standards. A good practice is to run the shielded DC main cable along the side of the building and connect it to the ground. You can also use a metallic protective pipe system.

Surge arrestors are important for protecting both the PV system and any electronic devices connected to it. These devices typically use Metal Oxide Varistors (MOV) and/or Gas Discharge Tubes (GDT) to divert high voltage away from sensitive equipment when needed. Keep in mind that both MOVs and GDTs have a limited lifespan and can only handle a certain number of surges.

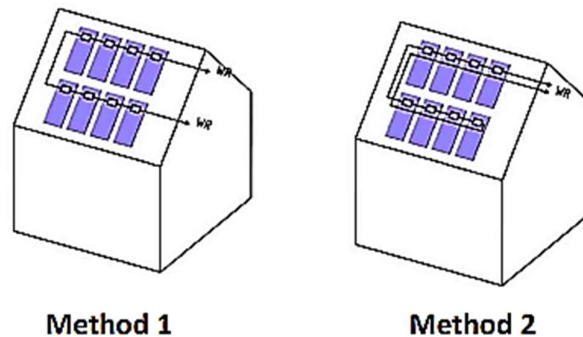


Fig. 5.14: The module cables should be placed close together (Method 2)

If you're using string protectors like fuses, DC breakers, or string diodes along with surge protection devices (SPDs), install the SPD between the junction box and the inverter.

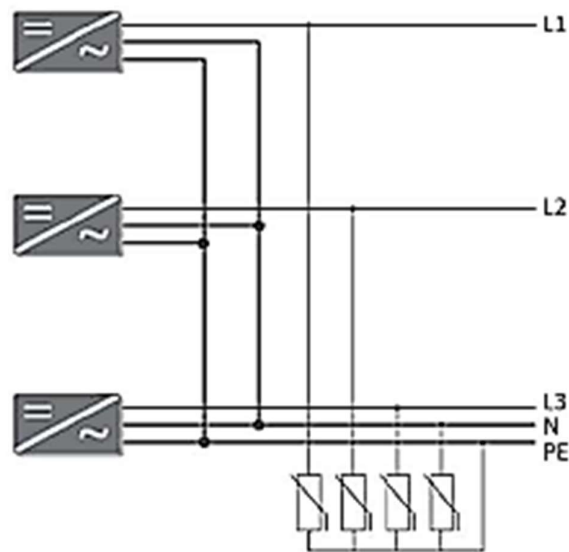


Fig. 5.15: Surge protection device (SPD) is connected between the junction box and the inverter

On the AC side, you can connect multiple inverters to the same SPD if they share a grid connection. Remember, the surge arrestors for the AC side are different. Always follow the wiring specifications for surge protection.

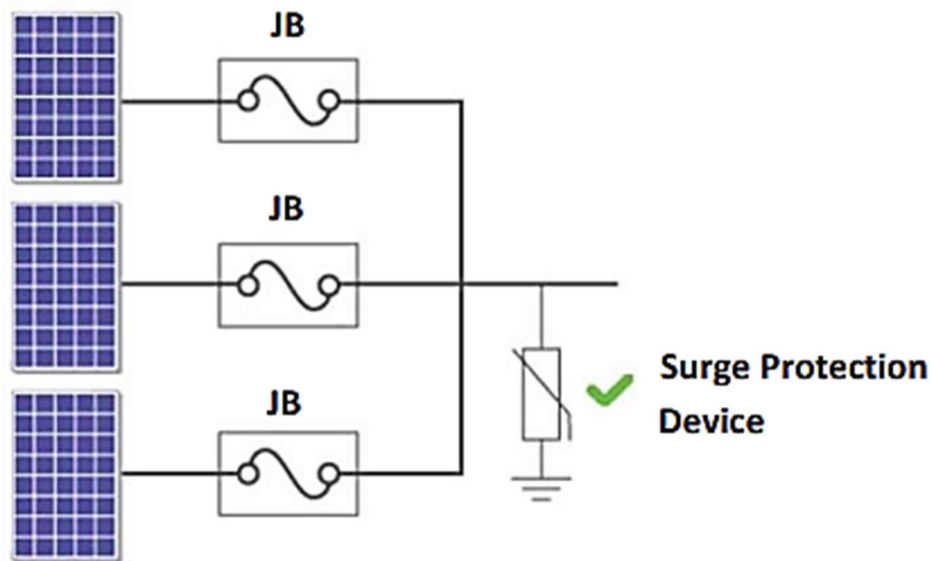


Fig. 5.16: Surge protection device (SPD) is connected between the junction box and the inverter

Earthing/Grounding

To protect against over voltages, it is important to properly earth or ground your system. This means equalizing potential and grounding effectively. Lead the grounding conductor to the earth using the shortest path possible and avoid loop formations. Ensure that the earthing conductors are laid straight for the best results.

The mounting system of the PV panels should be properly bonded. You can use materials like copper (16 mm^2), aluminum (25 mm^2), steel (50 mm^2), and even existing metal parts of the building, such as frames and railings, for earthing conductors.

Earthing is essential not just for creating a reference point but also for safety. It protects:

1. Personnel (engineers, technicians, and consumers) from:

- Electrocution
- Fire

2. Equipment and facilities from:

- Failure
- Fire

3. Electrical circuits from:

- Cable failures

For effective protection, the grounding system must respond quickly to reduce possible damage.

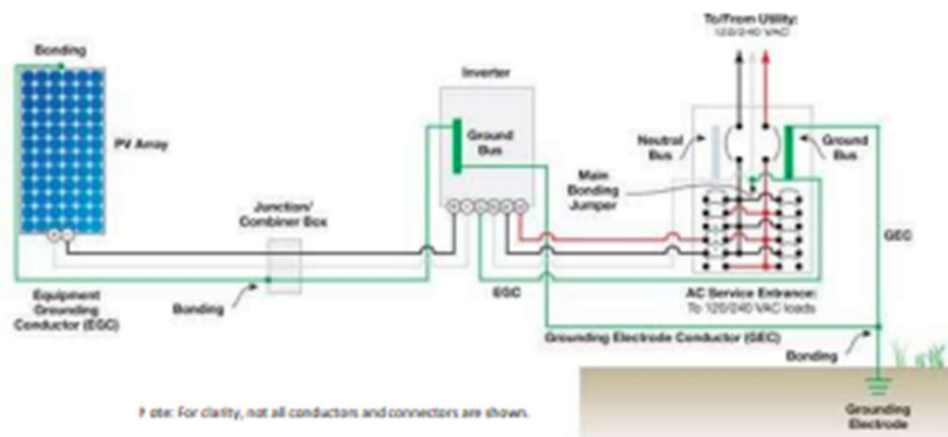


Fig. 5.17: Earthing/ Grounding of a Solar PV System

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. What is the main purpose of a lightning protection system?
 - a) To attract lightning to the building

- b) To keep people safe from direct lightning strikes
- c) To increase energy efficiency
- d) To reduce panel temperature

2. Surge arrestors on the DC side of a PV system are usually installed in the:

- a) Inverter
- b) AC distribution box
- c) Panel junction box
- d) Battery bank

3. Which of the following materials can be used for earthing conductors?

- a) Plastic
- b) Copper and Aluminum
- c) Wood
- d) Glass

4. What type of devices are commonly used in surge arrestors?

- a) Resistors and capacitors
- b) Diodes and transformers
- c) Metal Oxide Varistors (MOV) and Gas Discharge Tubes (GDT)
- d) Inductors and fuses

B. Fill in the Blanks

1. PV systems do not increase the chance of buildings being struck by _____.
2. External lightning protection includes devices used to catch lightning and direct it safely to the _____.
3. The earthing conductor should be led to the earth using the _____ path possible to avoid loops.
4. The mounting system of PV panels should be properly _____ to ensure safety.

C. Answer the following Questions

1. What is the function of surge arrestors in a PV system?
2. Why is proper earthing or grounding important in a PV system?
3. What is the difference between external and internal lightning protection?
4. What are the recommended materials and sizes for earthing conductors in PV systems?

Module 6: Interpretation of Drawings, Material Handling and Storage of Components on Site

Major System Components

The major components for solar PV system are solar charge controller, inverter, battery bank and loads (appliances) typically represented on the electrical diagram (SLD). Below some of the basic definitions of the solar components have been mentioned:

- PV Module – converts sunlight into DC electricity.
- Solar charge controller – regulates the voltage and current coming from the PV panels going to the battery and prevents battery overcharging and prolongs the battery life.
- Inverter – converts DC output of PV panels or wind turbine into a clean AC current for AC appliances or feedback into grid line.
- Battery – stores energy for supplying to electrical appliances when there is a demand.
- Cables (AC and DC), mounting structures and its accessories, Junction boxes (AC - Distribution Box, DC - Distribution Box/String Junction Box/String Combiner Box/Array Junction Box).



Fig. 6.1: Major system components

Session 1: Prepare Bill of Material

A bill of material is a formally structured list for an object (semi-finished or finished product) which lists all the component parts of the object with the name, reference number, quantity, and unit of measure of each component. A bill of material can only refer to a quantity greater than or equal to one of an object. It is a product data structure, which captures the end products, its assemblies, their quantities and relationships.

There are usually two kinds of bills of materials needed for a product: engineering and manufacturing BOM. The engineering BOM normally lists items according to their relationships with parent product as represented on assembly drawings. But this may not be sufficient to show the grouping of parts at each stage of the production process nor include all of the data needed to support manufacturing or procurement. These requirements may force the arrangement of the product structure to be different in order to assure manufacturability. Thus, engineering and manufacturing will usually have different valid views for the same product.

A Bill of Materials is a product data structure which captures the end-products, its assemblies, their quantities and relationships. The structure of a part's list determines the accessibility of the part's information by various departments in a company. It also helps to determine the level of burden put on the computational device in searching for product information. In many companies the BOM is structured for the convenience of individual departments. This, however, engenders problems in other departments.

Bill of Material:

A typical BOM format is shown below. Actual Contents/Description shall be listed as per the actual requirement.

Table 6.1: Form to tabulate BOM

Bill of Materials/BOM					
Sl. No.	Item	Description	Quantity	Cost	Remarks

Prepare BOM from Single Line Diagram, Civil/Mechanical Drawings and Electrical Drawings

Let's understand the preparation of BOM of PV Solar system by taking a simple case (50KW Solar Power system). In order to fetch the BOM of any PV solar system, following design documents one generally (but not limited to these) used.

Single Line Diagram

Civil structural General arrangement drawing

A Single Line Diagram (SLD) or sometimes called One-line diagram is a simplified notation for representing an electrical system. Electrical elements such as circuit breakers, transformers, capacitors, bus bars, and conductors are shown by standardized

schematic symbols. It is a form of block diagram graphically depicting the paths for power flow between entities of the system.

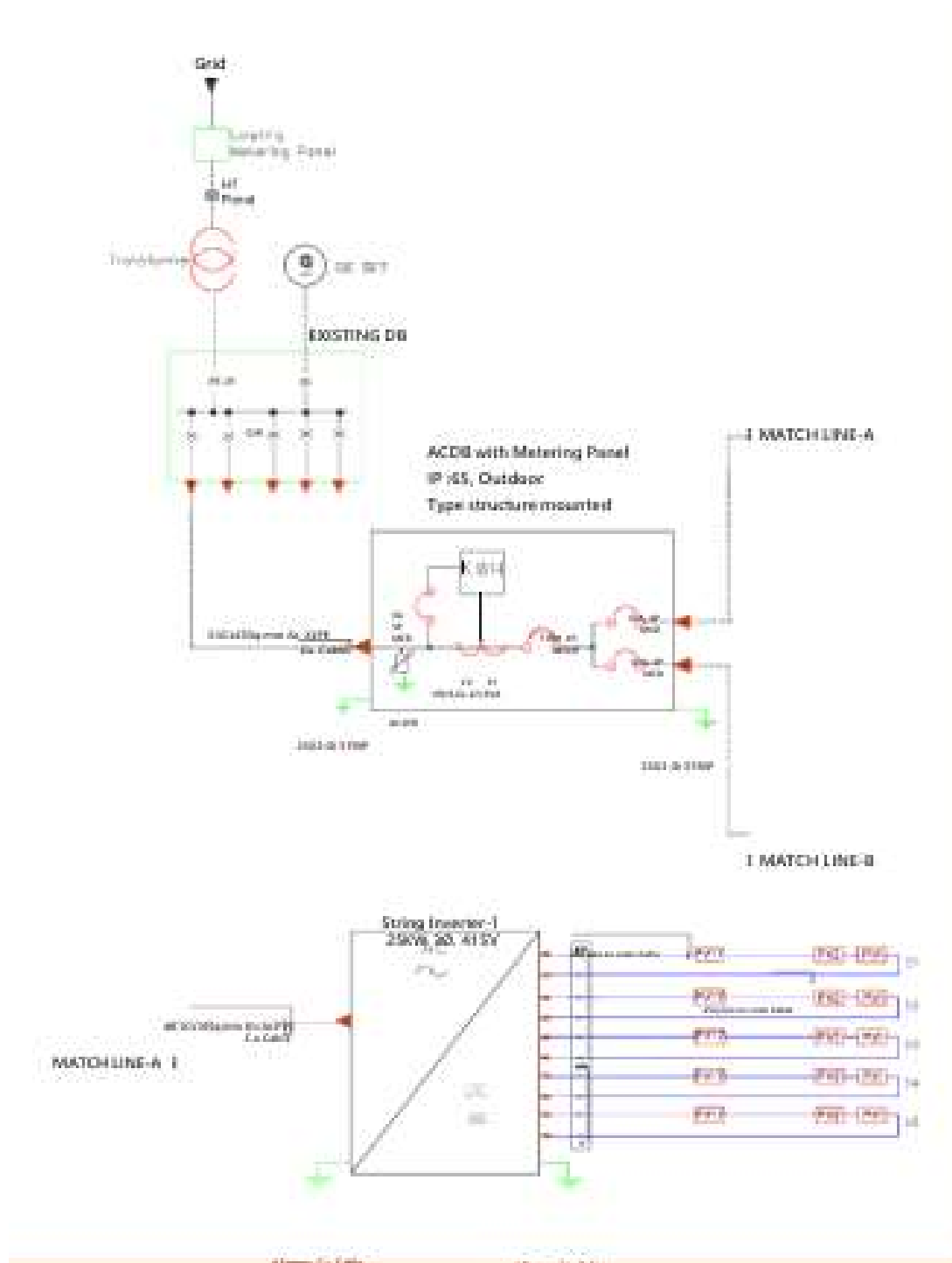


Fig. 6.2: Block Diagram Graphically Depicting the Paths for Power Flow Between Entities of the System

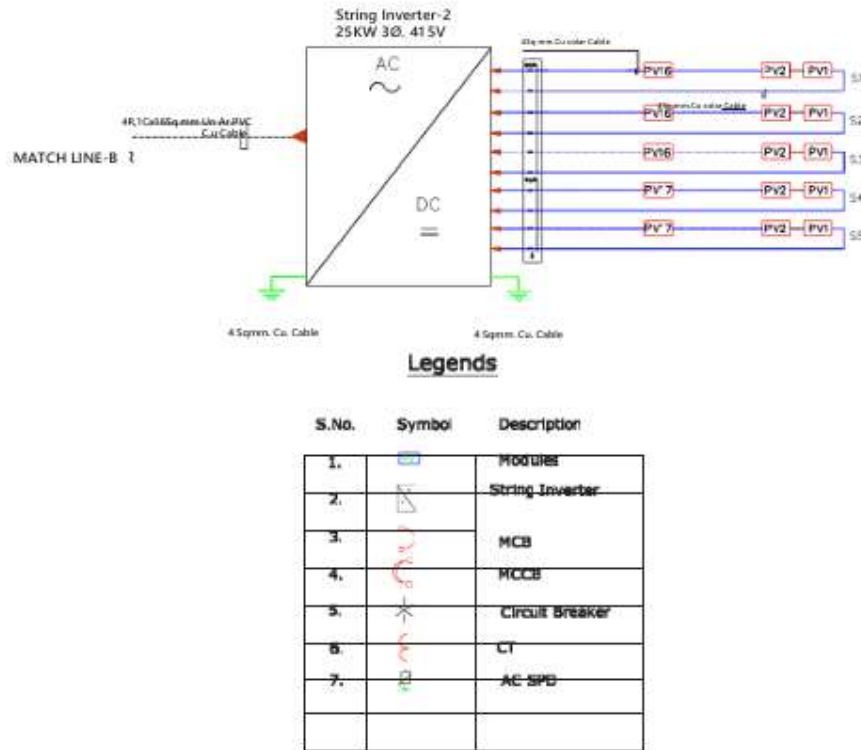


Fig. 6.1.2 Single Line diagram for a 50KW solar PV system

Fig. 6.3: Single Line Diagram for 50KW solar

Now let's start quantifying the items from the above shown SLD

Table 6.2: Sample Bill of Materials

SAMPLE BILL OF MATERIAL (BOM)				
ELECTRICAL COMPONENTS				
SL.	ITEM	DESCRIPTION	QTY	
1	Modules	300Wp, As per specification	167	
2	Inverter	25 KW Capacity, as per specification	2	
3	ACDB Metering Panel	IP65, outdoor type structure mounted	As Per Required	
4	Cable	1C X 16 SQ.MM Cu, AR, PVC	As Per Required	
5	Grounding Wire	4SQ.MM, Cu	As Per Required	
6	Tool & Tackles	AS PER VENDOR RECOMMENDATION	-	
7	Consumables		LOT	

Now let's see the Civil/ structural drawing. Below figure shows the plan view of the system arrangement reflecting the distance between two footings/ base.

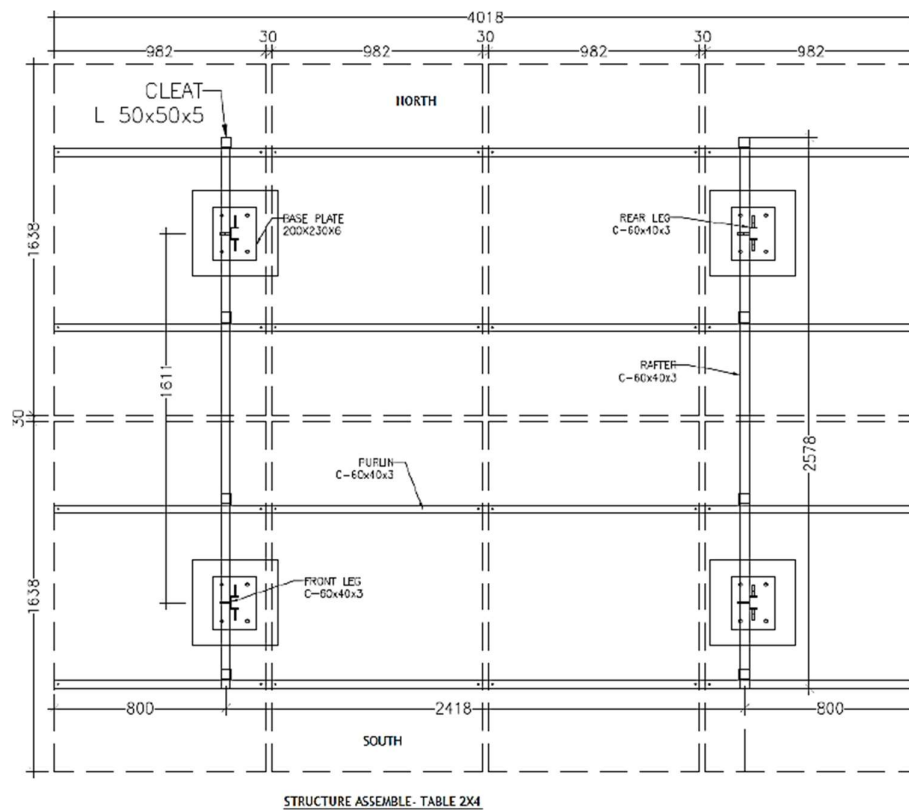


Fig. 6.4: Plan View of the System Arrangement Reflecting the Distance Between Two Footings/ Base.

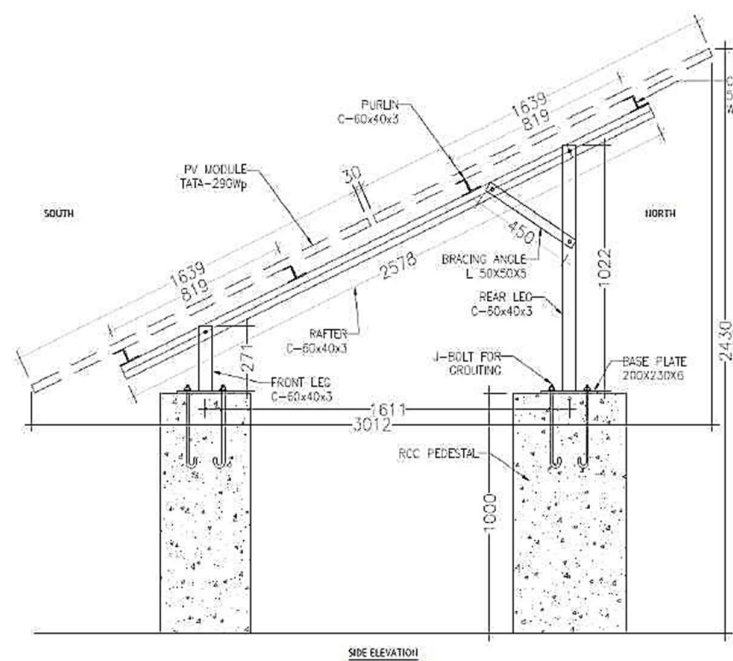


Fig. 6.5: Side View of the System Arrangement Reflecting the Distance Between Two Footings/ Base.

3 Civil/Structural drawings from AutoCAD simulation

Thus, BOM for the civil items from above shown civil drawings are as follows:

Table 6.3: Sample Bill of materials

SAMPLE BILL OF MATERIALS				
CIVIL STRUCTURAL COMPONENTS				
SL.	ITEM	DESCRIPTION	QTY	
1	Purlin	C-60X40X3 (mm); LENGTH:4018 mm	16100	mm
2	Rafter	C-60X40X3 (mm); LENGTH:2578 mm	5200	mm
3	Bracing Angle	L- 50X50X5 (mm); LENGTH:450 mm	900	mm
4	Front Leg	C- 60X40X3 (mm); LENGTH:271 mm	600	mm
5	Rear Leg	C- 60X40X3 (mm); LENGTH:1022 mm	2100	mm
6	Cleat	50X50X5 (mm)	As Required	
7	Base Plate	200X230X6 (mm)	4	Nos.
8	J Type Bolt		16	Nos.
9	Bolt	M10	As Required	

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. What is the primary function of a solar charge controller in a PV system?

- A) Converts DC to AC power
- B) Regulates voltage and prevents battery overcharging
- C) Stores solar energy
- D) Controls current flow to the inverter

2. The component responsible for converting DC output from PV modules into AC electricity is called:

- A) Solar charge controller
- B) Battery bank
- C) Inverter
- D) Module junction box

3. Which document is used to represent the electrical layout of a solar PV system using schematic symbols?

- A) Civil drawing
- B) Single Line Diagram (SLD)
- C) Mechanical layout
- D) Bill of Quantity

4. In a Bill of Material (BOM), which of the following details is generally not included?

- A) Quantity

- B) Cost
- C) Supplier's annual sales
- D) Description of item

B. Fill in the Blanks

1. A PV Module converts _____ into DC electricity.
2. The battery in a solar PV system stores energy for supplying to electrical _____ when there is a demand.
3. The inverter converts DC power from PV modules into _____ power for use in homes or feedback to the grid.
4. A Bill of Material (BOM) lists all parts of a product with their name, reference number, _____, and unit of measure.

C. Short Answer Questions

1. List any four major components of a solar PV system.
2. What is the function of a Single Line Diagram (SLD) in solar PV system design?
3. Why is a Bill of Material (BOM) important in a solar PV project?
4. What is the difference between Engineering BOM and Manufacturing BOM?

SESSION 2: PROCUREMENT OF THE SOLAR PV SYSTEM COMPONENTS

Steps to be Followed for the Procurement of Solar PV System Components

STEP 1: Approach stores of the Company with BOM & Specifications

Procurement for the components shall be done based on the quantity mentioned in the BOM & specification mentioned or attached with the BOM. Below are some specifications of major components for reference only.

- a) Solar panel specification: The Following key specifications (but not limited to these) must be taken into consideration for procuring the Solar panel.
- Rated Power at STC (Standard Test Conditions)
 - Rated Power Tolerance (%)
 - Temperature Coefficient
 - Open circuit voltage
 - Voltage at MPP
 - Short Circuit Current
 - PV Module
 - Current at MPP
 - Efficiency
 - Module Dimensions
 - Operating Temperature

Table 6.3: Specification Sheet for a solar PV panel

[illegible]

b. Inverter specification: Following key specification (but not limited to these) must be taken into consideration for procuring the Inverters.

- Type of Inverter
- AC Output capacity
- DC input voltage range
- Operating temperature range

The below specifications pertain to the standard branded SPV Module just for reference

Table 6.4: Sample Specification Sheet for Inverter

SPECIFICATION SHEET						
Model	100W/200W/300W / 400W/12 V	500W/ 24V	750W/ 24V	1000W/ 24V	1500W/ 48V	2000W/48 V
Rated Power	100W/200W/300W/ 400W	500W	750W	1000W	1500W	2000W
INPUT						
Nominal Input Voltage	12VDC	24VDC	24VDC	24VDC	48VDC	48VDC
Input Voltage Range (DC)	10.5-15.5VDC	21.0-31.0 VDC	21.0-31 VDC	42.0-62.0 VDC	42.0-62.0 VDC	42.0-62.0 VDC
Battery Low Alarm	10.7 VDC	21.5VDC	21.5VDC	21.5VDC	43.0VDC	43.0VD C
Battery Low Shutdown	10.5 VDC	21.0VDC	21.0VDC	21.0VDC	42.0VDC	42.0VD C
Output						
Efficiency	85%					
Output Voltage	110VAC 50- Hz/220 VAC 50 Hz					
Voltage Regulation	+/-3% TO +/-10% RMS					
Output Waveform	Sine Wave form					
THD	<5%					
Overload	Above 110%					
Protection	Overload, Short Circuit, Reverse Polarity through DC fuse, over temperature					
General						
Operating Temp Range	0 deg C to 40 deg C					
Storage Temp Range	-20 deg C to 70 deg C					
Thermal Management / Cooling	Controlled forced air cooling					
Relative Humidity	0-95% Non-Condensing					
Dimensions WxDxH (in mm)	200x361x85		240x380x100		250x450x125	250x450x125
Weight (kgs)	3.8		5.4	6	8	9
Indications	Low battery, Overload/ Short circuit, Inverter on					

c. Charge controller specification: Proper selection of Charge controller can make run the entire battery based PB system efficiently & longevity.

Solar charge controllers are rated and sized by the solar module array current and system voltage. There are two types of charge controllers:

- Pulse width modulation (PWM)
- Maximum power point tracking (MPPT)

PWM solar charge controller: The PWM charge controller is a good low-cost solution for small systems only, when solar cell temperature is moderate to high (between 45°C and 75°C).



Fig. 6.5: PWM solar charge controller, solar regulator 6A, 12V

Table 6.5 Sample Specification Sheet for a charge controller

TECHNICAL SPECIFICATION	
Type	Series Regulators Common Negative
Technology	Microcontroller-Based Control
System Voltage	240V
ELECTRICAL PARAMETERS	
Charging current	40 Amp
Solar Array	Single Array
Bulk Voltage	282 +/- 2V
	Adjustable 270 ~ 290 V
Absorption period	Hold battery voltage or bulk setting for a cumulative period of 1 hr
Float Voltage	270 +/- 2V
Indications	LED Indications for Bulk Mode, Float Mode, High Current, Low Battery
	High Battery, Array/ Battery Reverse Polarity
	An analogue type voltmeter and ammeter with a selector switch for monitoring the voltage of the solar array/ battery and charge current
ENVIRONMENTAL PARAMETERS	
Operating Temperature	0 Deg C to + 40 Deg C
Storage Temperature	0 Deg C to + 55 Deg C
Relative Humidity	0~ 95% Non-Condensing
Dimensions WxDxH (in mm)	400 x 475 x 151
Weight (in Kgs)	9.5

MPPT Solar Charge Controller

The MPPT are most common these days and can gain you up to 30% more power than the PWM controllers. The MPPT controllers also allow the strings of panels to be connected in series for higher voltages, keeping the amperage lower and the wire size smaller, especially for long-wire runs to the PV array.



Fig. 6.6: MPPT 60 150 Charge Controller

Below is the technical specification just for reference:

Table 6.6: Sample specification sheet for an MPPT solar charge controller

TECHNICAL SPECIFICATION	
Type of Product	MPPT With Load Charger
Voltage(V)	12 V - 24 V
Current(A)	20 A
Application	Off-grid and micro grid. Telecom grid solar system. Home lighting system and street lighting system.
Product Warranty	2 Years

- b. Solar Cables:** Solar cables are the interconnection cables used in photovoltaic power generation. A solar cable interconnects solar panels and other electrical components of a photovoltaic system. Solar cables are designed to be UV resistant and weather resistant. It can be used within a large temperature range and are generally laid outside.

Cables are generally sold in 6, 30, 50- and 100-foot lengths, with a wire gauge size of AWG 10 (30- amp capacity) or AWG 12 (25 amps). They're also typically rated to handle either 600 or 1,000volts.



Fig. 6.7: Solar Cable

- c. **Solar batteries specification:** Deep-cycle, lead-acid batteries are widely used in renewable energy and grid-backup system, and are ideally suited for these applications because of their long, reliable life and low cost of ownership. There are many companies that sell deep-cycle lead-acid batteries, so it is important to understand the technologies and other performance factors that affect overall operation and battery life.

Some important factors are as below:

- **Capacity-** Battery capacity is important because it's a measure of the amount of energy stored in the battery.
- **Voltage-** the battery bank voltage must be considered to ensure it matches the system requirements. The battery bank voltage is often determined by the inverter specifications if installing a DC-to-AC system or by the voltage of the loads in a DC system
- **Cycle Life-** The most critical consideration is cycle life, which provides the number of discharge/charges cycles the battery can provide before capacity drops to a specified percentage of rated capacity. Batteries from different manufacturers may have the same capacity and energy content and be similar in weight. But design, materials, process and quality influence how long the battery will cycle.

Below battery specification is just for reference:

Table 6.7: Sample Specification sheet for a Battery

SPECIFICATION SHEET									
Model	Nominal Voltage (V)	Nominal Capacity (AH)	Dimensions (mm)				Approx . Weight (Kg)	Terminal Position	Terminal Type
			Length	Width	Height	Total Height			
Vendor Specific	2	100	103	206	355	409	12.6	G	M10
	2	150	103	206	355	409	15.3	G	
	2	200	103	206	355	409	17.2	G	
	2	250	124	206	355	409	20.8	G	
	2	300	145	206	355	409	24.3	G	
	2	350	124	206	470	525	26.9	G	
	2	420	145	206	470	525	31.5	G	
	2	500	166	206	470	525	36.1	G	

STEP 2: Identify and list the variation in equipment specifications, if any & submit to design team, if necessary.

Before placing the order for components, make ensure that the components which are going to be ordered are matching the design requirement. It is also standard procurement practices that get the list of variation or deviation from the Vendor itself with the proper technical justification for further evaluation by the design team (if required) & obtain the approval or revised drawings.

STEP 3: Arrange the Tools and consumables

Identify the Tools & Tackles (get special tools recommended by Vendor, if any) required for installing the solar panels. Below are listed some Tools & Tackles required for mounting the solar panels.



Fig. 6.8: Types of Tools

- a. Hammer
- b. Plier
- c. Screwdriver
- d. Measuring Tape
- e. Driller
- f. Multi-meter
- g. Utility knife
- h. Ratchet set

Consumables

- a. Electrical tape
- b. Cable ties
- c. Cable clip
- d. Silicon caulking
- e. Bolts
- f. Splice
- g. Washer
- h. Mounting clips

STEP 4: List the Statutory requirements/compliances required for the components

To obtain subsidies or participate in government schemes, registration of module types with the Indian Ministry of New & Renewable Energy (MNRE) is required. Only MNRE approved suppliers and modules types are entitled to the MNRE policy schemes & subsidies.

MNRE compliance requires conformity to latest standards by the Bureau of Indian Standards (BIS). Major BIS standard for Solar PV module are:

- IS 14286 (adopts IEC 61215)
- IS 61701

Make sure the supplier confirms the statutory requirements according to customer before placing the order.

System Warranty: The majority of solar panels on today`s market come with a 25-year long warranty (also known as a performance guarantee). In most cases this means a guaranteed electrical production for 10 years at 90% of rated power output and 25 years at 80%.

STEP 5: Make sure all the material certificates are available with Supplier.

STEP 6: Complete all the required documentation w.r.t. Procurement.

Verify the Components On-Site

1. Plan and Receive the Equipment at Site:

Make ensure that before arrive the components at site, pre-installation works has been completed. If not, proper arrangement has been done for storage.

2 Material Handling

Make ensure that all the components are handled and stored properly as per standard operating procedures provide by supplier. It can be under sunshade, rain protected place. Make ensure electronics/ electrical components/ structural materials are placed properly at the site.

Sl. No	Dos	Don'ts	Remarks
1	Open the boxes carefully. Wrap the unpacked box properly once the inspection is done. Follow Vendor vendor-provided storage procedure strictly.	Do not spread the parts/ materials on the surface	
2	Always use gloves while handling hazardous equipment like batteries	Never handle the equipment like batteries with your bare hands as it contains acid.	
3	Wrap the nuts & bolts properly.	Do not start using tools & tackle without proper knowledge	

Check Materials Received On-Site

Most of the manufacturers bound some restrictions and deadlines when it subject to return or exchange the supplied items because of any reason, so it is always better to inspect immediately once the components arrived at site. Inspect all the components for sign of wear, poor seal, damage (take snapshots, if any). Make the report & document the status of material received at site.

Below is a check list for site verification, just for reference.

Sl. no	Item to be checked/ verified after receiving the purchased components at the Site.	Yes/ No	Remarks
1	Check Component qty as per final BOM		
2	Check that Equipment and parts are properly labelled as required		
3	Make ensure that all the components received damaged free		
4	Check the all the require documents like Manufacturer operation and maintenance instructions, Manufacturers As built drawing, Catalogues, storage & handling procedure, list of deviation are received		
5	System warranty		
6	All QC inspection reports		

7	Certificates regulatory required as per local/ national		
8	Check the received accessories for mounting panels are compatible with the fabricated structures at site		
9	Check all the recommended tools & tackles are received		

CHECK YOUR PROGRESS

A. Multiple Choice Questions

- The procurement of solar PV system components should be done based on:
 - Random selection
 - Quantity and specifications mentioned in BOM
 - Lowest market price
 - Vendor's personal choice
- The main advantage of an MPPT charge controller over a PWM controller is that it:
 - Is cheaper
 - Gains up to 30% more power efficiency
 - Requires no maintenance
 - Works only at low temperatures
- To receive MNRE subsidies, solar modules must:
 - Be imported from other countries
 - Be approved by BIS only
 - Be registered with the Ministry of New & Renewable Energy (MNRE)
 - Have a 10-year warranty
- The majority of solar panels come with a warranty of:
 - 10 years
 - 15 years
 - 20 years
 - 25 years

B. Fill in the Blanks

- The procurement of components shall be done based on the quantity and specification mentioned in the _____.
- The two types of solar charge controllers are _____ and _____.
- Solar cables are designed to be _____ resistant and _____ resistant.
- The MNRE compliance requires conformity to the latest standards by the _____.

C. Short Answer Questions

1. Why is it important to verify the specifications of solar components before placing an order?
2. What are some important tools and consumables required for installing solar panels?
3. Mention two key specifications considered while procuring a solar panel.
4. What should be checked when the solar components are received on-site?

SESSION 3: INSTALL CIVIL & MECHANICAL PARTS OF SOLAR PV SYSTEM**Equipment Foundation Construction for Solar PV Systems**

When installing a solar photovoltaic (PV) system, the solar array is typically mounted on rooftops, ensuring a few inches of gap and parallel alignment to the roof surface. If the rooftop is horizontal, the panels are positioned at a specific angle for optimal performance. In cases where panels will be mounted before roof construction, the roof design can incorporate support brackets for the panels, facilitating their installation alongside the roofing materials. If the roof is already built, retrofitting panels onto the existing structure can be done relatively easily.

Footing Types for Roof Installations

The recommended approach to securely mount PV panels on roofs is to utilise a pedestal-type footing, minimising roof penetration. The type of footing required is contingent upon the roof type, which in India typically falls into two categories: flat roofs and sloped roofs.

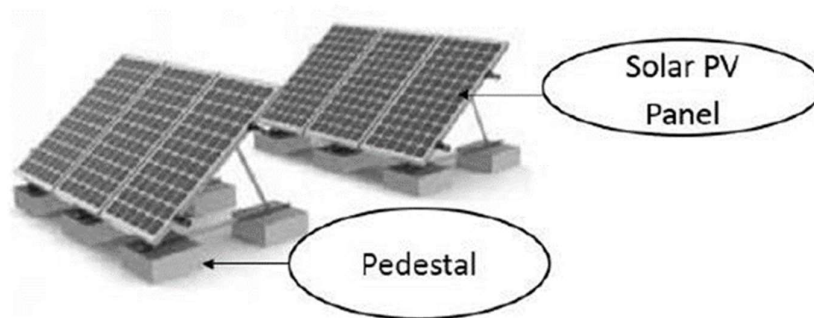


Fig. 6.9: Pedestal Solar PV Panel

The installation of PV panels can introduce various hazards that may compromise the roof's structural integrity. Roofs must not only bear the dead load of the PV system but also withstand external forces such as wind, hail, snow, debris, and extreme temperatures. The mounting structure must be designed to endure these environmental factors, ensuring a lifespan of at least 25 years.

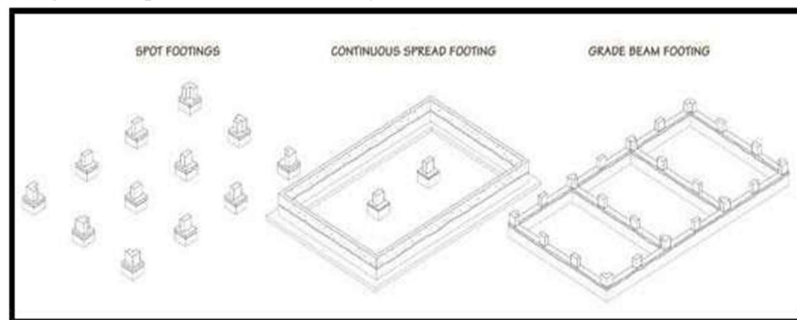


Fig. 6.10: Mounting Structure

Types of Footings

1. Spot Footings:

Spot footings, also known as pad footings, provide support at a single point, such as beneath a pier or post. They typically measure 2 feet by 2 feet in size, with a thickness of 10 to 12 inches, and are constructed using reinforced concrete rated for 3,000 to 5,000 pounds per square inch (psi).

2. Continuous Spread Footings:

Commonly used to establish a stable base around the perimeter of a structure, continuous spread footings connect the front and back legs of the structure. Their thickness and wider base are designed to support significant weight while distributing it over a large area. The dimensions can vary based on factors such as load, soil conditions, and wind sustainability analysis, often measuring 16 to 24 inches wide and 6 to 16 inches thick, utilizing reinforced concrete rated for 2,000 to 5,000 psi.

3. Grade Beam Footings:

Grade beam footings consist of continuous reinforced concrete components designed to support loads with minimal bending. These footings are typically created by excavating an 8-inch-wide trench to the necessary depth or constructed above the roof level to span the distance between supports. Unlike continuous spread footings, grade beams are designed to effectively distribute loads to their bearing points.

By carefully selecting the appropriate type of footing and ensuring proper installation practices, the longevity and safety of solar PV systems mounted on rooftops can be greatly enhanced.

Flat Roofs

In roof-mounted systems on flat roofs, solar panels are placed on a mounting structure above the roof. The panels are tilted at an angle using support structures. It's important to secure the mounts carefully because solar panels are large and wind forces can be strong. The type of roof will determine the kind of footing used. The roof's ability to support more weight will decide if the system can use ballast (weights) or needs to be anchored to the roof.

Ballast Mounted

In ballast-mounted systems, the flat roof mounts don't penetrate the roof. Instead, concrete blocks, slabs, or plinths rest on the flat roof without additional fixing, and support frames are attached using screw anchors. You can use standard building materials like curbs and paving slabs for the concrete blocks. If needed, a protective mat

should be placed beneath to guard the roof from sharp edges. Alternatively, concrete weights can be added to channels on the support frame.

Anchoring

If ballast mounting is not possible due to structural reasons, the solar array must be securely anchored to the roof. This means that the supporting frames are attached to crossbeams fixed to the roof itself or the roof parapet. Where the roof's waterproofing is pierced, the anchorage points must be sealed carefully. When designing the layout, it's best to minimize the number of penetrations. If you are refurbishing flat roofs, anchoring can be easily done as the pressure points of the solar structure can be sealed at the same time.

Slope Roof

On sloped roofs, the solar panels are placed above the existing roof covering using a metal support structure. This metal structure has three main parts:

- Roof mounts
- Mounting rails
- Module fixings

The roof mounts attach a rail system to the roof structure beneath the covering or directly to the roof covering itself if it's strong enough. The modules attach to the rails using specific fixing elements.

Locate Structural Footings

After you determine the type of footing, check the design to find the structural footing needed. A sample design is provided for your reference.

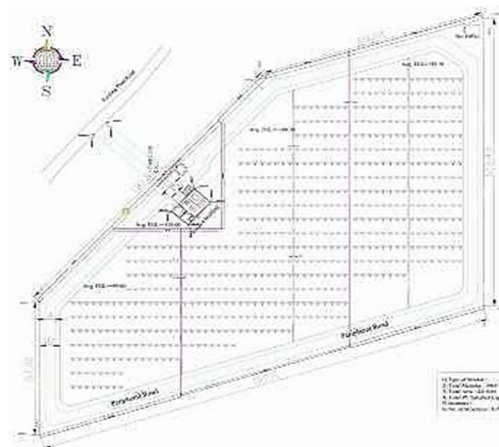


Fig. 6.11: Sample PV Array Layout Design

Arrange for Tools and Consumables Required for Civil/Mechanical Installation

1. Hammer	6. Plumb bob	11. Line dori
2. Screw Driver	7. Measuring tape	12. Clamps
3. Nail puller	8. Drill machine	13. Digging bar
4. Measuring square	9. Utility knife	14. Spade
5. Hand saw	10. Chisel	15. Spirit Level



Fig. 6.12: Tools and Tackles for Civil/Mechanical work

Construct Concrete Forms According to Design Specifications

Build concrete forms according to the design. For a pedestal, the roof usually needs to be chipped. The illustration below shows a side view of a reinforced cement concrete (RCC) pedestal.

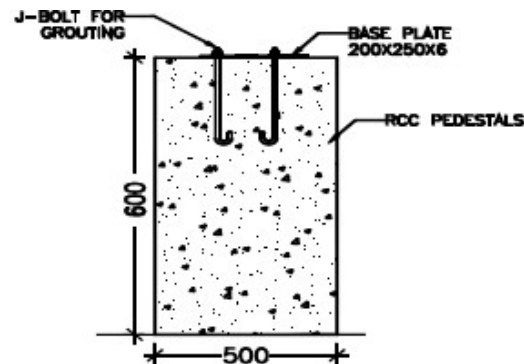


Fig. 6.13: Side view of an RCC pedestal

After preparing the pedestal as shown, attach a base plate that measures 200x250x6 using J-type bolts. The next illustration shows base plates available in the market with different numbers of holes.

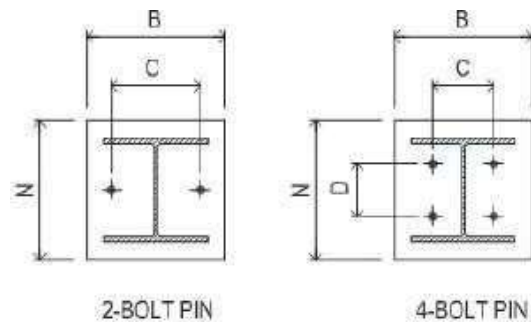


Fig. 6.14: Types of Base plates available in the market

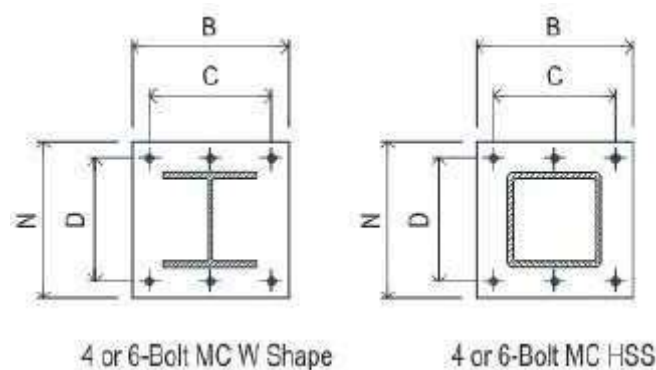


Fig. 6.15: Types of Base plates available in the market

A general concrete mixing ratio is displayed in the illustration below.

Table 6.8: Concrete Mixes and Purpose

Type of Concrete	Proportion of Mix				Nature of Work
M5	1	:	5	: 10	Mass Concrete for heavy walls, foundation, footings
M7.5	1	:	4	: 8	Mass concrete and foundations
M10	1	:	3	: 6	less importance
M15	1	:	2	: 4	For general RCC works (slabs, beams, columns, etc.)
M20	1	:	1.5	: 3	Water retaining structures, piles and general RCC structures
M25	1	:	1	: 2	Heavily loaded RCC structure, long span slab, beams, etc.

Install Mounting Posts, Roof Attachments and Anchors

Installation of a mounting post for fixed structures with legs

A foundation for supporting the mounting structure can be constructed in accordance with the site conditions. For installing the mounting post, kindly refer to the design

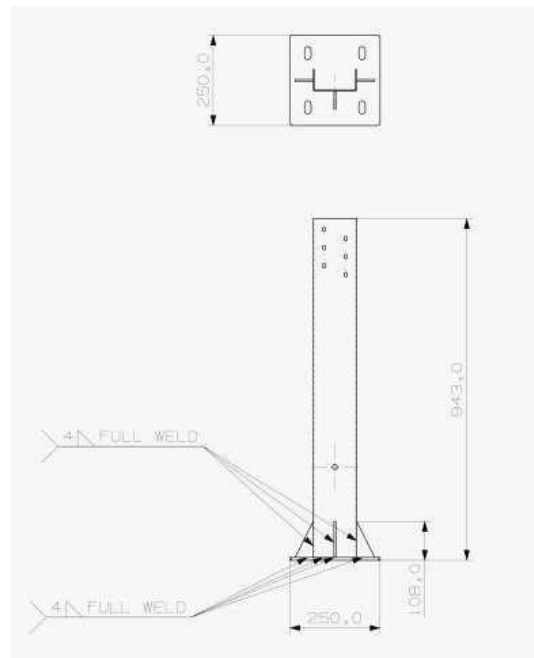
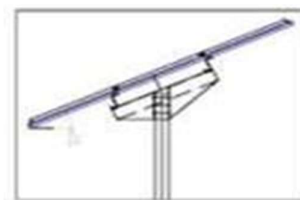


Fig. 6.16: Sample design for installing the mounting post

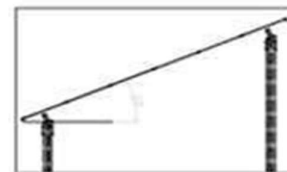
Install Mounting System

Different Types of Mounting Structures

1. **Single-Pole Static Structure:** This system installs quickly and securely supports solar panels on a single pole. It has fewer parts for easier assembly and uses strong, welded steel with rust-resistant hardware for long-lasting reliability. This design allows for seasonal adjustments to maximise energy production with a single person operating it.
2. **Double Pole Static Structure:** This structure is suitable for both flat and sloped ground and is often used in remote solar applications.
3. **Pitched Roof Mounting System:** This system makes it easy to install solar panels on different types of pitched roofs. The setup is simple—just click, position, and secure the panels. The



Single Pole Static structure



Double Pole Static structure



thinner rails lower costs while still providing stability.

4. Rails and Racks: This flexible system allows for easy mounting of framed and unframed panels on standard trapezoidal metal roofs. Unique hook designs help with fast and easy installation by attaching easily to standing seams. The positioning of screws improves stability and allows for simple adjustments.



5. Trapezoidal Roof Mounting Structure: This system can be customised to meet individual needs, offering variable tilt angles and multiple anchoring options, such as weights or roof penetrations, making it adaptable to challenging roof conditions.



6. Single Pole Ground-Mount System: This cost-effective design works for both laminate and framed panels. It uses ramming posts to avoid extra digging, making it look good and economical for large projects. Different layouts are available based on project needs.



7. Single Pole with Frames Type of Module: This system combines the benefits of both single-pole and double-pole designs. Maintenance is easier with the same number of panels. It fits various terrains and allows for panels to be installed vertically or horizontally. The simple design minimizes installation costs.



8. Double Static Concreted Pole: This design is for tough ground conditions, like landfills. It allows for arranging panels in multiple rows and columns. It requires very little maintenance over time.



9. Pole Top Mounting Structure: This option lets you produce energy anywhere without needing a connection to the power grid. The pole provides an ideal decentralised solution and can adjust to local conditions for optimal performance. The single post also offers theft protection. Like all systems, it is made from high-quality aluminum and stainless steel for long-lasting use with minimal maintenance.



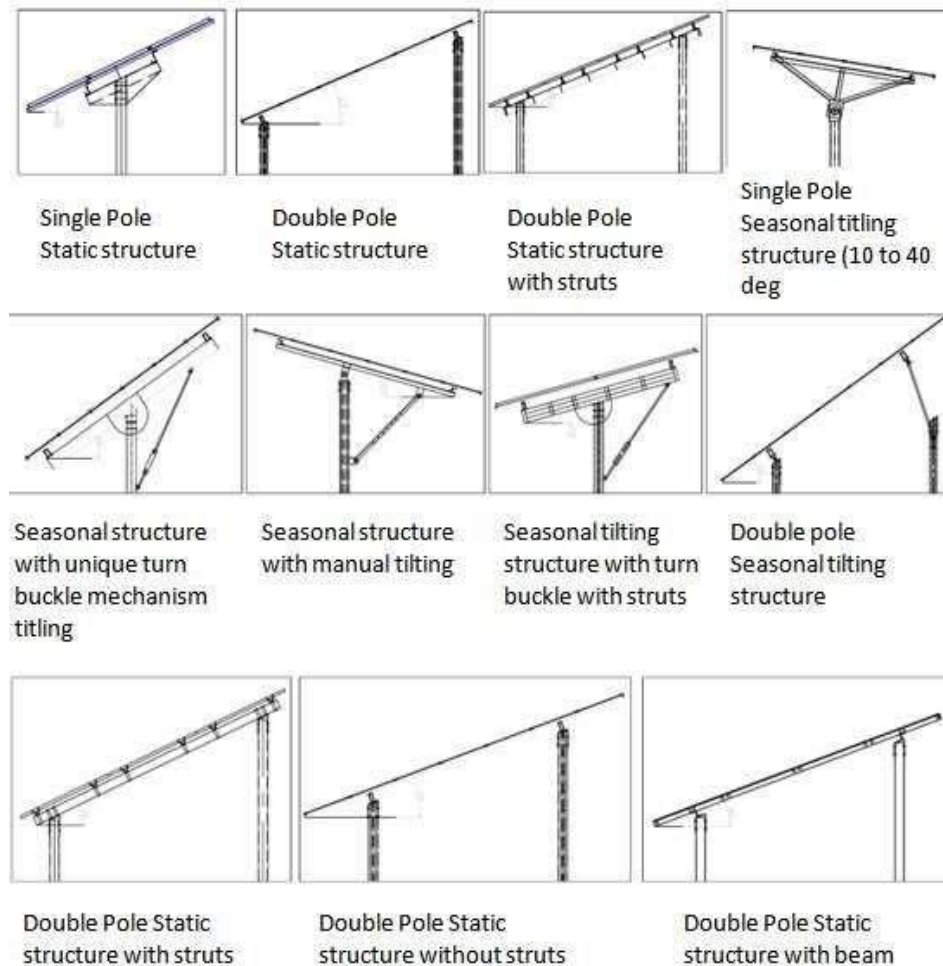


Fig. 6.17: Types of mounting structures

Installation of Mounting Structure

Installing the mounting structure is specific to the site and product. For installation details, refer to the design and user manual. Here are the typical steps to follow:

1. Locate the structural roof members and attach the fittings.

Panel Rack: The panel racking usually includes rails or rafters, roof mounts, and fasteners like mid clamps and end clamps. The rails hold the modules in place, while footings, standoffs, and other mounts secure the rails to the roof or base.

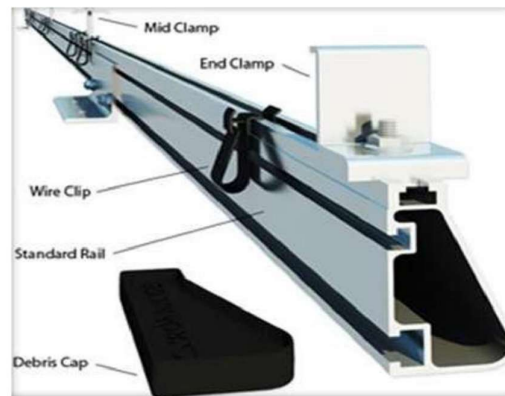


Fig. 6.18: Panel Racking - Rails/Rafters, Fasteners (Clamps)

Note: The best materials for the rails are aluminum and stainless steel (SS) fasteners. Aluminum keeps the structure lightweight, and SS fasteners provide strength and durability.

In the figure below, the detailed structural support for the module is shown with dimensions to help visualize the panel rack arrangement.

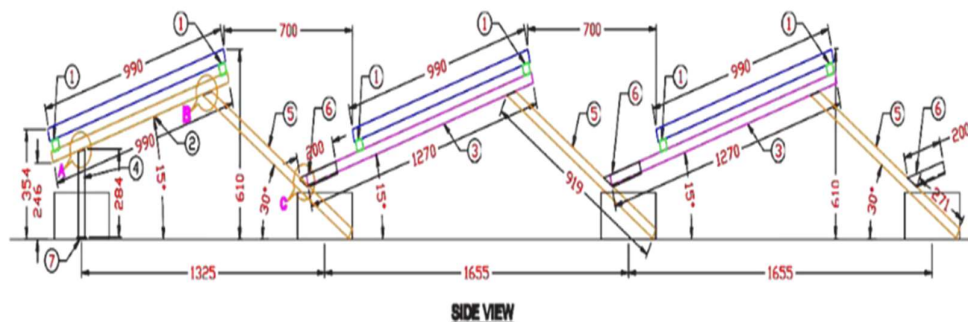
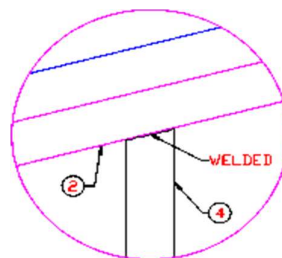


Fig. 6.19: Detailed structural support for the module

Avoid welding on site, as it can cause the structure to rust quickly. That's why nut and bolt mounting structures are now preferred.



View A

Fig. 6.20: Panel Racking Arrangement - Side View of Module Support Structure

Labels:

1. Purlin
2. Rafter-1 (based on length)
3. Rafter-2 (based on length)
4. Front Leg
5. Back Angle
6. Angle
7. Base Plate & Jointing Plate
8. Bolts

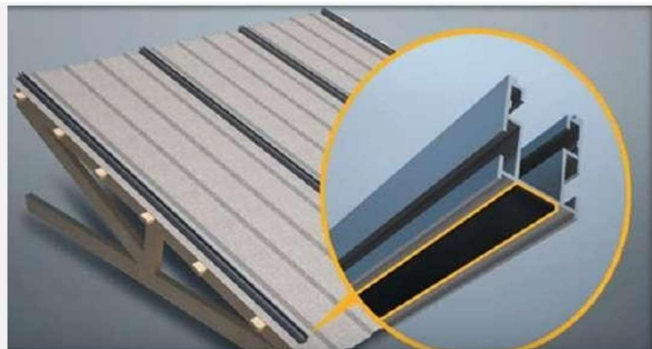
Installing Roof Attachments and Anchors for Flat Roofs

Follow these steps to securely fix the solar modules to the structural frame. First, ensure the array structure is level and plumb. If needed, add any secondary support to handle the weight of the system.

STEP 1: Place rails over footings



STEP 2: Place the Purlins over rails/ rafters



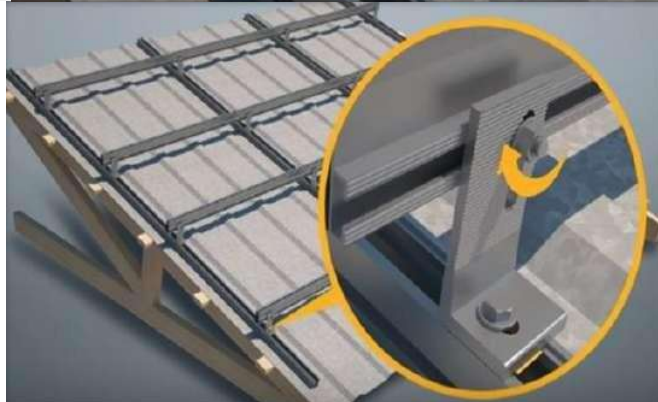
STEP 3: Fix the Purlins over rafters



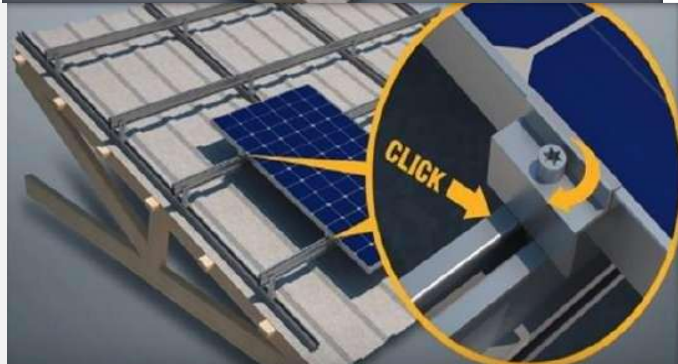
STEP 4: Fix the Clamps



STEP 5: Fix the purlin with a clamp to make elevation from roof



STEP 6: Now fix the PV modules and Level it over the elevated structure



Corrosion Protection and Weather Proofing for Cut Surfaces

Apply corrosion protection to cut surfaces and use weather-proof materials to prevent any leaks or penetration. Use corrosion-resistant materials like hot-dip galvanized steel or stainless steel after fabrication. This will noticeably extend the life of the structure.

The figure below shows the plan view of the PV system arrangement.

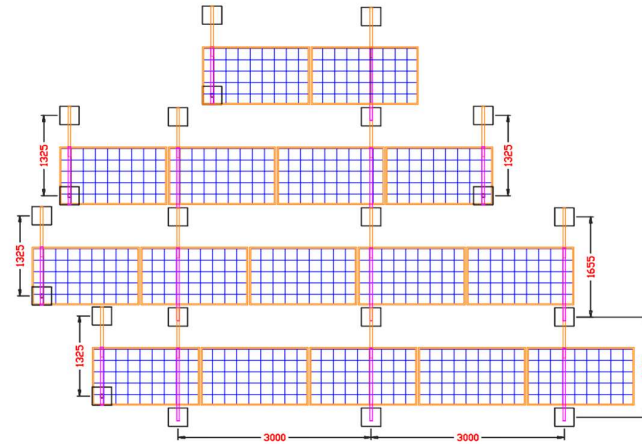


Fig. 6.20: Plan View of the PV System Arrangement

Installation of Roof Attachments and Anchors for Sloped Roofs

To install PV modules on sloped roofs, use roof hooks or anchors. Various types of roof hooks and anchors are available, depending on the roof structure. Below are some examples of hooks used for roofing tiles.



Fig. 6.21: Roof hook/anchor for roofing the tiles

Instructions for Installing Roof Hooks

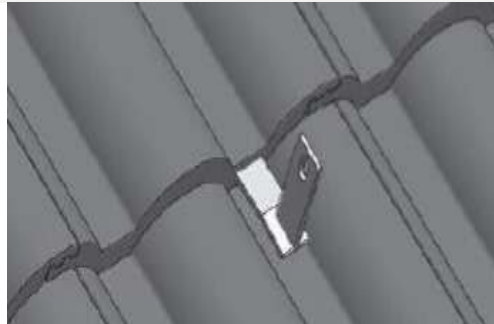
Step 1: Remove the tiles where you want to install the hook.



Step 2: Secure the hook to the rafter using screws.



Step 3: Replace the tile in its original position.

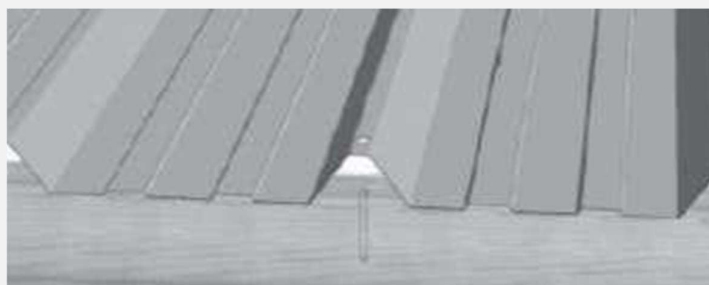


Use a hanger bolt fastener set for roofs made of fiber cement corrugated or trapezoidal corrugated materials.

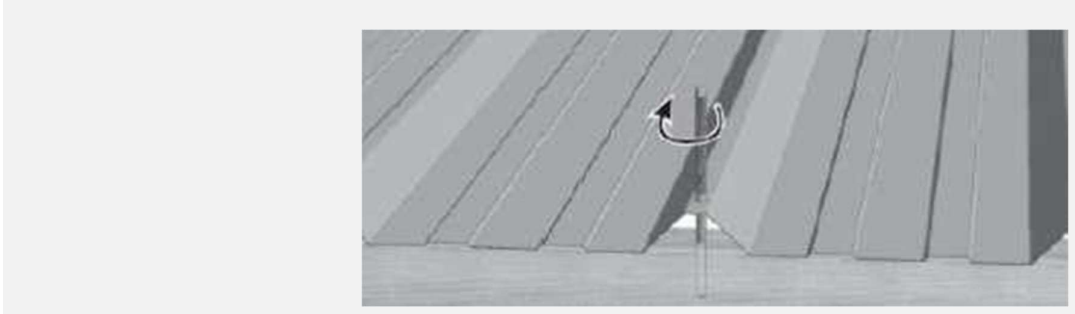


Installation Steps:

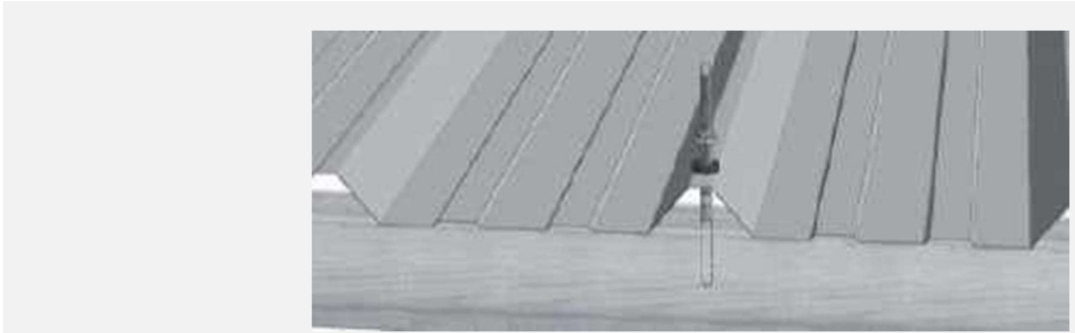
Step 1: Drill into the wood structure and covering.



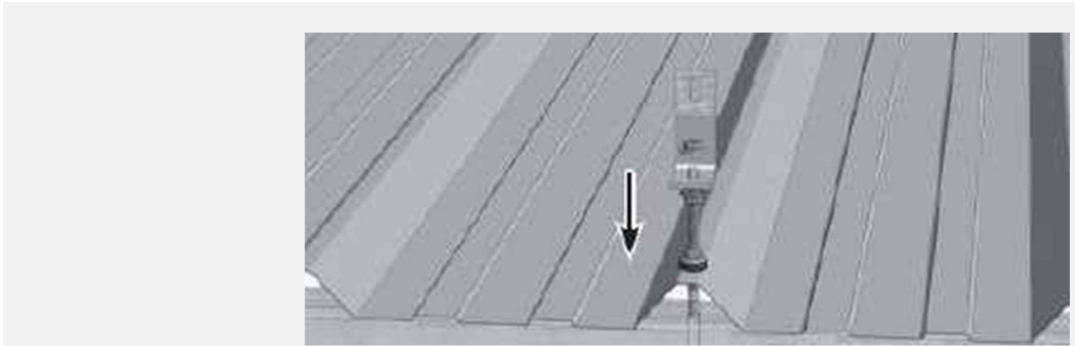
Step 2: Insert the hanger bolt and screw it in.



Step 3: Place a rubber seal and spacer, then screw on the nut and tighten it.



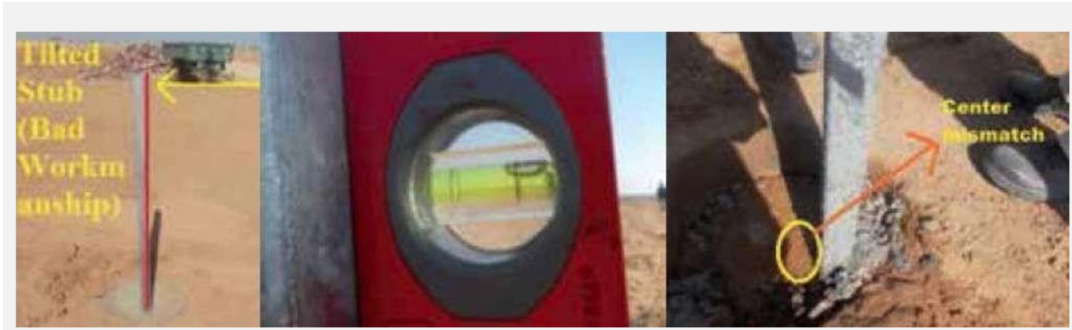
Step 4: Attach the flange.



Step 5: Install the module support or racking frame.



Step 6: Make sure the array structure is plumb and level.



Step 7: Add extra structural supports.

Step 8: Protect any cut surfaces from corrosion.

Step 9: Apply weatherproofing to prevent leaks or water penetration.

CHECK YOUR PROGRESS

A. Multiple Choice Questions

Q1. Which type of footing is commonly used to support a single point, such as beneath a pier or post?

- a) Continuous Spread Footing
- b) Spot Footing
- c) Grade Beam Footing
- d) Raft Foundation

Q2. What is the main purpose of using ballast mounting for flat roofs?

- a) To make holes in the roof for fixing panels
- b) To prevent roof leakage
- c) To avoid roof penetration and use weights for support
- d) To increase the roof height

Q3. Which material is best suited for rails in panel racking to keep the structure lightweight and durable?

- a) Mild steel
- b) Copper
- c) Aluminum
- d) Cast iron

Q4. What should be applied on cut metal surfaces to prevent corrosion and extend the life of the structure?

- a) Paint only
- b) Corrosion protection and weatherproofing materials
- c) Rubber coating
- d) Wood sealant

B. Fill in the Blanks

1. _____ footings are used to support loads with minimal bending and are made of reinforced concrete components.
2. The _____ roof mounting system allows solar panels to be placed on existing sloped roofs using metal support structures.
3. The best materials for rails are _____ and stainless-steel fasteners.
4. In ballast-mounted systems, concrete blocks or slabs are used to hold the solar panels in place without _____ the roof.

C. Short Answer Questions

- Q1. Explain the main difference between ballast mounting and anchoring systems for flat roofs.
- Q2. Why is corrosion protection important for solar PV mounting structures?
- Q3. What are the three main parts of the mounting structure on a sloped roof?
- Q4. List any four tools required for civil and mechanical installation of solar PV systems.

SESSION 4: INSTALL PHOTOVOLTAIC MODULE**General Safety**

- Only licensed and trained individuals should install, wire, and maintain PV modules.
- Read all instructions and information about PV modules before handling or installing them.
- Cover the surfaces of PV modules with an opaque material during installation to prevent electric shock.
- Do not disconnect modules that are in operation.
- Do not use lenses or mirrors to concentrate artificial sunlight on the modules.
- Only use natural sunlight and normal light for power generation.
- Check the wiring polarity before installation.
- Use only equipment, connectors, wiring, and support frames that are made for solar electric systems.
- Wear appropriate protective gear and take precautions to avoid electric shock, especially when DC voltage exceeds 30 VDC.

Storage and Unpacking

- Keep the original packaging until you are ready to install the PV modules.
- Store packaged PV modules in a clean, dry place with humidity below 85% and temperatures between -20°C and 40°C.
- Avoid stacking too many pallets on top of each other.
- Two people are needed to unpack the modules from the box. Always use both hands when handling the modules.
- Use wire cutting pliers, not a knife, to cut the zip ties.
- Do not stack modules directly on top of each other.

Module Handling

- Wear insulated gloves when handling the modules.
- Handle the modules carefully to avoid breakage.
- Do not lift the module by the junction box or cables.
- Do not place any objects on the module or press on its surface.
- Prevent any objects from falling onto the module.
- Do not drop the module.
- Keep the back of the module out of direct sunlight.
- Avoid wearing metal accessories when handling modules.
- Do not install or handle modules in wet or very windy conditions.

Module Mounting

There are two main methods for mounting PV modules on structures:

Mounting with Bolts

The frame of each module usually has four 9mm mounting holes, which are placed to support the module securely.

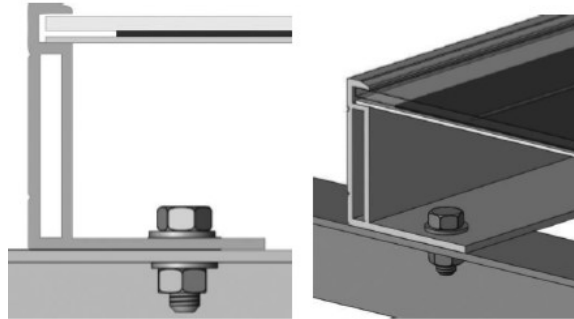


Fig. 6.22: Mounting with bolts

Mounting with Clamps

Use at least four clamps to attach the modules to the mounting rails. The clamps should not touch the front glass and must not bend the frame. Make sure clamps do not cast shadows on the modules.

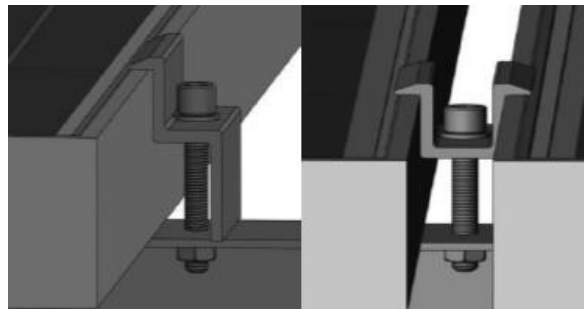


Fig. 6.23: Mounting with clamps

Instruction on Module Interconnection

- **Electrical Parameter Measurement:** To prevent potential mismatches, it is advisable to measure the electrical parameters of modules with power tolerances exceeding 5 percent prior to installation. This ensures that modules with compatible Maximum Power Point (MPP) currents are connected in the same string.
- **Use of Same Module Types:** It is recommended to utilize modules of the same type within the same system to ensure optimal performance.
- **Connecting Cables:** Modules equipped with single-pole touch-proof plug connectors facilitate quicker and easier interconnections.

- **Polarity Check:** Always verify the polarity of the cables when connecting modules together and with the PV array combiner or junction box. Incorrect polarity can lead to short circuits, potentially damaging bypass diodes and the inverter's input stage.
- **Disconnection Protocol:** Modules generate power only during daylight hours, so plug connectors should not be disconnected while under load. If disconnection is necessary, first turn off the inverter, and then trip the DC circuit breaker if one is installed.
- **Safe Disconnection:** Under open-circuit voltage conditions, plug connectors can be safely disconnected from the modules.
- **Modules without Preassembled Cables:**
 - For connecting lead strips, strip insulation to approximately 16mm.
 - If metal end sleeves are not used, ensure a secure connection in spring clamp terminals.
 - Always incorporate strain relief and correctly implement a waterproof cable feed-through.
 - Create a drip loop before the cable entry point into the module junction box.
 - Ensure that the junction box cover is sealed properly to maintain waterproof integrity.
- **Qualified Installation:** Wiring should be performed only by qualified installers and must comply with local codes and regulations.
- **Series Connection of Modules:** Modules are interconnected in series by plugging the positive connector of one module into the negative socket of the next. In a series configuration, the individual operating voltages of the modules combine to yield an increased output voltage. Ensure that all contacts are clean, dry, and free from corrosion before making connections.

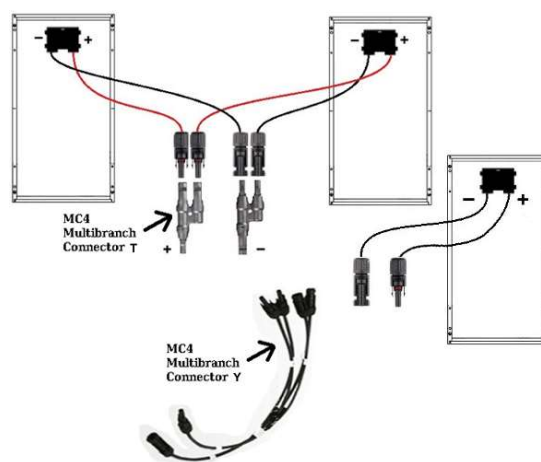


Fig. 6.24: Connection of PV modules using MC4 connectors

Grounding Requirements

Proper grounding or earthing is essential for all module frames and mounting racks, in accordance with the National Electrical Code (NEC).

To ensure effective grounding, all module frames and metallic structural components should be interconnected using an appropriate grounding system. The conductor selected for grounding can be made of copper, copper alloys, or other materials that meet the standards set by the NEC for use as electrical conductors.

Connection to the earth is established through the grounding conductor, which should be linked to a suitable earth ground electrode. This process is critical for enhancing safety and preventing electrical faults.

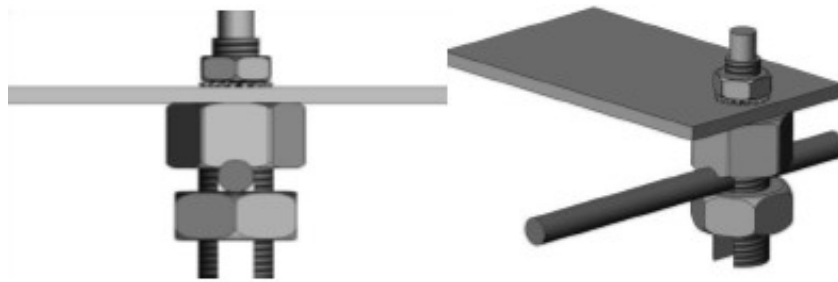


Fig. 6.25: Grounding of modules using earth ground electrode

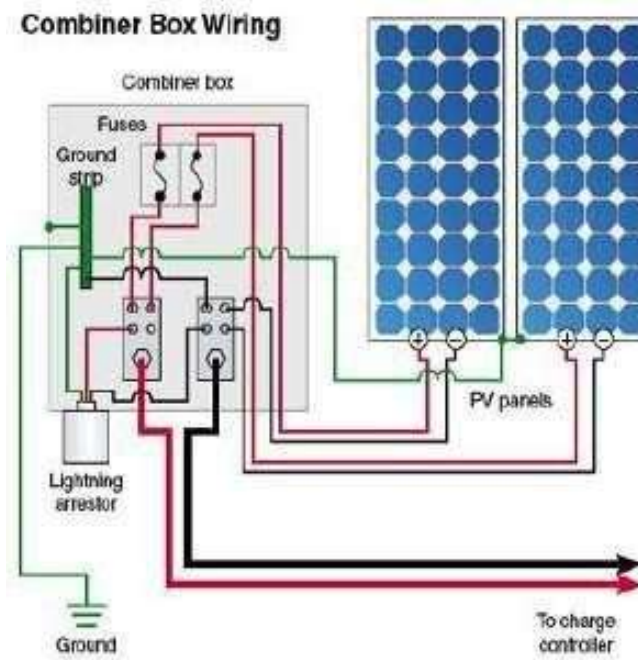


Fig. 6.26: Schematic diagram of grounding Solar PV Panels

7.4: Installation of Battery Bank Stand and Inverter Stand

A battery storage power plant represents a specialized form of energy storage, utilizing electrochemical batteries for this purpose. Unlike conventional storage power plants, such as pumped storage facilities that can reach capacities of up to 1000 MW, battery storage systems generally operate within the range of a few kilowatts (kW) to low megawatts (MW). The most substantial installed systems can achieve capacities of up to 36 megawatt-hours (MWh). In the private sector, smaller battery systems, often referred to as solar batteries, typically feature storage capacities of a few kWh and are used alongside similarly sized photovoltaic systems. These installations help generate revenue during off-peak hours, such as in the evening or at night, and support enhanced self-consumption of electricity.

In some cases, battery storage stations may integrate flywheel storage systems, which can effectively manage rapid fluctuations in power demand and supply.

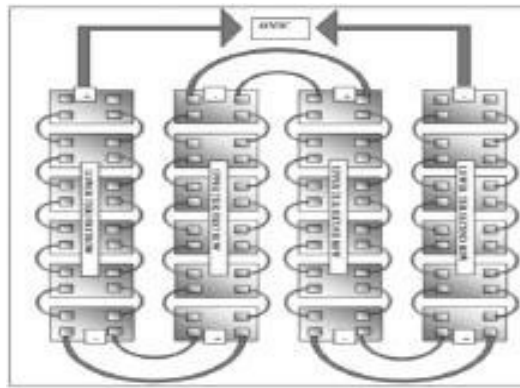


Fig. 6.27: System of interconnected batteries

Batteries can be installed using either racks or surface-mounted designs that incorporate spill containers for safety, as depicted in the images below.

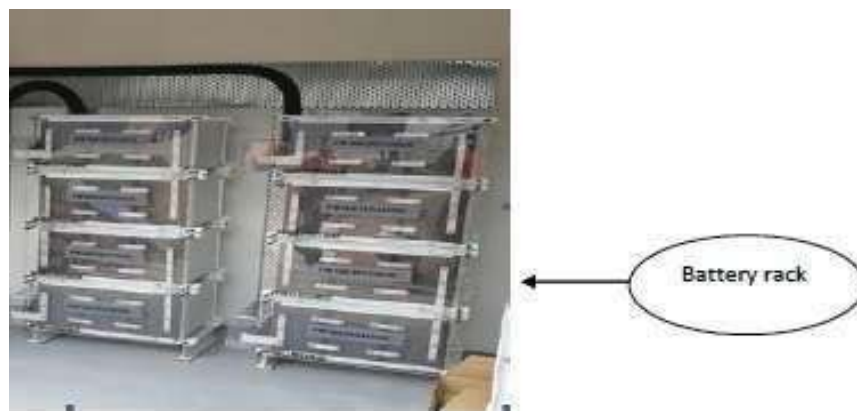


Fig. 6.28: Battery bank installed using racks with spill containers

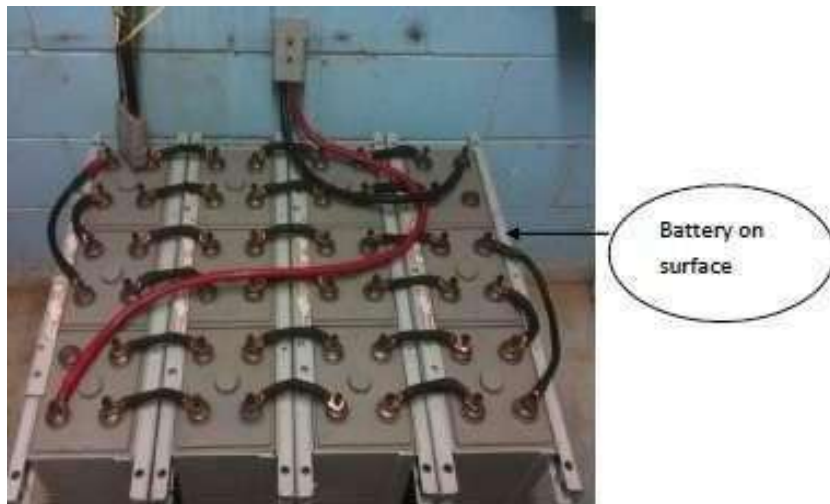


Fig. 6.29: Ground-mounted battery

Inverter Stand

A solar inverter, also known as a converter or PV inverter, plays a crucial role in converting the variable direct current (DC) output from photovoltaic (PV) solar panels into alternating current (AC) at utility frequency. This conversion enables the electricity to be fed into a commercial electrical grid or utilized by local off-grid networks. As a key component of the balance of system (BOS) in photovoltaic installations, solar inverters facilitate the use of standard AC-powered devices.

Solar inverters can be categorised into three primary types:

- **Stand-alone Inverters:** These are utilised in isolated systems and derive their DC energy from batteries charged by photovoltaic arrays. Many stand-alone inverters include built-in battery chargers to replenish the battery from an AC source whenever available. They do not interface with the utility grid and are not subject to anti-islanding protection regulations.
- **Grid-tie Inverters:** Designed to synchronise in phase with a utility-supplied sine wave, these inverters automatically shut down in the event of a utility supply loss to ensure safety. However, they do not provide backup power during outages.
- **Battery Backup Inverters:** These specialised inverters are designed to draw energy from batteries, manage charging through an onboard charger, and facilitate the export of excess energy back to the utility grid. They can supply AC energy to selected loads even during a utility outage and are required to include anti-islanding protection.

Grid-tied or grid-connected inverters typically come with mounting brackets and are usually installed near the PV modules on an outdoor structure or on a rack adjacent

to the battery area. It is important to position the inverter away from direct sunlight in the afternoon. Additionally, a canopy should be considered for sunshade and rain protection. As illustrated in the figure below, the inverter can be mounted on a supporting column structure or directly on a wall using brackets. so using brackets

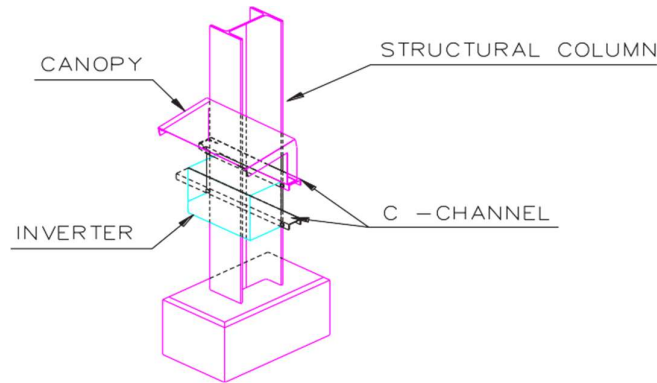


Fig. 6.30: Support structure for installation of inverter

CHECK YOUR PROGRESS

A. Multiple Choice Questions

- Q1. Which of the following is a safety precaution when handling PV modules?
- a) Disconnect modules while they are operating
 - b) Wear insulated gloves and protective gear
 - c) Use lenses to concentrate artificial sunlight on the modules
 - d) Lift the module by the junction box
- Q2. What is the recommended method to prevent water ingress when connecting modules without preassembled cables?
- a) Use only metal accessories
 - b) Create a drip loop and seal the junction box
 - c) Stack modules on top of each other
 - d) Use a knife to cut zip ties
- Q3. Which type of inverter is used in isolated systems and works with batteries charged by PV arrays?
- a) Grid-tie inverter
 - b) Stand-alone inverter
 - c) Battery backup inverter

d) DC-DC converter

Q4. Why is grounding important for solar PV module frames and mounting racks?

- a) To increase output voltage
- b) To prevent theft
- c) To enhance safety and prevent electrical faults
- d) To reduce inverter efficiency

B. Fill in the Blanks

1. PV modules should only be installed, wired, or maintained by _____ and trained personnel.
2. When handling PV modules, the back of the module should be kept out of direct _____.
3. Modules are interconnected in series by plugging the positive connector of one module into the _____ of the next.
4. Battery racks may include _____ containers for safety during installation.

C. Short Answer Questions

- Q1. What precautions should be taken when unpacking PV modules?
- Q2. Explain the difference between grid-tie inverters and battery backup inverters.
- Q3. What is the purpose of a drip loop in PV module wiring?
- Q4. List four safety measures to follow when handling or installing PV modules.

MODULE 7: TOOLS FOR SOLAR PV SYSTEM INSTALLATIONS

In the Installation of a Solar PV System, most of the tools are commonly used and easily found. There are very few highly specialised tools. Below are several lists that describe many of the tools needed for an installation in this Unit, you will develop an understanding of the identity of the tools are used for solar PV system installation.

This unit provides information on the uses of that tool for solar PV installation, like mechanical, electrical & electronics, marking, and suitable civil tools, and measuring tools. It will explain the types and uses of a large number of tools, a practical application of a selected group of tools, safety requirements, general care and limited repair. A user must have, choose and use the correct tools in order to do the work quickly, accurately, and safely. Without the proper tools and knowledge of how to use them, the user wastes time, reduces efficiency, and may face injury.

SESSION 1: MECHANICAL AND GENERAL TOOLS

a) Screwdriver

A screwdriver is a tool, manual or powered, for turning (driving or removing) screws. A typical simple screwdriver has a handle and a shaft and a tip that the user inserts into the screw head to turn it.



Fig 7.1: Screwdriver

The table below shows the different types of screwdrivers for various applications:

Table no. 7.1 different types of screwdrivers

Screwdrivers

	Flat Head (or Slotted Head) Screwdriver
	Phillips Screwdriver
	Pozidriv Screwdriver
	Robertson or Square Screwdriver
	Torx Screwdriver
	Hex Screwdriver or Hexagon Screwdriver

b) Hand Drill

A drill is a tool fitted with a cutting tool attachment or driving tool attachment, usually a drill bit or driver bit, used for boring holes in various materials or fastening various materials together with the use of fasteners. The attachment is gripped by a chuck at one end of the drill and rotated while pressed against the target material. The tip, and sometimes edges, of the cutting tool, does the work of cutting into the target material. Battery-less drills are now available for remote solar sites without an electrical connection.



Fig 7.2: Hand Drill

c) Spanner (Wrench)

Is a tool used to provide grip and mechanical advantage in applying torque to turn objects usually rotary fasteners, such as nuts and bolts, or keep them from turning? In solar system installation, the spanners are used mainly to fasten panels with purlins through nuts and bolts.



Fig 7.3: Spanner

d) Hammer

A hammer is a tool that delivers a blow to an object. It is used very often for different purposes in solar installations.



Fig 7.4: Hammer

e) Hacksaw

A hacksaw is a fine-toothed saw, originally and principally for cutting metal. They can also cut various other materials, such as plastic and wood.

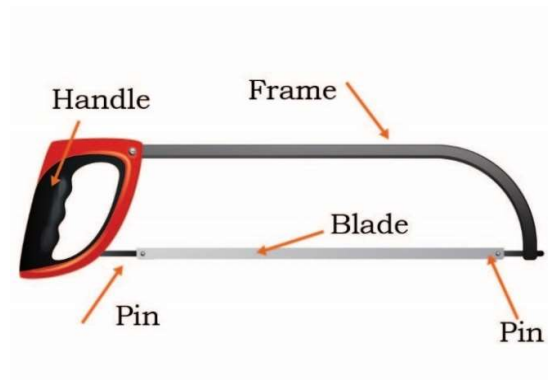


Fig 7.5: Hacksaw

f) Chisels

A long-bladed hand tool with a bevelled cutting edge and a handle that is struck with a hammer or mallet is used to cut or shape wood, stone, or metal.



Fig 7.6: Chisel

g) Nipper

A nipper (like a pair of scissors or pliers) is a tool used to "nip" or pull-out small amounts of hard material. It is used as an auxiliary tool in solar installation.



Fig 7.7: Nipper

h) Gimlet

A gimlet is a hand tool for drilling small holes, mainly in wood, without splitting. Such a handy tool offers ease of operation when the site needs only a few holes to carry on the further task.



Fig 7.8: Gimlet

i) Pipe cutter

A Pipe cutter is a type of tool used to cut pipe. Besides producing a clean cut, the tool is often a faster, cleaner, and more convenient way of cutting pipe than using a hacksaw.



Fig 7.9: Pipe cutter

j) Grinder

It is the power tool or machine tool used for grinding. This power tool comes in a variety of shapes and sizes, all of which perform the same three basic functions: cutting, grinding and polishing.



Fig 7.10: Grinder

k) Pliers

Pliers are a commonly used hand tool to hold objects firmly. It is also useful for bending and compressing materials during small-scale operations.



Fig. 7.11 Pliers

l) Crimping tool

A crimping tool is used to join two pieces of metal or other ductile materials (usually a wire and a metal plate) by deforming one or both of them to hold the other in place.



Fig 7.12: Crimping tool

m) Spirit level

A spirit level, bubble level, or simply a level is an instrument designed to indicate whether a surface is horizontal (level) or vertical (plumb). In solar installation, it is important for the erection of mounting structures.



Fig 7.13: Spirit level

n) Angle Finder

An angle finder is a tool used to determine the angle of inclination during the installation of the solar power plant. Solar panels are required to arrange at a tilt angle equivalent to the latitude of the location. Angle finder helps set solar panels at appropriate tilt angles for the right performance.



Fig 7.14: Angle Finder

o) Sun path Finder

The Solar Pathfinder is designed to give a full year's worth of solar radiation data in an instant. It does not matter what time of day or day of the year you take your analysis. It is easier to take the reading on somewhat cloudy or overcast days to avoid the sun's glare.

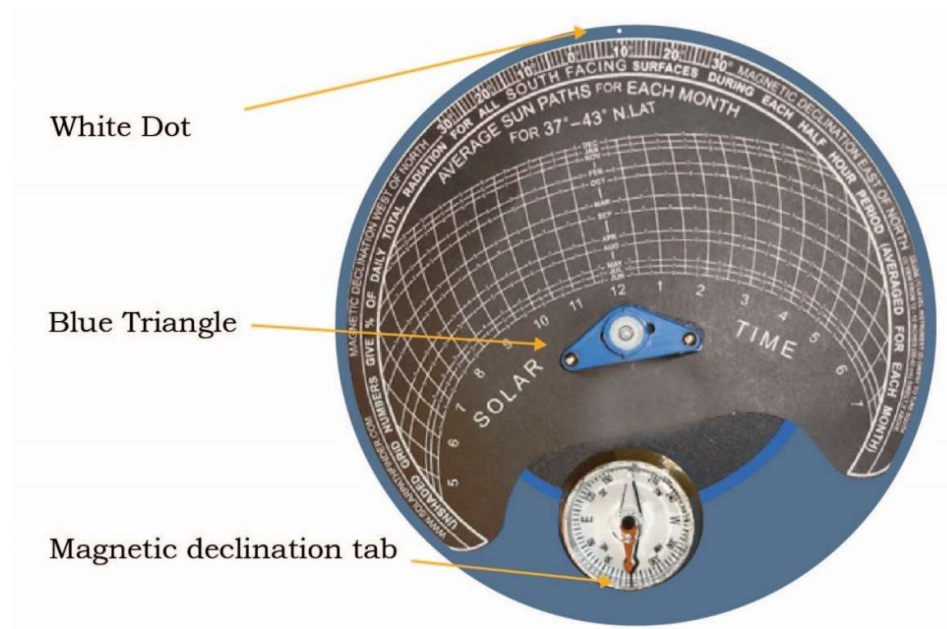


Fig 7.15: Sun path Finder

PRACTICAL EXERCISE

1. Identify the different types of mechanical tools.
2. Make a list of general tools that are used in a solar PV installation.
3. Draw the different types of screwdrivers

CHECK YOUR PROGRESS

A. Fill in the blank

1. The shaft is usually made of to resist bending or twisting
2. Electricaloffer faster operation and comfort to operators.
3. A is a tool that delivers a blow to an object.
4. A hacksaw is a....., originally and principally for cutting metal.
5. Try-square implement used to check and mark right angles in work
6. A..... is a tool used to "nip" or pull-out small amounts of a hard material?

7. A gimlet is a hand tool for, mainly in wood, without splitting.

B. Multiple Choice Question

1. which type of tool is used to cut pipe?

a. Pipe cutter

b. Spanner

c. chisel

d. reamer

2. Grinder tools are used for the

a. Grinding

b. Ramming

c. Cutting

d. measuring

3. Criming tools are used for

a. To join two pieces of metal

b. cutting a material

c. welding

d. grinding

SESSION 2: ELECTRICAL, SAFETY, MARKING, AND CIVIL TOOLS**ELECTRICAL TOOLS**

Electrical tools are those that are used to work on a power system. Wire and cable cutters, wire strippers, coaxial compression tools, telephony tools, wire cutters/strippers, cable tie tools, accessories, and more are just a few examples.

a) Multimeter

A multimeter or a multi-tester, also known as a VOM (Volt – Ohm – Milli -ammeter), is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter measures voltage, current, and resistance. Analog multimeters use a micro-ammeter with a moving pointer to display readings. Digital multimeters (DMM, DVOM) have a numeric display, and may also show a graphical bar representing the measured value.



Fig. 7.16: Multimeter

b) Earth Tester

The instrument used for measuring the resistance of the earth is known as the earth tester. All the equipment of the power system is connected to the earth through the earth electrode. The earth protects the equipment and personnel from the fault current. The resistance of the earth is very low. The fault current through the earth electrode passes to the earth. Thus, protects the system from damage.



Fig. 7.17: Earth Tester

c) Electrical resistance tester

The instrument is used for an insulation resistance (IR) test, which measures the total resistance between any two points separated by electrical insulation. The test, therefore, determines how effective the dielectric (insulation) is in resisting the flow of electrical current. With an insulation resistance test, manufacturers, installers, and quality testers can assess if a solar panel has adequate insulation between its electricity-conducting components and the module's frame.



Fig. 7.18: Electrical resistance tester

d) Pyranometer

It is an instrument used for measuring solar irradiance or insolation on a horizontal surface. It is designed to measure the solar radiation flux density (W/m^2) from the

hemispherical (1800) view. The instrument measures global (direct +diffuse) solar radiation within a wavelength range of $0.3\ \mu\text{m}$ to $3\ \mu\text{m}$.



Fig. 7.19: Pyranometer

e) Solar Power Meter

Handheld portable Solar power meters are also used as pyranometers. The solar radiation flux density has a direct correlation with the performance of a solar photovoltaic power plant. This product comes with a sensor that receives falling solar energy on it. The display unit provides digital data of solar irradiance.



Fig. 7.20: Solar Power Meter

f) Pyrhelimeter

A pyrhelimeter measures the direct component of solar irradiance, which is important when installing concentrating collectors.



Fig. 7.21: Pyrheliometer

g) Clamp Meter

A Clamp Meter Is an Electrical Test Tool That Combines a Basic Digital Multimeter with A Current sensor.



Fig. 7.22: Clamp Meter

SAFETY TOOLS FOR SOLAR INSTALLATION

Safety & Protective Equipment:

A solar PV system includes several components that conduct electricity. This includes the PV solar array, the inverter and other essential parts. This presents solar power safety concerns.

Installing solar panels and systems can be risky. Workers in the solar industry face various risks, like:

- Falls from high rooftops
- Electrocutation or other electric hazards
- Repetitive stress injuries
- Cuts or sprains

Because of the risks that businesses and workers face, the Occupational Safety and Health Administration requires employers to have safety training and protection for their employees.

The installer needs to visit the site, identify safety risks and develop specific plans to address them. This can include:

- Equipment to use for safe lifting and handling of solar panels
- Type and size of ladders and scaffolding
- Fall protection for rooftop work
- Personal protective equipment (PPE) for workers

Table no. 7.2 List of safety tools for use in solar PV installation.

S.No.	Items Description	Application	Sample Photo
1.	Safety helmet	Head protection	
2.	Safety Goggles with Clear Glass	Eye Protection: Use for a general purpose gives protection from dust	
3.	Earplug	Hearing Protection: Protection against noise	

4.	Leather cum cotton hand gloves	Hand Protection: For Material Handling	
5.	High Visibility Vest	Body protection: For High Visibility	
6.	Double Lanyard Full Body Harness	For protection against falls harness while working at a height	
7.	Double-density PU sole Safety shoe	Foot protection: For general-purpose use	
8.	Electrical hand gloves	For Arc flash and cut protection for the voltage >260V <=690V	



Fig. 7.23: Personal protective equipment (PPE) kit for workers

MARKING TOOLS

Marking and measuring are one of the most important parts of solar PV system Installation or other manufacturing work. Without the right measuring and marking, the components may not follow the right design and become useless. This is why it is necessary to have an arsenal of marking and measuring tools. These tools provide precise

measurement and even correct placement of components during the manufacturing process. Here, you can check the list of some marking and measuring tools-

a. Measuring Tape

A tape measure or measuring tape is a flexible ruler used to measure size or distance. It consists of a ribbon of cloth, plastic, fiberglass, or metal strip with linear-measurement markings. It is a common measuring tool.

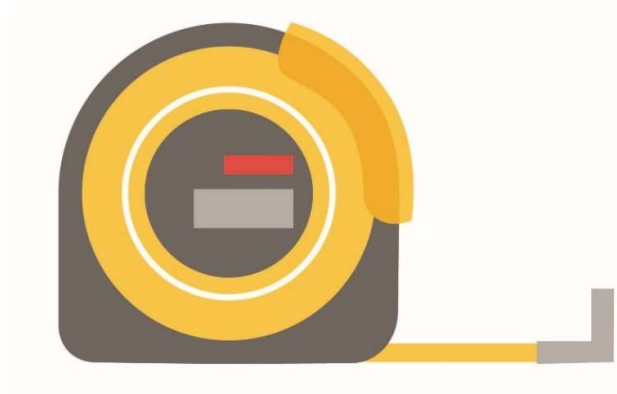


Fig. 7.24: Measuring Tape

b. Centre punch

A tool consisting of a metal rod with a conical point for making an indentation, to allow a drill to make a hole at the same spot without slipping



Fig. 7.25: Centre punch

c. Plumb bob

A plumb bob or a plummet is a weight, usually with a pointed tip on the bottom that is suspended from a string and used as a vertical reference line, or plumb-line. It is essentially the vertical equivalent of a "water level". It is an important tool for the straight erection of the legs of the mounting structure for solar panels.



Fig. 7.26: Plumb bob

d. Try Square

An implement used to check and mark right angles in solar installation work.

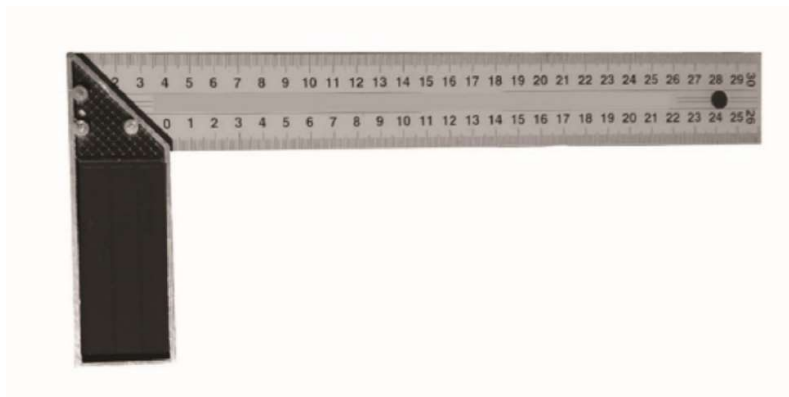


Fig. 7.27: Try Square

e. Solar Compass

Compass is used to locate the south direction for the installation of solar panels. In the northern hemisphere, solar panels should face true south because solar panels will receive solar radiation throughout the day.



Fig. 7.28: Solar Compass

f. Marking Gauge

A marking gauge, also known as a scratch gauge, is used in woodworking and metalworking to mark out lines for cutting or other operations. The purpose of the gauge is to scribe a line parallel to a reference edge or surface.



Fig. 7.29: Marking Gauge

CIVIL TOOLS

Construction tools play an important role in any construction work as they provide a good finish and ease of work by reducing man work. There are different types of construction tools and equipment used in construction.

a) Pickaxe

A pickaxe, pick-axe, or pick is a generally T- shaped hand tool used for prying. Its head is typically metal, attached perpendicularly to a longer handle, traditionally made of wood, occasionally metal, and increasingly fiberglass. It is used for making a deep trench in solar installation.



Fig. 7.30: Pickaxe

b) Spud

It is made of iron pointed at one side for making holes in the soil.

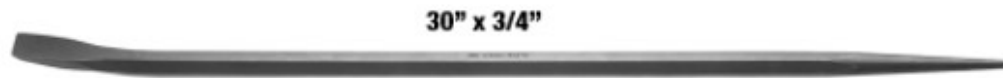


Fig. 7.31: Spud

c) Mortar pan

A mortar pan is a vessel made of steel or rigid plastic used to hold or carry sand, cement, mortar, and concrete. To use a mortar pan, fill it with a quantity of material that you are comfortable with carrying. Lift the Mortar Pan with a straight posture to avoid injury to your back.



Fig. 7.32: Mortar pan

d) Spade

A spade is a tool used for digging straight-edged trenches, slicing and lifting sod, and edging flower beds or lawns. It is made of a metal sheet and a wooden handle. It is a common tool used in small solar installations.



Fig 3.33: Spade

e) Tractor post hole digger

It is a tractor-operated hole digger ideal for digging pits in any type of soil with less time and effort. It is a useful tool for ground-mounted solar power plants. A Pile foundation is created in the holes for the erection of mounting structures for solar modules.



Fig. 7.34: Tractor post hole digger

f) Crowbar

It is a hand tool used to pull two objects apart.



Fig. 7.35: Crowbar

Practical Exercise

1. Identify the electrical and marking tools.
2. Measure a current, voltage, and resistance by the use of a multimeter.
3. Draw a table of safety tools for use in solar PV installation
4. Find the direction using a solar compass.

Check your progress**A. Fill in the blank**

1. uses a micro-ammeter with a moving pointer to display readings.
2. All the equipment of the power system is connected to the earth through the
3. The resistance of the earth is.....
4. Electrical resistance tester instrument is used for an.....

B. Multiple-Choice Questions

1. Which measuring instrument is used for the total resistance between any two points separated by electrical insulation?
 - a. Electrical resistance tester
 - b. Multimeter
 - c. Voltmeter
 - d. Analog
2. Handheld portable Solar power meters are also used as.
 - a. Pyranometer
 - b. Multimeter
 - c. Rotameter
 - d. Electrometer
3. A pyrliometer measures the direct component of
 - a. solar irradiance
 - b. resistance
 - c. current
 - d. none of these
4. Center punch is a-

- a. holding tool
 - b. cutting tool
 - c. marking tool
 - d. striking tool
5. Try square is used for marking at 90° to the edge of _____.
- a. blade
 - b. stock
 - c. burn slot
 - d. workpiece

C. Short Answer Question

Q1. Write two applications of the Clamp Meter

Q2. Write the four marking tool names

Q3 Write the four civil tools and their usage.

MODULE 8: INSTALLATION OF ELECTRICAL OF A SOLAR PV SYSTEM

The process of installing the electrical components of a solar photovoltaic (PV) system involves several key steps to ensure efficiency and safety. This includes the proper setup of solar panels, wiring, inverters, and connection to the existing electrical grid or battery storage. Each component plays a critical role in converting sunlight into usable electricity and requires careful consideration to optimize performance. Ensuring that the installation complies with local regulations and standards is essential for the longevity and effectiveness of the solar PV system. Proper installation not only maximises energy production but also enhances the reliability and safety of the entire system.

Session 1: Prepare for Solar Installation

Implement the Site Safety Plan and Maintain a Clear Work Area

Before starting any solar installation work, safety and cleanliness are the first steps to success.



Fig. 8.1: Clear site area before installation

Step 1: Identify the Work Area: Mark the area where the solar panels will be installed. This is your “solar work zone.” Everyone should know where the work starts and ends.

Step 2: Keep It Clean and Clear: No waste, tools, or debris should be lying around. All scrap materials should be kept in a separate storage corner, away from the main working area, especially when working on rooftops.

Step 3: Maintain Proper Spacing: Keep enough space between the working area and the storage area so materials can be moved safely. Always ensure there are clear entry and exit paths for bringing in tools and panels.

Step 4: Create Safe Boundaries: Use fencing or barrier tape to separate the installation zone. This helps prevent people from accidentally entering the work area.

Step 5: Wear the Right PPE (Personal Protective Equipment): Every person on site must wear safety gear such as:

- Helmet
- Safety gloves
- Safety shoes
- Harness (for rooftop work)
- Safety goggles

Checkpoints:

- Does every worker have proper PPE?
- Are all first aid items available on site?
- Is there a fire extinguisher or fire safety system nearby?

Step 6: Identify Power Lines: Before beginning installation, check for existing power cables, either underground or overhead. Mark them clearly and follow safe working practices to avoid electric shocks or damage.

Clarify the Maximum Working Voltage

Step 1: Know Your System Voltage: Before starting any electrical work, always check the design documents to find out the maximum working voltage of the solar system. This voltage tells you how much electrical energy will flow through the system during operation.

Why It Matters: Knowing the voltage helps you stay safe and choose the right protective gear. If the voltage is high, you need stronger insulation and better safety equipment.

Step 2: Choose the Right PPE (Personal Protective Equipment): Your safety gear must match the system's working voltage. Common PPE for electrical installation includes:

- Insulated gloves
- Safety shoes
- Helmet
- Eye protection (goggles)
- Arc flash suit (for high voltage work)

Select Required Personal Protective Equipment (PPE)

Before touching any tool or wire, ensure everyone has their PPE ready and checked. Even a small mistake with electrical work can cause shocks or burns. Safety gear keeps you protected.

Checklist before starting work:

- All workers are wearing complete PPE.
- PPE is in good condition (no tears, cracks, or damage).
- The voltage rating of PPE matches the system voltage.



Inspect and Demonstrate the Use of Electrical Installation Toolkit

Step 1: Prepare Your Toolkit

Before leaving for the site, make a checklist of all the tools and materials needed. It's difficult to get extra parts or tools once you're at the installation site, so be fully prepared!

Your checklist may include:

- Screwdrivers (insulated)
- Pliers and wire strippers
- Multimeter
- Crimping tool
- Drill machine and bits
- Measuring tape
- Electrical connectors and fasteners



Fig. 8.3: Electrical Tool Kit

Step 2: Check Tool Condition

Inspect every tool before use, make sure there are no loose wires, broken handles, or exposed metal parts.

Step 3: Demonstrate Proper Use

Show each worker how to safely handle and use electrical tools. For example, how to measure voltage with a multimeter or use a drill safely.

Step 4: Ensure Power Supply

Some tools, like drill machines, need electricity to run. Make sure there is a safe and reliable power source available at the installation site.

Step 5: Confirm Design and Location Information

Carry all design drawings and layout plans to the site. These will help you identify where each component will be installed.

Inspect and Maintain Testing Equipment**Step 1: Know Your Testing Tools**

Before beginning the installation, you need to have the right testing equipment ready. These tools help you check whether the electrical connections are safe, correct, and working properly.



Fig. 8.4: Testing equipment

Common testing instruments include:

- Multimeter – to measure voltage, current, and resistance.
- Continuity Tester – to check if the circuit is complete.
- Clamp Meter – to measure current without touching the wire.
- Insulation Tester – to check the insulation quality of cables.

Step 2: Inspect Before Use

- Make sure all testing instruments are in good working condition.
- Check for damaged wires, weak batteries, or broken probes.
- Calibrate instruments (if needed) to ensure accurate readings.

Step 3: Know How to Use Them

Every installer must be trained and confident in using testing instruments. The multimeter is one of the most important tools. It helps in:

- Continuity test – to ensure current can flow through the wire.
- Polarity test – to identify positive and negative terminals.
- Voltage measurement – to confirm system voltage matches design values.

Step 4: Maintain Regularly

- Clean the instruments after use and store them properly in a toolbox or protective case.
- Replace batteries on time.
- Do not expose instruments to extreme heat, moisture, or dust.

Check Your Progress

A. Multiple Choice Questions

1. Before starting solar installation work, what should be the first step?
 - a) Fix the panels immediately
 - b) Start wiring connections
 - c) Implement the site safety plan and maintain a clean area
 - d) Connect the inverter
2. Which of the following is not a Personal Protective Equipment (PPE)?
 - a) Helmet
 - b) Safety gloves
 - c) Slippers
 - d) Safety shoes
3. What is the function of a multimeter during solar PV installation?
 - a) To clean solar panels

- b) To measure voltage, current, and resistance
 - c) To tighten nuts and bolts
 - d) To store electrical energy
4. Why is it important to know the maximum working voltage of a solar system?
- a) To calculate sunlight hours
 - b) To choose correct PPE and safety equipment
 - c) To measure temperature of panels
 - d) To select color of wires

B. Fill in the Blanks

1. The area where solar panels are installed is called the _____.
2. PPE such as _____ is required for rooftop work to prevent falls.
3. A _____ tester is used to check if an electrical circuit is complete.
4. Before using any tool, make sure it is in good _____.

C. Short Answer Questions

1. Why should the installation area be kept clean and clear before starting work?
2. What are the common Personal Protective Equipment (PPE) used in electrical installation?
3. Name any two testing instruments used during solar PV installation.
4. Why is it necessary to inspect electrical tools before use?

SESSION 2: INSTALL ELECTRICAL COMPONENTS**1. Selecting the Location of the DC Combiner Box**

The DC Combiner Box is a very important part of a solar PV system. It collects the DC from multiple solar panels and sends it safely to the inverter. Before installing, select a safe and convenient location.

Guidelines for Choosing the Location:

- Choose a strong and stable surface that can hold the weight of the combiner box.
- The location should be easily reachable for inspection and maintenance.
- Always mount it vertically never at a forward tilt or horizontally.
- Keep the working area clean and dry.
- During installation, make sure PV modules are covered to prevent live current flow.

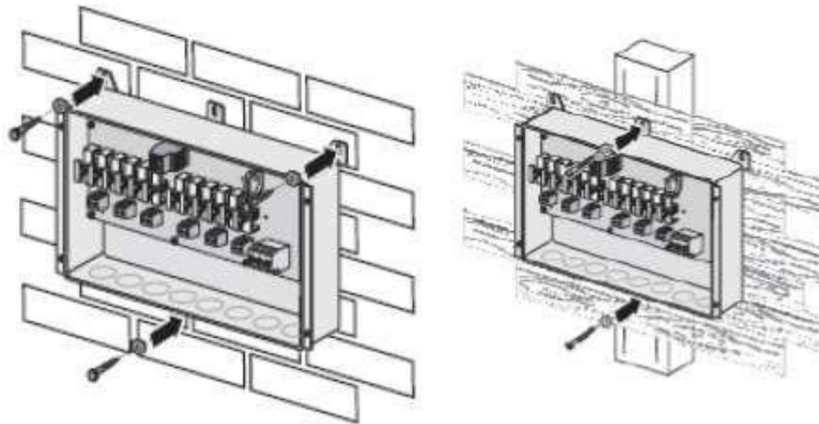


Fig. 8.5: Wall & structure mounting of DC Combiner Box

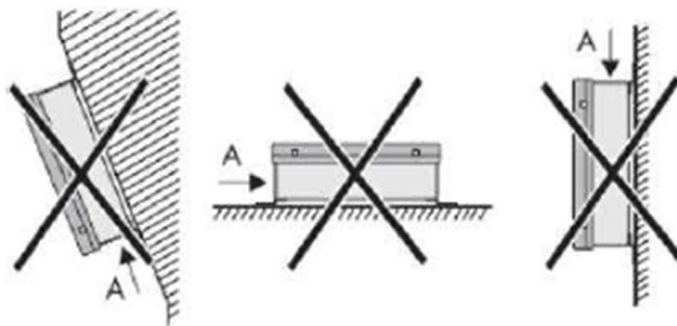


Fig. 8.6: Wrong mounting of DC Combiner Box (SMA)

. Installation Steps for the DC Combiner Box

Step 1: Unpacking and Inspection

- Carefully open the shipping box.
- Check for any damage to the combiner box or accessories.
- If you find damage, report it immediately to the dealer or shipping company.

Step 2: Mounting the Combiner Box

Follow these simple steps for safe mounting:

1. Place the combiner box at the **selected wall location**.
2. Adjust and **align it properly**.
3. Use the mounting holes to **mark the drill points** on the wall.
4. Remove the box and **drill the holes** at marked points.
5. Insert **wall anchors** into the drilled holes.
6. Place the combiner box back and align it with the drilled holes.
7. Insert **screws through the mounting holes** and tighten them **clockwise**.
8. Check that the combiner box is **securely fixed** and does not wobble.

3. Installing the DC Disconnect Switch

The DC Disconnect Switch allows you to safely disconnect the DC power during maintenance or emergencies.

Important Points to Remember:

- A DC circuit has two wires positive (+) and negative (-).
- Usually, the negative wire is grounded (based on system design).
- According to the National Electrical Code (NEC) Section 690.5(A),
 - Only the ungrounded (live) conductor should be switched.
 - In a negative-grounded system, the positive wire is switched.

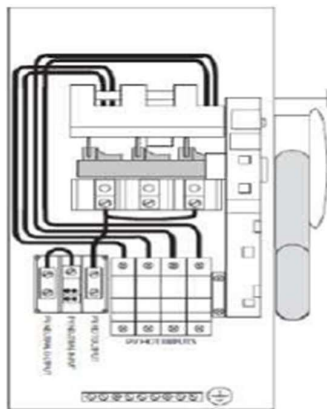


Fig. 8.7: DC combiner box

Installation Steps:

- Mount the DC disconnect switch using proper hardware on a firm surface.
- Follow the same method used for mounting the DC Combiner Box.
- Ensure that the switch is easily accessible and properly labelled.

4. Installing the DC Energy Meter

A DC Energy Meter measures the total energy generated by your solar system.



Fig. 8.8: Solar energy meter

Installation Guidelines:

- Use appropriate mounting hardware to fix the DC energy meter on a flat surface.
- Install it near the DC disconnect **switch** for easy wiring and monitoring.
- Make sure the display is visible and protected from sunlight or rain.

Safety and Good Practice Tips:

- Always wear PPE (gloves, helmet, and safety shoes) while installing.
- Double-check polarity (positive and negative) before making any connection.
- Never work on live wires ensure the system is de-energised first.
- Label all components clearly for easy identification during maintenance.

Confirm Battery Bank Location and Install Batteries

Batteries store the energy generated by solar panels for later use. Choosing the right **location** for your battery bank is very important for both performance and safety.

1. Choose the Right Location

Keep these points in mind before placing the batteries:

Ventilation: The battery room must **be** well-ventilated and **cool**.

- During charging, batteries release hydrogen gas, which can be explosive.
 - Always allow gases to escape safely.
 - Display a “No Smoking Zone” sign in the area.
- Nearness to the Solar Array: Place the batteries as close as possible to the solar panels or charge controller. This helps reduce voltage drop and improves charging efficiency. The connecting cable should be thick enough to limit voltage drop to 2% or less.
- Accessibility: Keep enough space around the batteries for easy inspection, cleaning, and maintenance. Only trained persons should handle batteries.
- Temperature: Batteries work best at low and stable temperatures. High temperatures (above 40°C) can reduce battery life and efficiency. Protect batteries from direct sunlight and heat sources.
- Battery Boxes: Always keep batteries in a vented battery box.

This prevents:

- Accidental short circuits
- Injury to children or animals
- Contact with moisture or water puddles
- Avoid placing batteries directly on the floor. Use wooden or insulated **stands**.

Security and Safety:

- Install batteries in a locked, safe area.
- Prevent unauthorised access, theft, or damage.
- Keep fire extinguishers nearby for emergency use.

Prepare and Connect Battery Bank and Install Inverter

Preparing Battery Terminals and Interconnection Cables

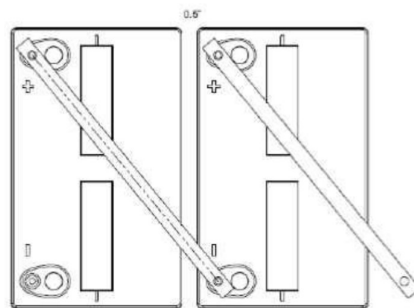


Fig. 8.9: Battery interconnection

Before connecting the batteries, it is important to make sure the battery terminals are clean and shiny. During storage or transport, the terminals can develop a thin layer of oxidation (rust-like coating), which increases resistance and reduces performance.

To clean them, use a brass bristle brush and gently rub the terminal surface. Then, apply a thin layer of special anti-oxidant grease (like NO-OX-ID or NCP-2) to protect the terminals from further oxidation.

If there is only one battery, simply attach the cables to the positive and negative terminals and tighten the screws firmly.

If there are multiple batteries, arrange them properly in series or parallel as per the system design:

- Series connection increases voltage.
- Parallel connection increases current (capacity).

Use a crimping tool to strip the cable ends and attach suitable cable connectors or lugs before connecting them to the terminals. This ensures a safe, secure, and long-lasting connection.

Making Secure Connections with Fine-Stranded Cables

In solar systems, fine-stranded flexible cables are commonly used because they are easy to bend and install. However, these cables must be handled carefully.

Electrical standards require that fine-stranded cables be terminated only with connectors or lugs specifically designed for them. Using the wrong type of connector (meant for solid wires) can break the fine strands, leading to overheating or even fire.

Always choose the correct lugs, terminals, and installation method for flexible cables. This ensures a strong and safe connection that performs reliably for years.

Testing Battery Bank Polarity and Voltage

After connecting all the batteries, it's time to test the battery bank.

First, perform a polarity test to make sure the positive and negative terminals are connected correctly according to the design.

Then, measure the open-circuit voltage using a multimeter:

- For series connections, total voltage = (number of batteries) × (voltage of one battery).
- For parallel connections, total voltage = voltage of one battery.

If the measured voltage does not match the expected value, check the connections again one battery might be connected in reverse polarity.

Installing the Inverter

The inverter converts the DC power from batteries or solar panels into AC power for household use.

Choosing the Right Location

- Install the inverter in a cool, dry, and well-ventilated place.
- Avoid areas where people touch it often because its surface can become very hot during operation.
- The ideal temperature range is -25°C to $+65^{\circ}\text{C}$.
- Keep the inverter away from direct sunlight and water.

Mounting the Inverter

1. Check the mounting dimensions and mark the hole positions using a pencil.
2. Drill the holes in the wall using a drill machine.
3. Fix the mounting bracket tightly using screws and wall plugs.
4. Ensure there is enough clearance around the inverter for airflow and maintenance.
5. The wall or surface should be strong enough to support the inverter's weight (around 26 kg).
6. Lift the inverter carefully and hang it onto the mounting bracket.
7. Make sure it is securely fixed and level.



Fig. 8.10: Installation of Inverter mounting structure

Installing Utility Disconnects and AC Components

To ensure safety and easy maintenance, several AC-side components must be installed after the inverter.

1. AC Disconnect Switch

This switch allows you to cut off AC power from the inverter to the main service panel. It is usually installed between the inverter and the home's electrical panel. Follow the same mounting procedure used for the DC Combiner Box.

2. Double-Pole Circuit Breaker

Install a double-pole circuit breaker in the main breaker panel. It protects both “hot” conductors and helps disconnect the AC power safely. Mount it as per design and ensure it is securely installed.

3. AC Combiner Box

The AC Combiner Box collects AC output from multiple inverters and sends it to the main power line. Install it close to the inverter for safety and easy wiring. Use the same mounting steps as for the DC Combiner Box.

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. What is the main function of a DC Combiner Box in a solar PV system?
 - a) To convert DC power to AC power
 - b) To collect DC from multiple solar panels and send it to the inverter
 - c) To store energy for night use
 - d) To measure energy output

2. According to NEC Section 690.5(A), in a negative-grounded system, which wire should be switched?
 - a) Negative wire
 - b) Ground wire
 - c) Positive wire
 - d) Neutral wire

3. Why should the battery room be well-ventilated?
 - a) To keep the room bright
 - b) To prevent overheating of solar panels
 - c) To allow hydrogen gas to escape safely
 - d) To reduce the size of batteries

4. What is the role of an inverter in a solar PV system?

- a) It stores solar energy
- b) It converts DC power into AC power
- c) It blocks current flow from the grid
- d) It charges the battery

B. Fill in the Blanks

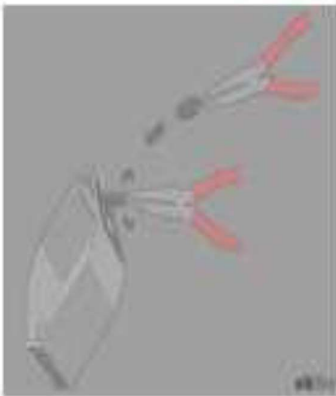
1. The DC Combiner Box should always be mounted _____ and never at a forward tilt or horizontally.
2. A _____ switch allows safe disconnection of DC power during maintenance.
3. Batteries must be placed in a _____ battery box to prevent short circuits and moisture contact.
4. The inverter should be installed in a _____, dry, and well-ventilated place.

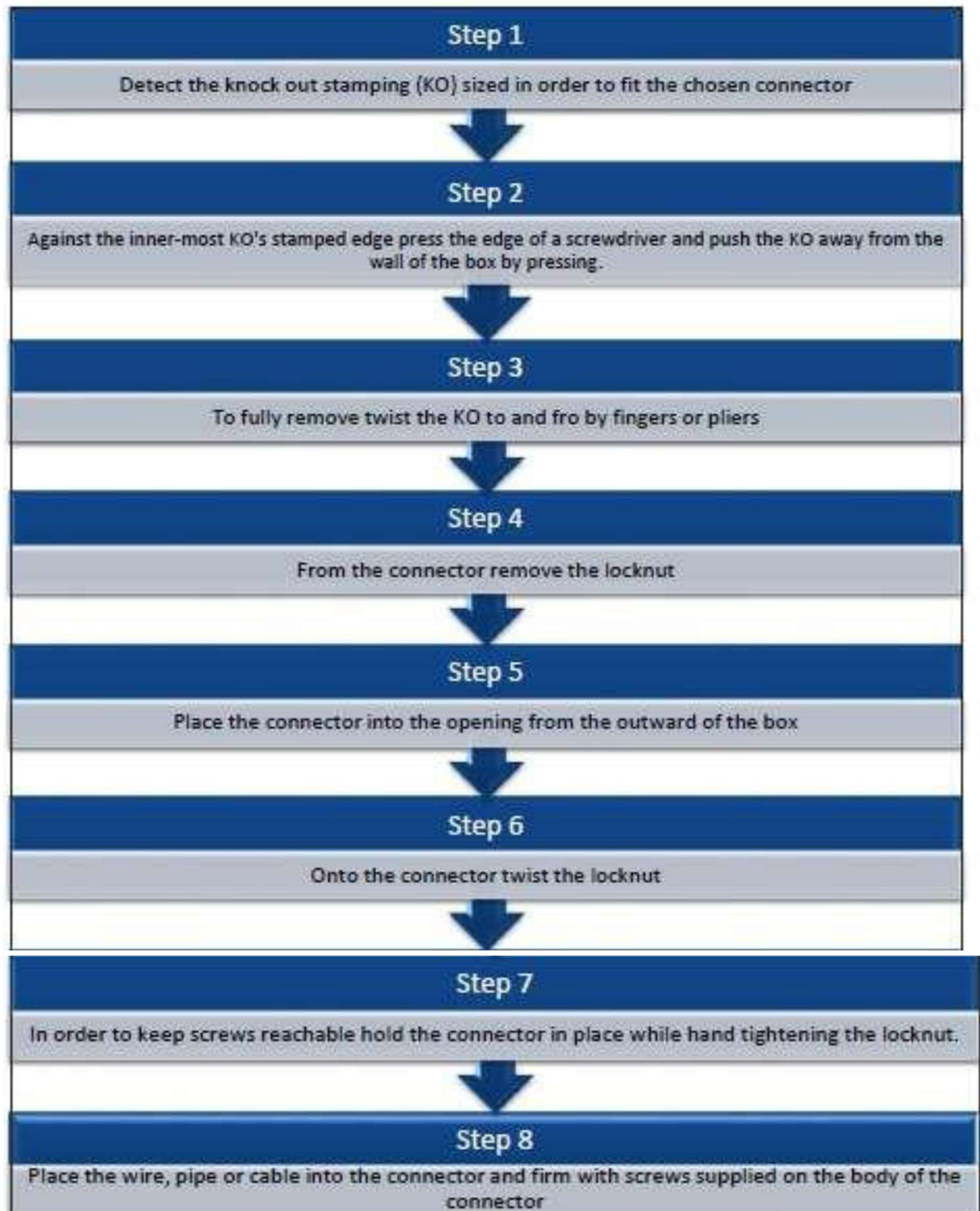
C. Short Answer Questions

1. What safety measures should be followed while installing the DC Combiner Box?
2. Why is it important to check battery polarity and voltage before operation?
3. Mention two important guidelines for installing batteries safely.
4. What is the purpose of installing an AC disconnect switch?

SESSION 3: INSTALL CONDUITS AND CABLES

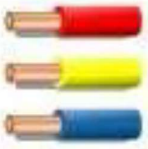
Preparing cable conduit step by step:

STEP 1	STEP 2	STEP 3
		
STEP 4	STEP 5	STEP 6
		
STEP 7		STEP 8
		



Selecting the Correct Cable Type, Colour, and Gauge

Choosing the right cable is like choosing the right veins for electricity to flow smoothly and safely through the system. Every wire has its own role, and colour codes help us easily identify them. According to standard wiring safety codes, red, yellow, and blue wires are used for live connections, black is for neutral, and green is for earth (ground). These colours make it easy to connect wires correctly and prevent accidents.

	Phases	Neutral	Protective earth/Ground
Standard wire insulation colors			

When selecting cables, always consider the following factors:

- **Material:** The cable should be well-insulated to prevent electric shocks or fire hazards.
- **Maximum Voltage Rating:** This tells you how much voltage the wire can safely handle.
- **Gauge (Thickness):** The gauge number indicates wire size — common ones are 10, 12, or 14. Remember, a larger number means a thinner wire. Choose the right gauge to carry the required current without overheating.

Installing Cables for Modules, Inverter, and Other Components

After selecting the correct cables, the next step is to install them properly. The process begins by connecting the solar modules to the inverter and then linking other components such as charge controllers, batteries, and energy meters. Each connection must be tight, clean, and as per the wiring diagram to ensure safety and smooth current flow. Always use proper cable ties, conduits, and protection covers to avoid damage or short circuits.

Think of this as setting up the “nervous system” of your solar installation — if each connection is correct and neat, your system will function efficiently and safely for years!

1. Connect modules together
2. Lay down cables up to the DC combiner box
3. Insert cables into DC combiner box
4. Insert cables into DC disconnect switch
5. Wiring to DC energy meter
6. Wiring to inverter
7. Wiring to AC disconnect switch
8. Wiring to AC combiner box

Step 1: Connect the Modules

Use MC4 connectors to connect the PV modules together. You will either connect them in series or parallel, depending on the design. To find out how many modules are in series and how many are in parallel, check the design.

Note that the distance to the combiner box may vary; one side of the panel string might be further than the other. To make sure both ends reach the combiner box, cut the extender cable in a spot that allows both ends to connect with some slack for adjustments.



Fig. 8.11: Module interconnection

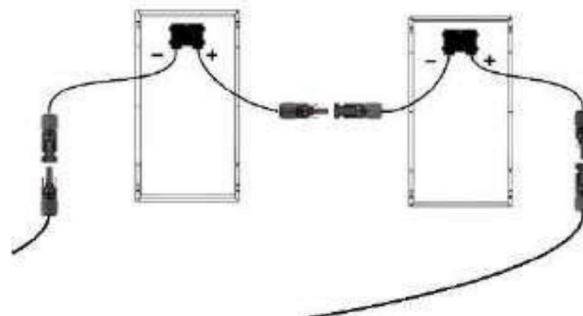


Fig. 8.12: Diagram for the connection of PV modules

STEP 2: Lay Down Cables to the DC Combiner Box

Bring all the string cables from the solar panels to the DC combiner box. Do not lay the cables out in the open because UV rays from sunlight can damage them. Instead, use a cable trench or cable tray to protect the cables as you move them to the next component. Make sure to bundle the cables together securely using cable ties.



Fig. 8.13: Properly bundling cables with cable ties

STEP 3: Insert cables into the DC combiner box

The DC combiner box is the hub where all PV string cables come together. Inside the box, connections include: DC positive and negative outputs, grounding terminal, fuses, surge protection devices (SPD), DC circuit breaker, and communication/meters.

- First, check how many strings you need to insert based on your design.
- Open the Combiner Box.
- For the cable conduits, break out the necessary number of knockouts.
- Use a separate conduit for each string cable.
- Insert the cable conduit into the holes.
- Pull the cable conduits tighter for the electrical connection.
- Choose a fuse rating that protects the wiring and equipment based on your design.
- Connect the equipment grounding. • Connect the PV modules.
- Insert the string fuses.
- Connect the negative string to the correct location.
- Connect the positive string to the correct location.
- Connect the output wires and leave them for the inverter connection.

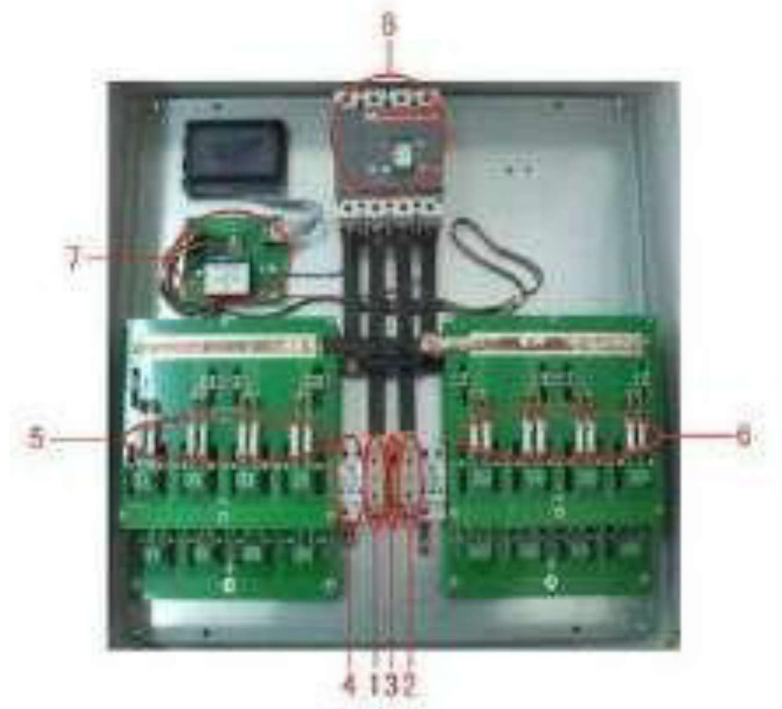


Fig. 8.14: A typical combiner box connection area

1. DC Positive Pole Combine Output	2. DC Negative Pole Combine Output
3. Grounding Terminal	4. DC 1000V SPD
5. DC Positive Pole Fuse	6. DC Negative Pole Fuse
7. Communication Metering Board	8. DC Circuit Breaker

Connecting Equipment Grounding in PV Systems

To ensure safety and compliance, the grounding in photovoltaic (PV) systems must be installed according to the National Electrical Code (NEC) guidelines. Below are the steps for connecting grounding to a DC combiner box:

1. **Prepare the Cable:** Start by stripping the end of the cable approximately 0.3 inches (or 8 mm) to expose the metal for connection.
2. **Open the Screw Terminals:** Use a flat-head screwdriver to fully open the screw terminals by turning them counter clockwise. This will create enough space to insert the stripped cable.
3. **Insert and Secure the Cable:** Plug the stripped end of the cable into the screw terminal. Once properly positioned, turn the screw terminal clockwise to tighten and secure the connection firmly.

Following these steps will help ensure a reliable grounding system for your PV setup.

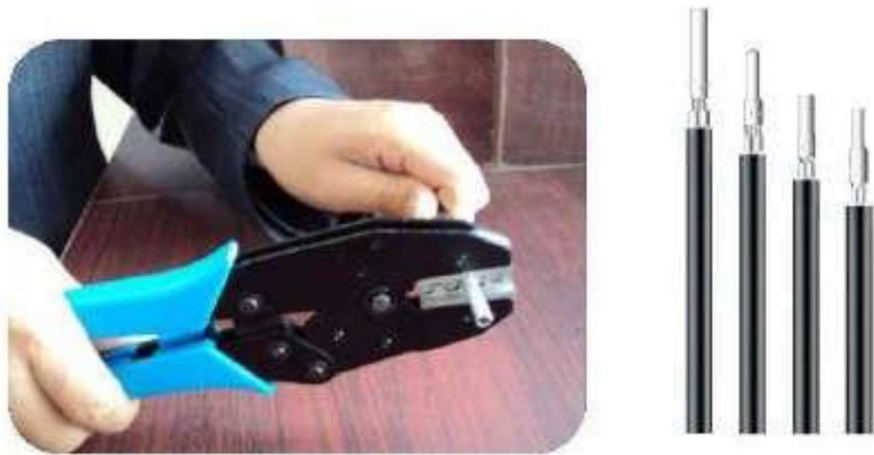


Fig. 8.15: Cable stripping using a crimping tool

Step 4: Inserting Cables into the DC Disconnect Switch

When the PV negative is grounded, connect the PV positive wire conductors to the terminals marked “PV Hot Inputs” in the fuse holder. The PV negative conductors should be wired into the terminal block located to the left of the fuse holders, labelled “PV Neutral Input.”

If the PV positive is grounded, the process is reversed: connect the PV negative wire conductors to the “PV Hot Inputs” terminals, while the PV positive conductors should be connected to the terminal block marked “PV Neutral Input.”

Step 5: Wiring to the DC Energy Meter

Next, bring the wires from the DC disconnect switch and connect them to the energy meter. It is crucial to ensure that the polarity of the cables is correct during this connection to maintain proper functionality.

Step 6: Wiring to the Inverter

For the negative strings, follow these steps:

- Strip approximately 0.3 inches (around 8 mm) of insulation off the cable.
- Using a flat-head screwdriver, fully loosen the screw of the terminal by turning it counterclockwise. Insert the stripped cable into the opened terminal.
- Tighten the screw by turning it clockwise to secure the connection.

Repeat this process for the positive strings at the input terminal, ensuring the connections for both the DC positive and DC negative output terminals are securely made.

STEP 7: Wiring to AC disconnect switch

The AC disconnect switch is used to safely isolate the inverter from the home's electrical panel. To wire it correctly:

- Connect the red wire to the bottom screw at the back of the breaker.
- Connect the black wire to the other screw at the back.
- Tighten the screws to make sure the wires are secure.
- Attach the white wire (neutral) to the neutral bar, which can be located on the left or right side of the breakers. Tighten the screws firmly.
- Finally, connect the bare copper wire (ground) to the ground bar, which also holds other copper or green ground wires.

STEP 8: Wiring to AC combiner box

The AC combiner box protects and distributes AC power from the inverter to the home. It is usually a thermo-plastic IP65 DIN rail-mounted box, designed to keep components safe from dust and water.



Fig. 8.16: AC combiner box

Key components inside the AC combiner box include:

- Incoming cable from the solar inverter (single-phase 3-core or three-phase 5-core)
- AC circuit breaker (2-pole or 4-pole) to isolate AC circuits when needed
- AC surge protection device (SPD), Class 2 as per IEC 60364-5-53, to protect against voltage spikes
- Outgoing cable to the building's electrical distribution board

When wiring:

- Mount all components securely on the DIN rail.
- Connect the incoming cable from the inverter to the AC breaker and SPD.
- Connect the outgoing cable to the home's main electrical panel.
- Ensure all connections are tight, neat, and clearly labelled.



Fig. 8.17: 6 AC distribution box (AC MCB for AC isolation, Surge protection device and Input side fuse protection)

Terminate Cables

Termination connectors

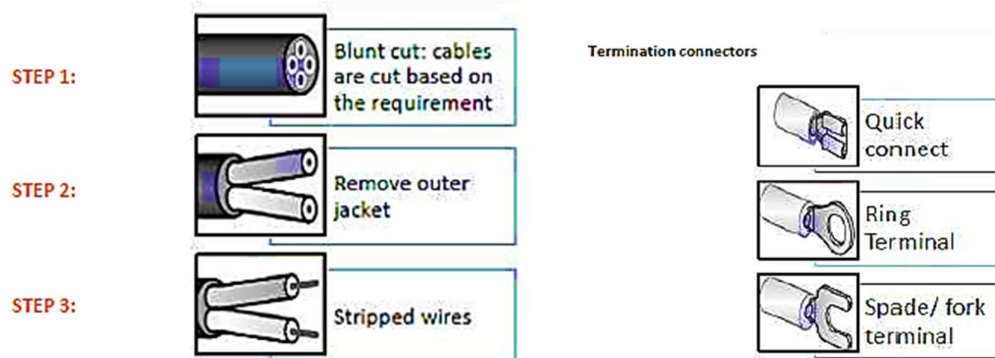


Fig. 8.18 Types of termination connectors

Mostly ring terminal is used where cables are connected by using screw and bolts.

Check Cables for Continuity

The continuity of cable conductors is checked by using a megger test. For maintenance purposes of the cable, this test should be carried out periodically.

Continuity test:

Tools and Equipment required

- Multimeter
- Wire nipper
- Screwdriver test
- Box spanner

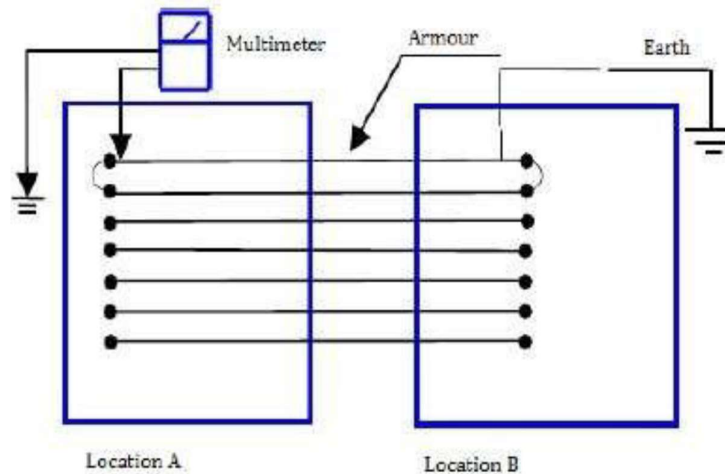


Fig. 8.19: Electrical diagram for continuity test

This test is done to check whether a cable is electrically continuous or if there is a break in the conductor. A multimeter is used for this purpose.

Procedure:

1. Set the multimeter to the 200-ohm resistance range.
2. At Location A, connect one probe of the multimeter to the cable conductor to be tested and the other probe to earth.
3. At Location B, have a staff member connect the earth to the same conductor of the cable.
4. If the earth connection is weak at both ends, also connect the cable armour to earth.
5. Observe the multimeter needle or display. If it shows a deflection or reading, the conductor is continuous and unbroken.
6. To test another conductor, use the first tested conductor as a reference. Connect one probe to the first conductor at Location A and the other probe to the second conductor. At Location B, have the staff short both conductors together.
7. Repeat this method for all other conductors in the cable to ensure continuity throughout.

Proper Labelling of Conduits and Cables

In a solar power plant, there are many cables running across modules, combiner boxes, and inverters. Proper labelling of these cables is very important, especially during maintenance or troubleshooting. Without clear labels, it is easy to make wrong connections, which can damage equipment or create safety hazards.

On the DC side, there are usually only two main cables after the combiner box: one positive and one negative. However, after the PV modules, there are multiple string cables, and each string must be clearly identified. Strings are typically labelled as String 1, String 2, String 3, and so on, to match the system design.

After the DC combiner box, labelling can be done either by numbers or colours. Most systems use colour coding because there are only two wires:

- Red → Positive (+)
- Black → Negative (-)

CHECK YOUR PROGRESS

A. Multiple Choice Question

1. Why is it important to use conduits for solar cables?
 - a) To make the system look attractive
 - b) To protect cables from UV rays, heat, and physical damage
 - c) To increase the voltage of the system
 - d) To reduce the cable length
2. Which colour is used for the earth (ground) wire in standard wiring codes?
 - a) Black
 - b) Green
 - c) Red
 - d) Yellow
3. What tool is used to check the electrical continuity of cables?
 - a) Clamp meter
 - b) Megger
 - c) Multimeter
 - d) Ammeter
4. What is the main purpose of proper labelling of cables in a solar PV system?
 - a) To match the colour of panels
 - b) To make the system look tidy
 - c) To prevent confusion and ensure safe maintenance
 - d) To increase the current flow

B. Fill in the Blanks

1. Red, yellow, and blue wires are used for _____ connections in a solar PV system.
2. A larger gauge number means the wire is _____ in thickness.
3. The continuity test is done to check whether a cable is _____ or broken.
4. On the DC side, the red cable represents the _____ terminal and the black cable represents the _____ terminal.

C. Short Answer Questions

1. Why is it important to select the correct cable type, colour, and gauge for a solar PV system?
2. What are the main components inside an AC combiner box?
3. Describe the purpose of performing a cable continuity test.
4. Why is proper cable labelling necessary in a solar power system?

SESSION 4: GET THE GROUNDING SYSTEMS INSTALLED

Determine the Grounding Conductor Size

Before starting, refer to the system design to find the type of material, size of the grounding conductor, and type of grounding required. This ensures the grounding system will safely handle any fault currents and protect both the equipment and people.

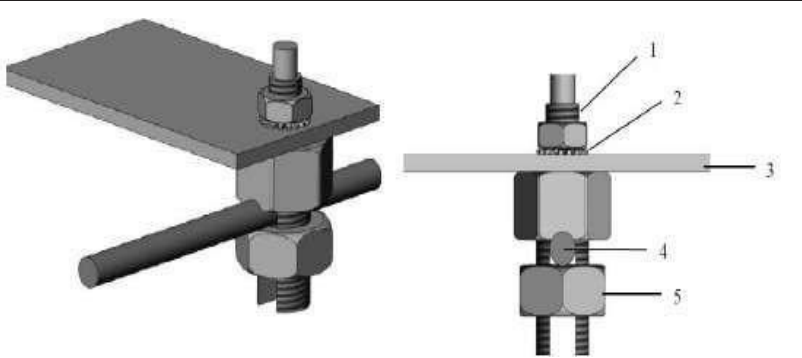
Grounding PV Modules and Mounting System

All PV module frames and mounting racks must be properly grounded, following the National Electrical Code. Grounding ensures that if a fault occurs, electric current safely flows into the earth, protecting both equipment and humans.

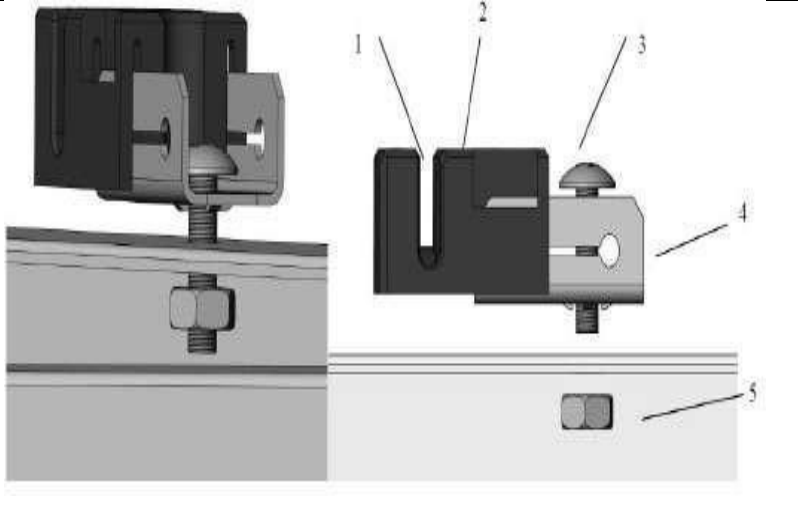
Proper grounding is done by bonding the module frames and all metallic structural parts together using a suitable grounding conductor (usually copper or copper alloy). This conductor is then connected to the earth via an electrode.

Common grounding methods for PV modules include:

Method 1:

S. No.	Description	
1	Wire bolt	
2	Mounting a wash hex nut	
3	Aluminum frame	
4	4 to 16 mm ² cable	
5	HEX nut	

Method 2:

No.	Description	
1	Wire slot (available for 4-6 mm ² cable)	
2	Slider	
3	Bolt	
4	Base	
5	Nut	

Grounding the DC Combiner Box and Inverter

The inverter must also be grounded through its ground bar. For grounding the inverter, follow the same procedure as for the DC combiner box.

Grounding of DC Combiner Box Grounding of the inverter

The inverter must be properly grounded using its ground bar, following the same procedure as for the DC combiner box. Proper grounding ensures that in case of a fault, electricity safely flows to the earth, protecting both equipment and people.

Before starting, check your design to know the pit size and the size/type of the electrode (rod or plate). Then follow these steps:

1. Dig a pit according to the design specifications.
2. Place a copper rod or plate vertically in the pit. This acts as the earth electrode.
3. Attach earth leads (wires connecting components to the electrode) at two different points on the electrode using nuts and bolts. If there are two electrodes, use separate leads for each.
4. Apply a thin layer of grease on all joints to prevent corrosion.
5. Bring all grounding wires through a metallic pipe, keeping it about 1 ft (30 cm) above the ground.
6. Around the electrode, add a 30 cm layer of powdered charcoal and lime to retain moisture, improving conductivity.
7. Connect all wires tightly to their components using thimbles and nuts, ensuring no two components share the same electrode. Keep electrodes at least 3 m apart.
8. All metallic parts and earth continuity conductors must be securely connected to the earth lead.
9. Test the earthing system using an earth tester. The maximum allowable resistance is 1 Ω . If resistance is higher, increase the size of the earth lead, not its length.
10. For better performance, leave the pipe ends open and hydrate regularly to maintain moisture around the electrode.

Various specifications recommended by Indian Standards for earthing are:

When installing an earthing system, certain standards must be followed to ensure safety and proper operation. The earthing electrode (rod or plate) should be placed at least 1.5 meters away from the building it is protecting, to avoid interference with the structure. The earth resistance must be low enough to allow fault currents to flow freely, so that protective devices like relays or fuses operate correctly. Resistance can vary with weather and soil moisture, but it should not exceed 1 ohm.

The earth wire and electrode must be made of the same material, usually copper, to ensure uniform conductivity. Always install the electrode vertically in the ground, so it passes through consistent soil layers and avoids contact with different layers that could reduce its effectiveness.



Fig. 8.20: Connection of ground wire to the metallic part of a building

Make sure to bond all the electrical equipment's grounding parts together

it's an important safety step! This is also a recommended practice according to IEEE Standard 1100-1999. For the appropriate bonding conductor size, please refer to your specific guidelines design.

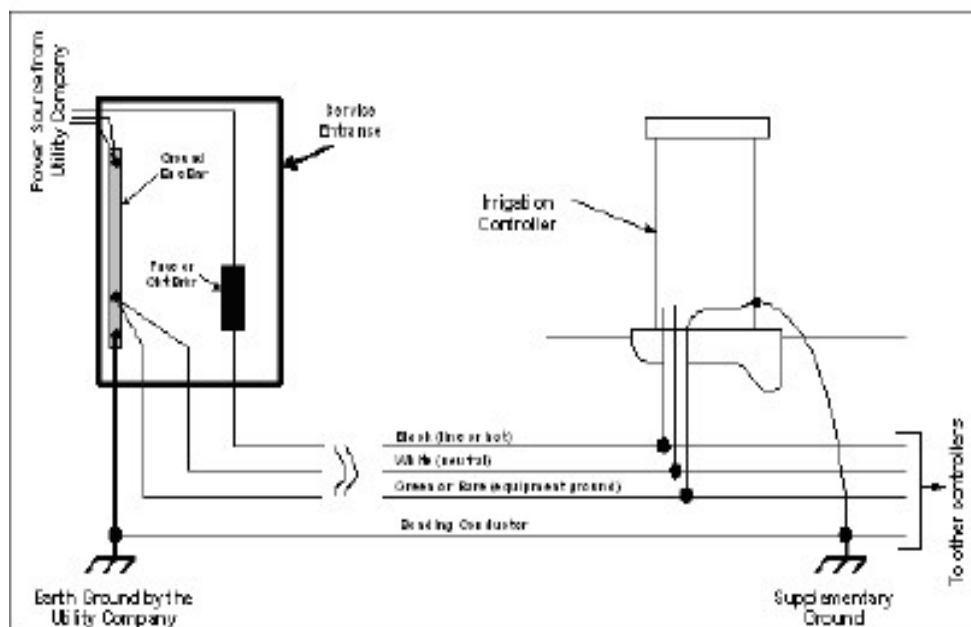


Fig. 8.21: Sample design reference for grounding

Install Battery Bank

Confirm and Install Battery Bank Enclosure/Racks

Refer to the design to know whether the design includes a battery rack system or not. If it includes then note down which type of rack system is it.



Fig. 8.22: Battery Bank enclosures/racks

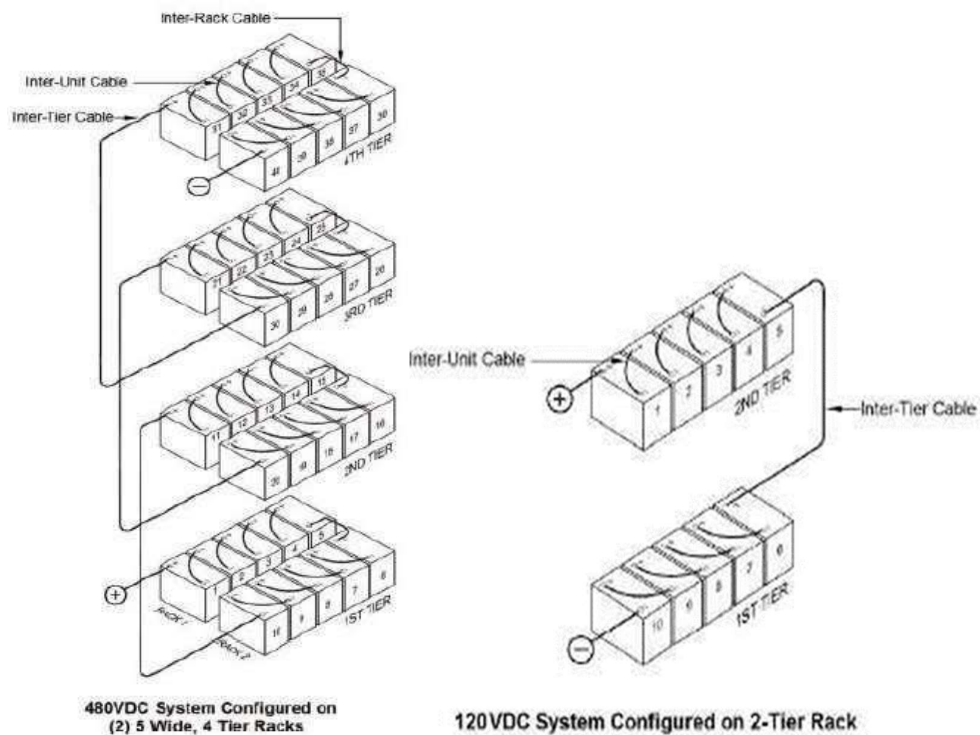


Fig. 8.23: Arrangement of batteries on rack systems

Install Batteries and Prepare Battery Terminals

For installation of batteries, refer to section 1.2.4. Make battery terminal clean before connection. Cleaning process is given below.

STEP 1: Make your cleaning agent



STEP 4: Rinse



STEP 2: Apply the paste



STEP 5: Dry



STEP 3: Scrape off deposits



STEP 6: Prevent future corrosion



STEP 7: Replace the clamps

**Install Battery Interconnection Cables and Apply**

Anti-Oxidant Material: For installation of battery interconnection cable refer to section. As mentioned above diagram applies antioxidant material at the interconnection.

Case study of a 10-kW solar power plant

Crystalline photovoltaic modules are mounted with the help of rail mounting structure on rooftop of a building. Ballasted foundations are created to hold mounting structure firmly.



Fig. 8.24: MC4 connectors are used to connect PV modules together



Fig. 8.25: MC4 connector

Cable trays are used to carry DC cables from PV panels to the inverter.



Fig. 8.26: Cable tray

DC cables from PV panels are inserted into inverter by using cable conduit.



Fig. 8.27: Cable conduits

AC output cables from inverter are fed to the AC distribution box



Fig. 8.28: Inverter and AC distribution box

From the AC distribution box, AC cables are fed to the utility distribution box with the help of a cable tray.



Fig. 8.29: Cable tray

CHECK YOUR PROGRESS**A. Multiple Choice Questions**

1. What is the main purpose of grounding in a solar PV system?

- a) To improve power generation efficiency
- b) To provide a safe path for fault current and protect people and equipment
- c) To reduce the cost of wiring
- d) To store excess current in the ground

2. What material is most commonly used for grounding conductors?

- a) Aluminium
- b) Copper or copper alloy
- c) Steel
- d) Iron

3. What should be the maximum allowable earth resistance for a solar PV grounding system?

- a) 10 ohms
- b) 5 ohms
- c) 1 ohm
- d) 0.1 ohm

4. Why should a layer of charcoal and lime be placed around the earthing electrode?

- a) To keep insects away
- b) To improve moisture and conductivity of the soil
- c) To make the pit look clean
- d) To prevent wire theft

B. Fill in the Blanks

1. The grounding system helps in safely carrying _____ current into the earth.
2. The earthing electrode should be installed at least _____ meters away from the building.
3. Before starting the grounding work, always check the _____ for the type and size of grounding conductors.
4. According to IEEE Standard 1100-1999, all grounding parts of electrical equipment must be _____ together.

C. Short Answer Questions

1. Why is grounding important in a solar PV system?
2. What are the main steps in installing an earthing system for a solar PV plant?
3. What should you do if the earth resistance is more than 1 ohm?
4. Why is it necessary to use the same material for the earth wire and electrode?

Module 9: Test & Commission Solar PV System

After installation, the solar PV system must be tested and commissioned to ensure all components work properly, safely, and as per design. Testing confirms electrical performance, mechanical stability, and safety compliance before the system starts operation.

SESSION 1: OVERALL SYSTEM INSPECTION

Before starting the testing and commissioning activities, it is necessary to perform a complete inspection of the solar PV system. This ensures that every part of the installation is complete, correctly installed, and safe for operation.

Assess Array Location

Before proceeding with detailed testing, it is important to assess the solar array location to confirm that it meets all design and safety requirements. The array location affects the efficiency, safety, and longevity of the solar PV system. During assessment, the following points should be checked

- The PV array should be free from shadows throughout the year — use a sun path finder to check this.
- There must be safe and easy access for maintenance and cleaning.
- The array should be protected from animals and vandalism.
- Provide enough space behind the panels for proper air circulation to avoid overheating.
- The aesthetic appearance of the building or site should also be considered.
- The array should be placed close to the charge controller, inverter, or battery to minimise power loss through cables.



Fig. 9.1: Shadow-free installation on Howrah Municipal Corporation Building



Fig. 9.2: Incorrect site selection for array installation

Check Equipment Location

- Ensure that all controls, power conditioning units, and instruments are installed in locations where access is limited and properly controlled.
- Verify that all electrical disconnect switches and circuit breakers are also installed in secure and easily accessible positions, allowing only authorized personnel to operate them.



Fig. 9.3 Access to the inverter is controlled



Fig. 9.4: Inverter and control equipment installed in a control room

Check Battery Location

- Ensure that batteries are placed in a dry area to prevent moisture-related damage.
- Batteries should not be in direct contact with cold surfaces like concrete to avoid performance issues.
- Install batteries in a properly ventilated container, box, or room that allows safe and easy access for maintenance and replacement.



Fig. 9.5: Location of batteries in a well-ventilated room



Fig. 9.6: Batteries kept in a box, container and rack

Testing of Solar Array

Overview of Testing Methods and Parameters

STEP 1: Check the physical condition of the photovoltaic (PV) array. Ensure module frames are straight and free from corrosion or any physical damage.

STEP 2: Ensure no shading on the modules throughout the day. Even small “spot” shading on a few cells or modules can create hot spots and permanently damage the panel.

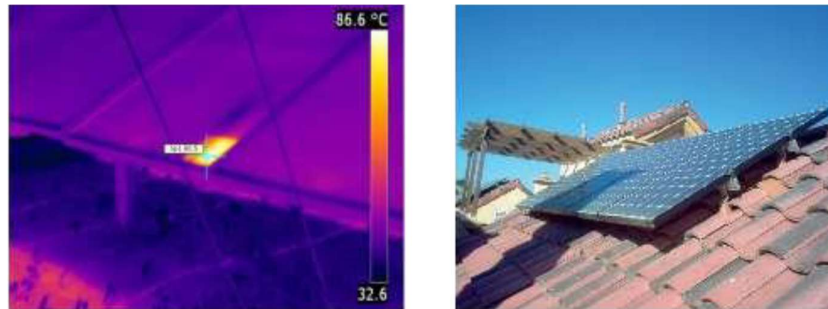


Fig. 9.7: Spot shading causes hot spot and may damage a module

STEP 3: Inspect all mounting hardware and confirm that fasteners and connections are tight and secure.

STEP 4: Check that all conduits and connections are properly tightened and undamaged.



Fig. 9.8: Properly managed PV array cable

STEP 5: Visually inspect wires and insulation for any cuts, cracks, or damage.

STEP 6: Check junction boxes for loose, damaged, or broken parts.

STEP 7: Gently pull all wire connections to ensure they are properly secured.

STEP 8: Confirm that array wiring is protected and not easily accessible to unauthorised personnel.



Fig. 9.9: Poor quality conduit and unprotected cable can be easily damaged

STEP 9: Check all strings for continuity, voltage, and polarity using a multimeter.

STEP 10: Verify that string voltages are within 5% of the expected open-circuit voltage (VOC). If not, investigate possible causes such as wiring issues or shading before proceeding.

How to Conduct a Continuity Test

- Turn the multimeter dial to Continuity Test mode. The display should show “OL” or “ Ω ” when probes are apart.
- Insert the black lead into the COM jack and the red lead into the V Ω jack.
- Connect the probes across the string (open circuit condition).
- The multimeter beeps if continuity exists; no beep indicates a broken connection.
- Switch OFF the multimeter after testing.

How to Test Voltage and Polarity

- Set the multimeter to the DC Voltage range.
- Insert the black lead into the COM jack and the red lead into the V Ω jack.
- Connect probes across the string (open circuit).
- Observe the open-circuit voltage (VOC) on display. A negative sign indicates reversed polarity.
- Switch OFF the multimeter after use.

STEP 11: Recheck polarity at the junction box, as incorrect connections are common here.

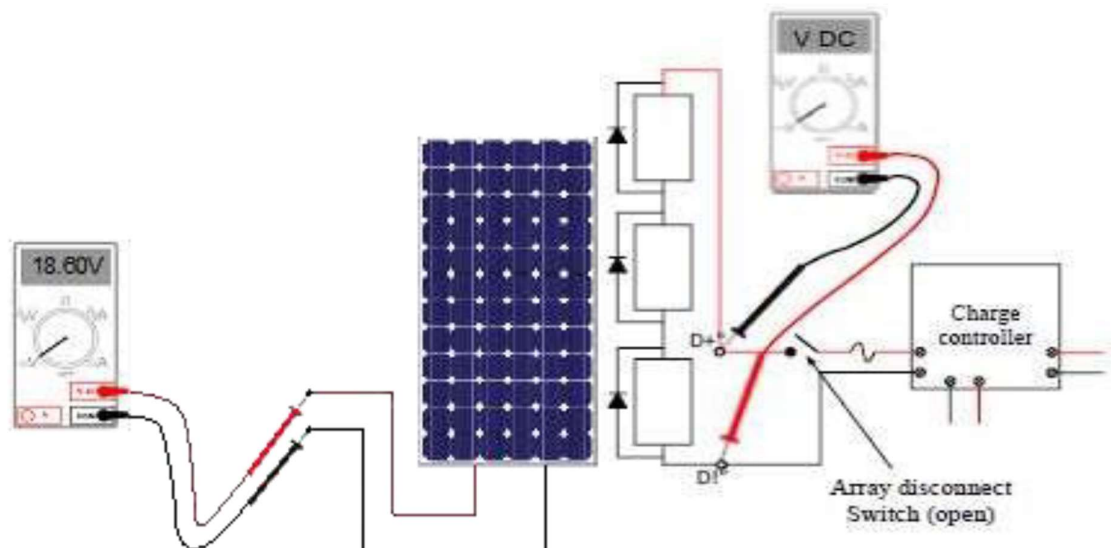


Fig. 9.10: Measuring module and string open circuit voltage

STEP 12: Record all test results in the inspection worksheet.

Wrong polarity Correct polarity



Fig. 9.11: Checking of reverse polarity using a clamp-on meter (Voltmeter)

Attention!

Loose connections and wrong polarity can cause fire hazards and damage the entire PV system. Always double-check connections before commissioning.



Fig. 9.12: Fire breaking out at the site of a solar PV system

Wire and Earthing Continuity Tests

Continuity Tests

Follow the same procedure as mentioned above to test the continuity cable.

1. Once the tests at the array are complete, continuity should be confirmed from the array to the PV array DC isolator
2. Check the continuity between the inverter and the inverter AC isolator (applicable to a grid-connected system)
3. Check the continuity between the kWh meter and the inverter AC isolator (applicable to a grid-connected system)
4. Measure the voltage of the grid on the output of the inverter AC isolator (applicable to a grid-connected system)

Tests for Earthing and Lightning Protection

At this time, turn off (open) all disconnect switches.

Use an ohmmeter to check the continuity of the entire grounding system.

1. Make sure that all module frames, metal conduit and connectors, junction boxes, and electrical components chassis are earth grounded.
2. Using a DC voltmeter, check the polarity of all system components and wiring.
3. If plastic conduit is used, make sure a grounding wire has been run through it to provide continuous grounding.
4. If metal conduit is used, the conduit itself functions as the ground conductor, where allowed by code. If not allowed by code, a grounding wire must be used.

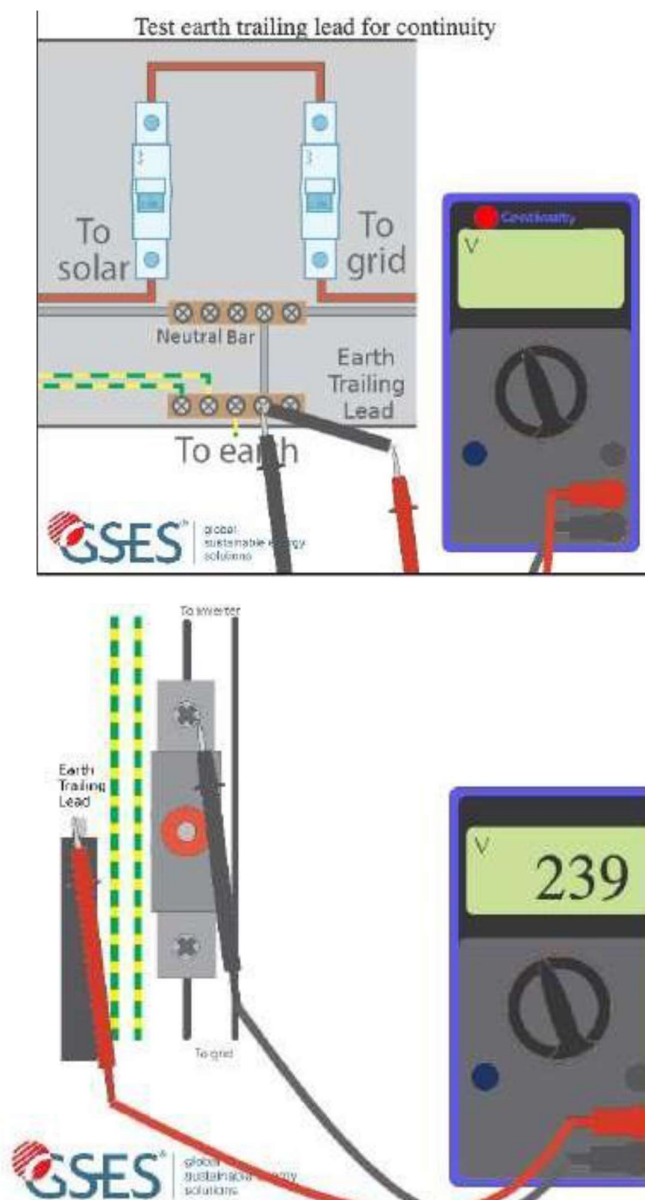


Fig. 9.13: Earth continuity and leakage test

Testing of Charge Controller

Steps to be Followed

1. Follow the manufacturer's instructions, if available, for the specific charge controller in the system.
2. Check all terminals and wires for loose, broken, corroded, or burnt connections or components.
3. Check all displays, LED indicators and status monitoring system are in operation
4. Check that overcharge protection and under charge protection of charge controller is functioning correctly.
5. If charge controller is equipped with a temperature compensation device, check whether temperature probe is functioning correctly
6. Make sure there are no loose strands of multi-strand wire. These can short out on other terminals or other wires' loose strands.



Fig. 9.14: Testing of charge controller

Testing procedure for shunt charge controllers (12V system):

1. STEP 1: Set multimeter to appropriate DC voltage range to measure the voltage between the array positive and array negative (terminals).
2. STEP 2: Measure the DC voltage between the battery positive and battery negative terminals on the controller. If the controller is operating properly, it should be between 13.5 and 14.5 volts per module in series.

Testing procedure for series charge controllers:

You will require a DC portable adjustable power supply of suitable voltage range to carry out this test.

1. Step 1: Disconnect all wiring from the controller, except the temperature compensation probe, if the controller has one. Set the power supply to zero volts.
2. Step 2: Connect the power supply and DC voltmeter (Multimeter set at DC voltage) to the controller's + and - "array" input terminals.
3. Step 3: Watching the meter, slowly increase the power supply voltage until it is equal to the nominal voltage rating of the charge controller.
4. Step 4: Continue to increase the voltage until the meter reads one-half volt above the charge termination setting of the controller. At this point, the "charging" LED should

go off. Record the charge termination voltage and compare with manufacturer's data sheet.

5. Step 5: Turn the power supply voltage back to zero, then move the meter and power supply to the + and - "battery" terminals on the charge controller. Slowly increase the Voltage. At first, the low voltage disconnect LED may be off. Once you supply enough voltage to operate the controller, but are still below the low voltage disconnect setting, the LED should be on. When the voltage is higher than the disconnect setting, the LED should go off. The voltage at which the LED comes on is the low battery reconnect voltage and should be recorded and compared with the manufacturer's data sheet.

Since many charge controllers have a time delay on load reconnection, it may be necessary to leave the power supply connected for a few minutes. The time required varies with the model of charge controller.

Testing procedure for Pulse charging

If the charge controller has a pulse charging feature, follow the same steps as described in testing procedure for series charge controller except modify step 4 as follows:

Turn the power supply voltage up very slowly. As the voltage approaches the charging termination setting, the controller should start pulse charging. The controller is trying to pulse voltage into the batteries. The charging LED should be flashing on and off. If the controller has a fully charged LED, it should be off.

Note that some controllers pulse so fast that you can not see the flashing of the LED.

Testing procedure for Multistage charge controller

For this test, an ammeter will be needed, as well as the voltmeter. Set the ammeter for the highest setting first, then change settings downward. During the test the current flow will range from amps to milliamps. Connect the ammeter to the controller's "battery" terminals.

Follow the same steps as described in testing procedure for series charge controller except modify step 4 as follows:

Turn the power supply voltage up very slowly. At first, the current flow should be a few amps. As the voltage approaches the charging termination setting, the controller should start "trickle" charging at a few hundred milliamps.

Testing of Batteries

General Conditions

1. The tops of the batteries should be clean and dry. Caps should all be in place and secure.
2. All wiring connections should be secure.
3. Confirm that there are no shelves, hooks, or hangers above the batteries.

4. Check the electrolyte level of every cell in every non-sealed battery. It should always be above the top of the plates, but below the tops of the battery cases.
5. Ventilation systems must be functional.
6. Label each battery with a number for the battery and numbers for each cell.

Determine State of Charge with a Hydrometer

A hydrometer describes the state of charge by determining the specific gravity of the electrolyte. Specific gravity is a measurement of the density of the electrolyte compared to the density of water.

Usually, the specific gravity of electrolyte is between 1.120 and 1.265. At 1.120, the battery is fully discharged. At 1.265, it is fully charged.

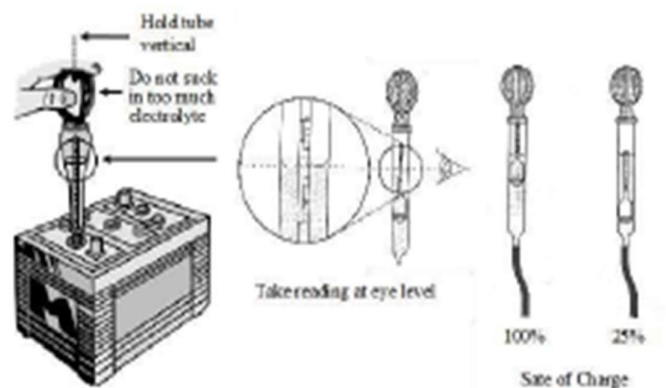


Fig. 9.15: Measurement of state of charging using a hydrometer

1. To use a hydrometer, squeeze the bulb while the inlet tube is still above the electrolyte level. Lower the hydrometer into the electrolyte and gradually release the bulb to suck in electrolyte.

Reading a Hydrometer

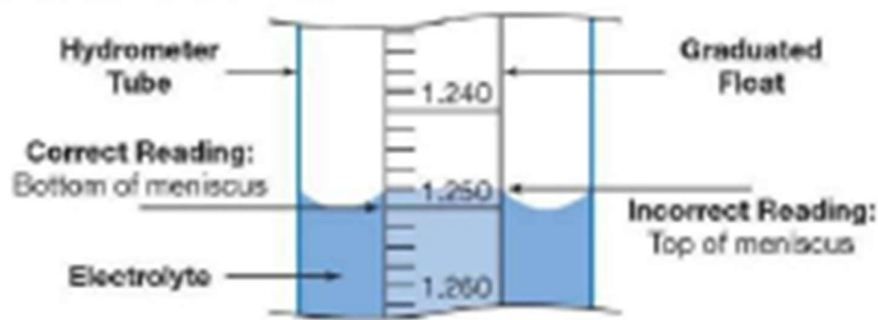


Fig. 9.16: Reading a hydrometer

2. When emptying the hydrometer, slowly squeeze the bulb with the inlet just above the electrolyte level, but still inside the battery cell. These methods reduce the chances that electrolyte will spurt out of the battery or the hydrometer.
3. At the first cell being checked, fill and drain the hydrometer with electrolyte three times before pulling out a sample. This brings the hydrometer to the same temperature as the electrolyte.
4. Take a sample of electrolyte and allow the bulb to completely expand. Hold the hydrometer straight up and down, so the float is not touching the sides, top, or bottom of the tube.
5. Look straight across the electrolyte level to read the float, as shown in Figure above. Ignore the curve of the electrolyte up onto the sides of the hydrometer.
6. Record the specific gravity of each cell on a copy of the sheet provided at the end of this manual.

Table 9.2: Specific gravity to corresponding battery state of charge

Electrolyte Temperature (oC)	Specific Gravity Reading and State of Charge				
	SG Reading at 100% SOC	SG Reading at 75% SOC	SG Reading at 50% SOC	SG Reading at 25% SOC	SG Reading at 0% SOC
48.9	1.249	1.209	1.174	1.139	1.104
43.3	1.253	1.213	1.178	1.143	1.106
37.8	1.257	1.217	1.182	1.147	1.112
32.2	1.261	1.221	1.186	1.151	1.116
26.7	1.265	1.225	1.190	1.155	1.120
21.1	1.269	1.229	1.194	1.159	1.124
15.6	1.273	1.233	1.198	1.163	1.128
10.0	1.277	1.237	1.202	1.167	1.132
4.4	1.281	1.241	1.206	1.171	1.136
-1.1	1.285	1.245	1.210	1.175	1.140
-6.7	1.289	1.249	1.214	1.179	1.144
-12.2	1.293	1.253	1.218	1.183	1.148
-17.8	1.297	1.257	1.222	1.187	1.152

Start-up Procedures

Start-up of Standalone System

1. Start the inverter and make sure the inverter is actually coming on by turning on an AC load.
2. Measure and record the current draw of the inverter in both idling and operating states.

3. Measure and record the voltage drop between the inverter and battery on the positive and negative leg while under load. Measure the current draw simultaneously and use this to calculate the resistance to arrive at the loss between the battery and the inverter.

- Measure Battery
- Measure Current

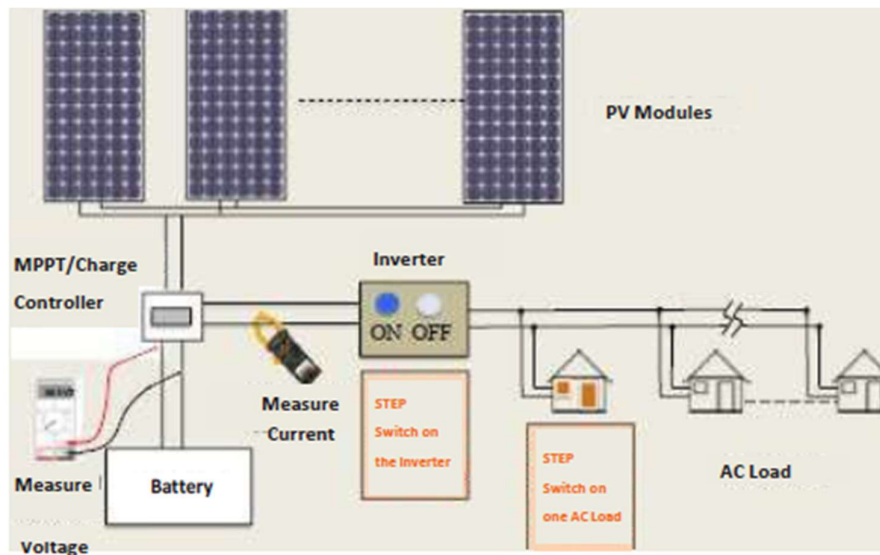


Fig. 9.17: Start-up of a Standalone PV System

Start-up of Grid-Connected System

1. If inverter has an on/off switch, ensure that it is in the off position.
2. After you have completed all other tests, refer to the inverter's system manual and follow the start-up procedure.
3. Typically, this will involve turning on the PV array DC isolator followed by inverter AC isolator.
4. Check and confirm that the solar array is feeding power onto the grid.
5. If you do not have a display meter, use a clamp on ammeter to measure either the AC or DC current.
6. Measure the DC input voltage and confirm that it is within operating limits of the inverter
7. Measure the AC output voltage.
8. If a kWh meter exists in the system, confirm that the inverter is producing the expected power output with respect to available DC power.

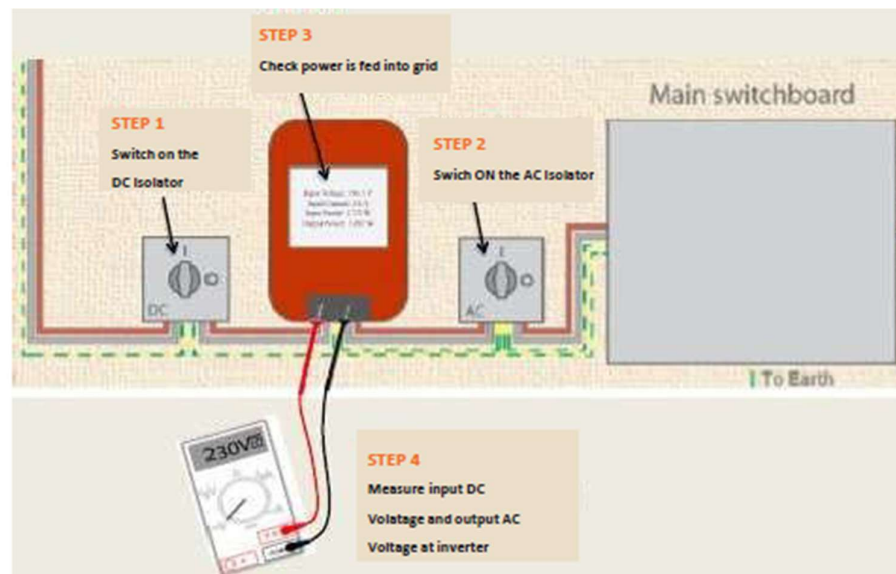


Fig. 9.18: Startup of grid-connected inverter

CHECK YOUR PROGRESS

A. Multiple Choice Questions

- What is the main purpose of testing and commissioning a solar PV system after installation?
 - To check aesthetic appearance
 - To ensure all components work safely and as per design
 - To increase system cost
 - To clean the solar panels
- What should be avoided when installing solar arrays to prevent power loss and overheating?
 - Open space
 - Proper air circulation
 - Shading
 - Cable protection
- Which instrument is used to check the continuity of PV strings?
 - Clamp meter
 - Multimeter
 - Ammeter
 - Hydrometer
- What does a negative sign on the multimeter display indicate during voltage testing?
 - Loose connection
 - Correct polarity

- c) Reversed polarity
- d) High voltage

B. Fill in the Blanks

1. The solar PV system must be _____ and commissioned before starting operation.
2. The PV array should be free from _____ throughout the year to ensure maximum efficiency.
3. Loose connections and wrong _____ can cause fire hazards in the PV system
4. The specific gravity of a fully charged battery is around _____.

C. Short Answer Questions

1. Why is the assessment of array location important before testing?
2. What is the purpose of a continuity test in a solar PV system?
3. What are the key safety checks for batteries during inspection?
4. How is the state of charge of a battery determined using a hydrometer?

SESSION 2: UNINTENTIONAL ISLANDING FUNCTIONALITY TEST

(Final test for grid-connected PV system)

1. Conduct this test after the system has been operating correctly for a few minutes.
2. This test must be conducted during noon time in a sunny day.
3. PV system shall produce more than 20% of the rated output of the PV array or the inverter – whichever is less.
4. If there is more than one inverter, tests should be carried out for each inverter.

Test 1: Inverter Must Cease Supplying Power Within Two Seconds of a Loss of Mains

STEP 1: Keep DC supply from the solar array connected to the inverter.

STEP 2: Place the voltage probe in the inverter side of the AC main switch.

STEP 3: Turn OFF the AC main switch through which the inverter is connected to grid.

STEP 4: Measure the time taken for the inverter to cease attempting to export power with a timing device and record.

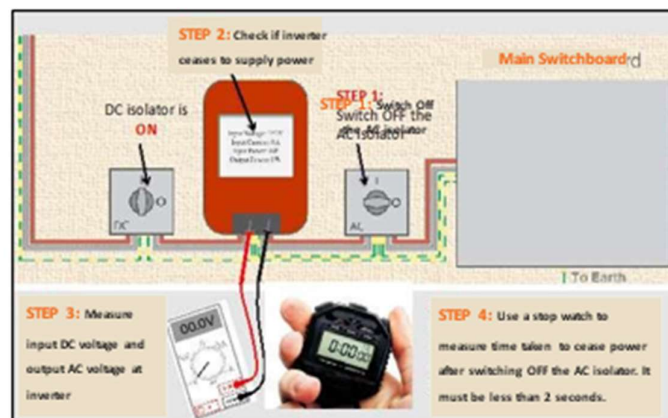


Fig. 9.18: Unintentional Islanding Functionality Test 1

Test 2: Inverter Must not Resume Supplying Power Until

Mains have Been Present for More than 60 Seconds

STEP 1: Keep DC supply from the solar array connected to the inverter.

STEP 2: Place the current probe in the inverter side of the AC main switch.

STEP 3: Turn ON the AC main switch through which inverter is connected to grid.

Step 4; Measure the time taken for the inverter to re energise and start export power with timing device and record

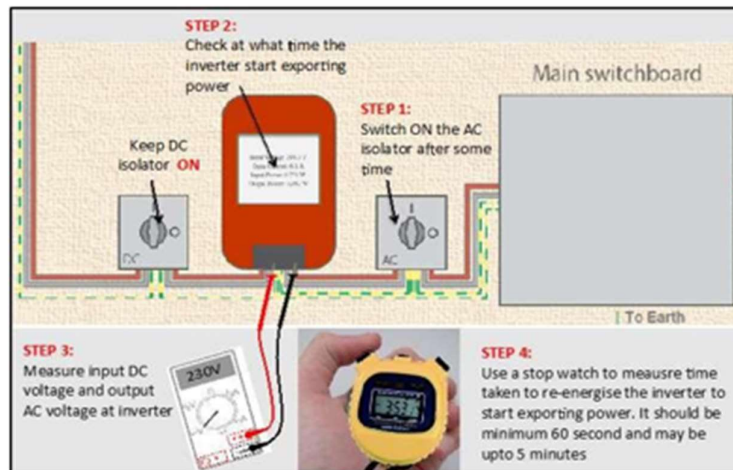


Fig. 9.19: Unintentional islanding functionality test 2

Sample Inspection Record Sheets

All questions in the record sheet below shall be answered YES or NO.

If the answer is NO, an explanation shall be given for each “NO” and remedial action to be taken as per the instructions given in his chapter. If deviation is unavoidable, you must report to your supervisor or engineer and raise your concern.

Table 9.3 Sample inspection record sheet

Overall System Inspection	
Array Location:	
1. Is the PV array free from shadow in all days of the year?	
2. Is the PV array having access for maintenance?	
3. Is the PV array protected from animals and vandalism?	
4. Is the PV array having ample space for air-cooling?	
Equipment Location:	
5. Is access to the inverter battery and other equipment controlled?	
6. Is the access to the disconnect switch or circuit breaker controlled?	
Battery Location:	
7. Is the battery bank located in a dry location?	
8. Are batteries being in contact with cold surfaces, such as concrete?	
9. Are batteries placed in a box/ rack or inside a room?	
Testing of Solar Arrays:	
10. Are there any physical damages to any PV module?	
11. Is there any corrosion in the structure?	
12. Is there any spot shading on any module during noon time?	

13. Are there any loose fasteners or connections to the mounting surface? 14. Are all conduit and connections tight and undamaged? 15. Are all conduits and wire insulations undamaged? 16. Are all junction boxes physically intact and tight? 17. Did all wiring pass the pulling tests? 18. Is there any wire that is readily accessible to any person? 19. Did all individual strings pass the continuity test? 20. Did all individual strings pass the open circuit voltage test? 21. Did all individual strings pass the polarity test? 22. Are the voltages of the strings within 5% of VOC? 23. Is polarity in the junction box correct? 24. Did the cable from the PV array to the DC isolator pass the continuity test?	
Wiring and earthing continuity tests:	
25. Did all cables pass continuity tests? 26. Did the earthing cable pass continuity tests? 27. Is all the metallic part in the system bonded correctly? 28. Did all system components and wiring pass polarity tests? 29. Is the resistance test using a megger successful?	
Testing of Charge Controllers:	
30. Did you check the charge controller as per the manufacturer's procedure? 31. Did you check all terminals and wires for loose connections in CR? 32. Did you check the functionality and display of and indicators of CR?	
Testing of Batteries:	
33. Are batteries kept dry, and vents are clear and clean? 34. Are all connections in the battery bank secured? 35. Is the electrolyte level of the batteries appropriate? 36. Is the ventilation system in the battery bank room working? 37. Did you level all the batteries with a specific number? 38. Did you note the state of charge of all the cells of the batteries?	
Unintentional islanding Functionality test	
39. Did the system pass the TEST 1? 40. Did the system pass the TEST 2?	

CHECK YOUR PROGRESS**A. Multiple Choice Question**

1. What is the main purpose of the unintentional islanding functionality test in a grid-connected PV system?
 - a) To check the inverter efficiency
 - b) To verify inverter response when the grid supply fails
 - c) To test the battery performance
 - d) To measure solar radiation

2. During Test 1, how long should it take for the inverter to stop supplying power after loss of mains?
 - a) 1 second
 - b) 2 seconds
 - c) 10 seconds
 - d) 60 seconds

3. According to Test 2, after the grid supply returns, the inverter should not resume power supply until the mains have been present for more than:
 - a) 10 seconds
 - b) 30 seconds
 - c) 45 seconds
 - d) 60 seconds

4. At what time of day should the unintentional islanding test be performed?
 - a) Early morning
 - b) Evening
 - c) Noon time on a sunny day
 - d) During cloudy weather

B. Fill in the Blanks

1. The unintentional islanding functionality test ensures safety when the _____ supply fails.
2. During Test 1, the inverter must stop supplying power within _____ seconds after grid loss.
3. During Test 2, the inverter should not start supplying power until the mains have been stable for more than _____ seconds.
4. If more than one _____ is used in the system, the test must be performed for each one.

C. Short Answer Questions

1. What is meant by “unintentional islanding” in a solar PV system?
2. What are the steps involved in Test 1 (Loss of Mains)?
3. What are the steps involved in Test 2 (Grid Recovery)?
4. Why is the unintentional islanding test important for grid-connected solar systems?

Module 10: Operation and Maintenance of Solar PV Power System

This module focuses on the essential practices for the effective operation and maintenance of solar photovoltaic (PV) power systems. It covers key principles and best practices to ensure optimal performance, extend the lifespan of solar installations, and guarantee safety and efficiency. Participants will learn about routine inspections, preventative maintenance strategies, troubleshooting common issues, and the importance of monitoring system performance. By mastering these concepts, individuals will be well-equipped to maintain solar PV systems effectively, ensuring they continue to deliver reliable and sustainable energy.

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SESSION 1: CLEANING AND TESTING OF SOLAR PANEL MAINTENANCE

Solar Photovoltaic panel cleaning technology can considerably increase the efficiency of electricity generated and also increase the durability of Solar panels. The various cleaning methods, such as electrostatic cleaning systems, super-hyperbolic coating methods, mechanical methods, microcontroller-based automatic cleaning methods, self-cleaning nano domes, and various characteristics of dust particles are discussed in this session. This unit throws light on various cleaning methods for solar photovoltaic panels and maintenance of solar water pumping systems. Before we clean the solar panel will follow the instructions below –

- Never use an abrasive sponge or soap for your solar panel cleaning as may scratch the glass. The best way to clean solar panels is by using a soft rag or biodegradable soap.
- It is important not to use harsh materials when cleaning solar panels as they could cause damage, and solar panels are costly to repair.
- For your safety and the safety of others around you, use a long-handled wiper to clean the panels while you are standing on the ground.
- If you must get on the roof, take proper care as once you begin cleaning, the roof becomes slippery and you could slide off when you get down, so use safety ropes or a harness for support.

- Always watch out for dirt on the solar panels to make sure it doesn't build up since they can absorb sunlight better when they are free of dirt.

A few methods of cleaning solar panels discuss below.

1. Solar Panels surfaces with a soft brush or a sponge: In this method, use a foam base brush or a sponge. Generally soft brush use needs to clean 10-20 solar PV panels it is the simplest way to clean the panel.



Fig. 10.1: Clean Solar Panel surfaces with a Soft Brush or a Sponge

2. Cleaning with Power washing:
High-pressure water flushing is the process of cleaning a solar panel by spraying it with water from a nozzle. Power washing with plain water is the best method because it is quick and effective, but it is risky. The glass/metal seal on the front of the modules cannot withstand the potential force from power washing, and forcing water into the module will almost certainly destroy it and void the warranty. However, believe that with caution, power washing can be effective. When the modules are hot, do not spray them with water. The glass may break, and even if it does not, you may cause damage to the metal/glass.

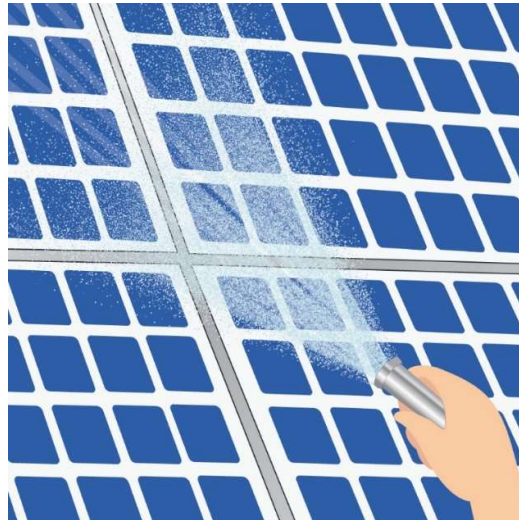


Fig. 10.2: Cleaning with Power washing

3. Photovoltaic cleaning machines powered by electricity (semi-automatic):

This technology used small and medium-sized solar panel arrays. It is easy operation and has high-cost performance. A typical diagram is shown below in fig. 10.3



Fig. 10.3: cleaning machines powered by electricity

4. Automatic cleaning:

Technology now allows the automatic cleaning of solar panels without the use of water or labour. The system takes advantage of the fact that most dust particles have an electric charge, which is especially useful in dry environments. The entire panel vibrates to shake dust loose.



Fig. 10.4: Automatic cleaning

TESTING OF SOLAR PANEL: Solar panel testing is key to assuring both the quality and safety of a module. Solar panels have a long lifespan: properly built and installed equipment should generate usable electricity for more than 25 years. Given the longevity of your investment, you want to make sure that any equipment on your roof will perform well and operate safely on your roof.

The power rating of a solar panel is given by the manufacturer and the number simply represents the amount of power that the solar panel is capable of producing under the most ideal conditions. However, in reality, solar panels are rarely exposed to ideal conditions for more than a few hours per day.

Essentially, testing your solar panels will allow you to make sure that they are generating enough power to meet your needs and let you know if you need to reinstall them so you can optimize their performance and get the highest possible amount of solar electricity out of your system.

Now can measure the following term of solar panel with the help of a multimeter-

- Open circuit voltage (Voc)
- Short circuit current (Isc)
- Operating current

We can use the following steps for testing solar panel

1)

Model : NPA 100S- 12H-SQ		
Max Power	Pmax	100w
Operating Voltage	Vmp	16.77V
Operating Current	Imp	6.26A
Open Circuit Voltage	Voc	19.83V
Short Circuit Current	Isc	6.56A
All rating at STC 1000W/m ² . AM 1.5 spectrum. 25°C		
 Warning Electrical Hazard This solar module produces electricity when exposed to light. Cover all modules in the PV array with opaque material before making any wiring connections or operating the terminal box. 		

(2)

Module Type	ESP-310
Rated Maximum Power (Pmax)	310W
Power Tolerance	0-5W
Current at Pmax (Imp)	8.38A
Voltage at Pmax (Vmp)	37.0V
Short-Circuit Current (Isc)	9.01A
Short-Circuit Voltage (Voc)	45.5V
Nominal Operating Cell Temp (NOCT)	45±2°C
Weight	23.0ZKG
Dimension	1956*992*45mm
Maximum System Voltage	1000V
maximum Series Fuse Rating	15a
Cell Technology	Poly-si
All technical data are measured at STC 1000W/m ² , 25°C AM 1.5	
    Module Application Class A	

Module Name	CHSM6612P-300
Maximum Power	300.0Wp
Open Circuit Voltage (Voc)	45.16V
Short Circuit Current (Isc)	8.91A
Voltage at Pmax (Vmp)	35.74V
Current at Pmax (Imp)	8.40A
Fuse Rating	15A
Maximum System Voltage	DC1000V
Power Tolerance	D~+5W
Nominal Operating Cell Temp (NOCT)	46°C
Cell Technology	Poly-si
Module Application: Class A	Module Safety Class II
All technical data are measured at STC 1000W/m2, 25°C AM 1.5	
Warning: This solar module produces electricity when exposed to light. One module on its own is below the safety extra low volt level, but multiple modules connected in series (summing the voltage) or in parallel (summing the current) represents a danger.	
Company Name: ABCDEFGH Address- XXX-XXXX-XXXXX Tel: +86-576-5306316666666 Fax: +86-576-530631666666	
  	

(3)

Fig. 10.5: 1,2,3 A typical solar panel specification

- Open circuit voltage (Voc): When the maximum load is connected to a PV device (resistance = infinite), a PV device produces maximum voltage and zero current, referred to as its open-circuit voltage, Voc.

Locate the open-circuit voltage (Voc) on the specs label (as per the fig no.2.3) on the back of your solar panel. Remember this number for later.

For this example, I'm using the New power100W 12V panel. It has a Voc of 19.83V. Prep your multimeter to measure DC volts. To do so, plug the black probe into the COM terminal (common terminal) on your multimeter. Plug the red probe into the voltage terminal. Set your multimeter to the DC voltage setting (and the correct voltage range if yours isn't auto-ranging). It is indicated by a solid line above a dotted line next to the letter V. Locate the positive and negative solar panel cables. The positive cable is typically the one with the male MC4 connector, which has a red band around it. Touch the red probe of your multimeter to the metal pin inside the positive MC4 connector. Touch the black probe to the metal pin inside the negative MC4 connector. Read the voltage on your multimeter and compare it to the open circuit voltage (Voc) listed on the back of panel. (If voltage reading is negative, reverse the probes and measure again.) measured a Voc of 19.85V on panel. The claimed Voc for this panel is 19.83V, so were spot on. The voltage measure with multimeter should be close to the open circuit voltage listed on the back of the panel. It doesn't have to be identical, though.

- Short circuit current (I_{sc}): When zero load is connected to a PV device (resistance = zero), the device produces maximum current and zero voltage, referred to as it's short-circuited current (I_{sc}).

Locate the short circuit current (I_{sc}) on the specs label on the back of the panel. Remember this number for later. panel's I_{sc} is 6.56A.

Prepare your multimeter to measure amps. To do so, move the red probe to the amperage terminal. Set multimeter to the amp setting (A), choosing the right limit if yours isn't auto-ranging. The short circuit current you're measuring should be close to the one listed on the back of the panel. We measure 6.53A. it is similar to the I_{sc} listed on the back of the panel, panel is working fine.

Operating current: When different load connected to a PV device (varying resistance) to measure the current, can use a multimeter. Again, these devices are affordable and worth investing, if you are running a solar power system. They can also be found at most hardware and automotive stores. If want to make sure are getting an accurate reading; you will also need to use a variable resistor box. These devices allow you to get readings at different levels of resistance.

Once you have the appropriate tools, you can use the multimeter to test your solar panels by following these steps:

- Locate the junction box (protected enclosure for electrical wiring)/converter box, which is usually located at the back of the solar panel. If it has a cover, remove it.
- Locate the positive and negative connectors and make sure are certain you know the difference. Consult the instruction manual for your solar panel if they are not clearly marked, or if you are unsure that you have correctly identified them.
- Make sure solar panel is receiving the same amount of sunlight that it normally would.
- Set the multimeter to read DC power (DC Voltage and DC current respectively). Also set the multimeter to measure a voltage level that is suitable for solar panel, meaning will want to set it higher than the voltage rating the solar panel has. This will make sure can get an accurate rating and the multimeter itself is not interfering.
- Connect the multimeter to the solar panel correctly, meaning the positive and negative clips of the multimeter are connected to the correct connectors.
- Note the voltage reading. Once you have your reading, turn the multimeter off, then you can disconnect the device from your solar panel.

- Following the steps above should give an accurate reading of the solar panel voltage. If are testing a fairly new solar panel in conditions where it is receiving adequate sunlight, the voltage should be fairly similar to the voltage rating the solar panel had when panel is in good working condition.

MAINTENANCE OF SOLAR WATER PUMPING SYSTEM

Routine maintenance

Once the solar pumping scheme has been installed and commissioned, several simple actions are to be followed by the owners of the system to prevent failure of the water supply due to an unexpected system shutdown. Routine maintenance activity is similar to the daily tasks that need to be performed while operating the solar water pumping system. Inspection is required day to day or during the week to check that all components are working and damage-free. Follow the chart below for schedule maintenance:

Table No. 10.1 Routine Maintenance for SWPS (solar power pumping system)

INSTRUMENTS	ACTIVITY	TIME
Solar panel	Cleaning	Weekly and monthly/when dirty
	Trimming trees	If needed to avoid shadow
MMS	tightening of clamps and nuts and bolts	If needed
Inverter	Reading	Once a month
Piping system for cleaning	Inspect water piping, repair	Fortnightly
Wiring	Fault of wiring	Once a quarter
		Once a year

Preventive maintenance: A fundamental element of maintenance services, preventive maintenance involves regular visual and physical inspections as well as verification activities to comply with the operating manuals. The preventive maintenance plan details a list of inspections that should be performed at predetermined intervals (typically quarterly, biannually, or annually) by a technician with specialized knowledge. Tracking records of preventive maintenance carried out will optimize activities further. The maintenance contract should include this scope of services and each task frequency. Ideally, such a contract will be negotiated together with the installation contract. It is the responsibility of the contractor in charge of maintenance to prepare the preventive maintenance plan for the duration of the contract period.

CHECK YOUR PROGRESS

A. Short Answer Question

1. Explain the importance of maintenance.
2. What is the Open circuit voltage?

3. Which parameter of the solar panel is measured by a multimeter?
4. Discuss the various cleaning methods of solar panels.
5. What do by short circuit current?

B. Fill in the blank

1. A digital multimeter is used for
2. Unit of current is
3. Junction box is
4. setting should be used to test a fuse.

Module 11: Maintain Personal Health and safety at the project site

A workshop or building where tools and machines are used for making or repairing things. Portable. Includes suspension for easy manual handling, e.g., in connection with a spring-suspended portable apparatus for use along assembly lines. Working on assemblies and jobs with hand tools and instruments, mostly on workbenches, is generally referred to as 'Fitting work'. A fitting work is required when different parts are to be assembled in position after they have been finished, and alignment of machine parts, bearings, engine slide valves, and similar other works call for a fitter's work. All the above types of work require the use of a large number of hand tools, and a fitter must have a good working knowledge of all these tools and instruments.

SESSION 1: PERSONAL PROTECTIVE EQUIPMENT

To create a safe and efficient work environment, it is important to have clear work procedures. These procedures guide employees on what to do, helping to reduce risks and keep everyone safe. By following these guidelines consistently, we can lower the chances of accidents and injuries.

Basics of Work Safety During Solar PV Installations

1. Maintaining a Safe Work Area
2. Safe methods of using tools and equipment

First Aid Kit

1. Wash the injuries/wounds with clean water
2. Apply First Aid on burns\injuries\wounds
3. Apply Sodium Hydroxide (NaOH) solution when burns are due to the battery's acid

Use and Maintain Personal Protective Equipment (PPE)

1. Importance of Personal Protective Equipment: PPE
2. Eye\Ear Protection
3. Head Protection
4. Foot and Leg Protection
5. Hand and Arm Protection
6. Safety Belt\Body Harness and Overalls (Full Body Suit)

PERSONAL PROTECTIVE EQUIPMENT (PPE)

PPE means personal protective equipment or equipment you use to guarantee your (own) safety. Use PPE always and anywhere where necessary. Observe the instructions for use, maintain them well, and check regularly if they still offer sufficient protection. PPE refers to the equipment which protects the user from health hazards or safety risks at work. It includes Safety Shoes, Safety Helmets, footwear, goggles, etc. Personal Protective Equipment should be provided to all employees who are exposed to safety and health

risks at work. In the automobile industry, workers frequently move from one workplace to another and perform a variety of tasks. The employee should be trained on how and when to use protective equipment.

1. Safety for The Head

Wearing a helmet offers protection and can prevent head injuries. Select a sturdy helmet that is adapted to the working conditions. These days you can find many elegant designs and you can choose extra options such as an adjustable interior harness and comfortable sweatbands.



Fig. 11.1: Safety for The Head

2. Protect Your Eyes

The eyes are the most complex and fragile parts of our body. Each day, more than 600 people worldwide sustain eye injuries during their work. Thanks to a good pair of safety glasses, these injuries could be prevented. Do you come into contact with bright light or infrared radiation? Then welding goggles or a shield offer the ideal protection!

Eye Protection

Protecting the eyes is extremely important because even a minor accident can cause long-term eye damage or even blindness. Here are several of the most common types of eye protection equipment:

- Goggles - This is good for preventing objects from flying into the eyes such as sawdust, stones, and shards of glass.
- Welding Masks - While welding masks sometimes cover the entire face, their main function is to protect the eyes from the extremely bright light of a torch. These masks are darkened significantly to prevent the light from reaching and damaging the eyes.
- Sunglasses - This is a simple type of PPE that most people never give a second thought. If you're regularly working in the sun or around bright lights, wearing sunglasses can help prevent many eye conditions down the road.

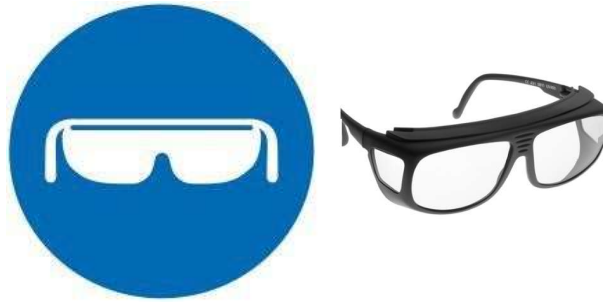


Fig. 11.2: Protect Your Eyes

3. Hearing Protection

Do you work in an environment with high sound levels? In that case, it is very important to consider hearing protection. Earplugs are very comfortable, but earmuffs are convenient on the work floor, as you can quickly put them on or take them off.

- **Ear Plugs** - Earplugs are easy to use and provide a fair amount of protection by preventing loud noises from entering the ear at all.
- **Ear Muffs** - Ear muffs go over the entire ear, and when worn properly, can provide a significant amount of noise reduction.
- **Electronic Ear Muffs** - These advanced hearing protection devices work like ear muffs to stop the noise from coming in, but also have an electronic microphone that picks up voices and other noises and then plays them into the ear so people can still hear. The sounds are played at a low level so they do not cause damage.



Fig. 11.3: Hearing Protection

4. Maintain a Good Respiration

a. Respirators

Respirators are a type of personal protective equipment designed specifically to protect the lungs of the people wearing them. They can help filter out dust, debris, chemicals, and many other potential dangers. There are many types of respirators used for PPE, including:

- b. Basic Facemask** - A facemask can minimize the risk of exposure to simple biological contaminants, dust, debris, and other harmful impurities in the air. In a pinch, even a simple handkerchief could serve as a facemask (though not recommended for regular use).

- c. **Filtered Respirator** - If there are known impurities that can cause serious damage or illness, having a filter on the respirator is important. There are many types of filtered respirators available depending on how many impurities need to be removed.
- d. **Self-Contained Breathing Apparatus** - In situations where the air is extremely toxic, a self-contained breathing apparatus allows the employee to bring a supply of fresh air with them. This is also used when there is no oxygen to breathe, such as underwater.

Wearing a mask at work is no luxury, definitely not when coming into contact with hazardous materials. 15% of the employees within the EU inhale vapours, smoke, powder or dust while performing their job. Dust masks offer protection against fine dust and other dangerous particles. If the materials are truly toxic, use a full-face mask. This adheres tightly to the face, to protect the nose and mouth against harmful pollution.



Fig. 11.4: Maintain a Good Respiration

5. Protect Your Hands with The Right Gloves

Hands and fingers are often injured, so it is vital to protect them properly. Depending on the sector you work in, you can choose from gloves for different applications:

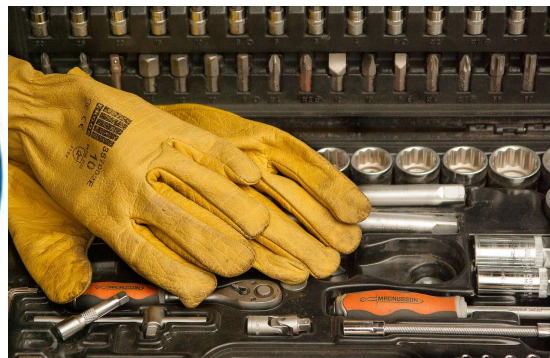


Fig. 11.5: Protect Your Hands with The Right Gloves

Like Protection against vibrations, cuts by sharp materials, cold or heat, bacteriological risks, and Protection against splashes from diluted chemicals.

- **Plastic Gloves** - Plastic (or latex) gloves are among the most common types of skin protection equipment. They can keep a wide range of hazards away, including biological and chemical solutions.
- **Cut-Resistant Gloves** - Employees who work with sharp objects should wear cut-resistant gloves. These gloves are made of special materials that prevent blades from slicing through them.

6. Skin & Body Protection Equipment

Many chemicals and other materials can cause serious injuries or illnesses when they come in contact with the skin. When working with these hazards, having proper personal protective equipment is extremely important.

- **Protective Clothing** - The most common type of skin protection equipment is general protective clothing. Something as simple as a lab coat helps reduce the risk of getting splashed with potentially hazardous solutions. While it isn't a high level of protection, it is sufficient for many situations.
- **Heat-Resistant Clothing** - When working with fire or other high-temperature hazards, employees should wear heat-resistant clothing. This could be heat-resistant gloves or it could be an entire suit, depending on the situation. Preventing accidents is crucial in a crowded workshop. That is why a good visibility at work is a must: a high-visibility jacket and pants made of a strong fabric can help prevent accidents. Just like hand protection, there are versions for different applications.



Fig. 11.6: Wear the Correct Work Clothing

- **Electricity-Resistant Clothing** - When working with or around high voltage areas, having PPE that can reduce the risk of electrical shock is essential. This could be rubber boots, gloves, or an entire body suit.
- **Face Shields** - Face shields reduce the risk of having something splash up into the face, causing damage. Whether working with hot items, corrosive materials, or biological materials, face shields can protect one of the most vulnerable parts of the body.
- **Hard Hats** - Hard hats are a great way to keep someone's head safe when working in an area where something could fall on i

7. Protection for The Feet

Even your feet need solid protection. Safety shoes (type Sb, S1, S2, or S3) and boots (type S4 or S5) are the ideal solutions to protect the feet against heavyweights. An antiskid sole is useful when working in a damp environment, definitely if you know that 16,2% of all industrial accidents are caused by tripping or sliding. On slippery surfaces, such as snow and ice, shoe claws are recommended. Special socks can provide extra comfort.



Fig. 11.7: Protection for the feet

8. Safety sign



Fig. 11.8: Safety sign

Worst-Case Scenario

Prevention is better than cure. A smart thing is to be prepared for the worst. A classic first-aid kit is no luxury but a first-aid kit for the eyes can also be an essential first aid. If the employee comes into contact with chemicals, a safety shower is mandatory, so that he can rinse the substances off his body at any moment.

- **Solar Home Systems – Safety Risks**

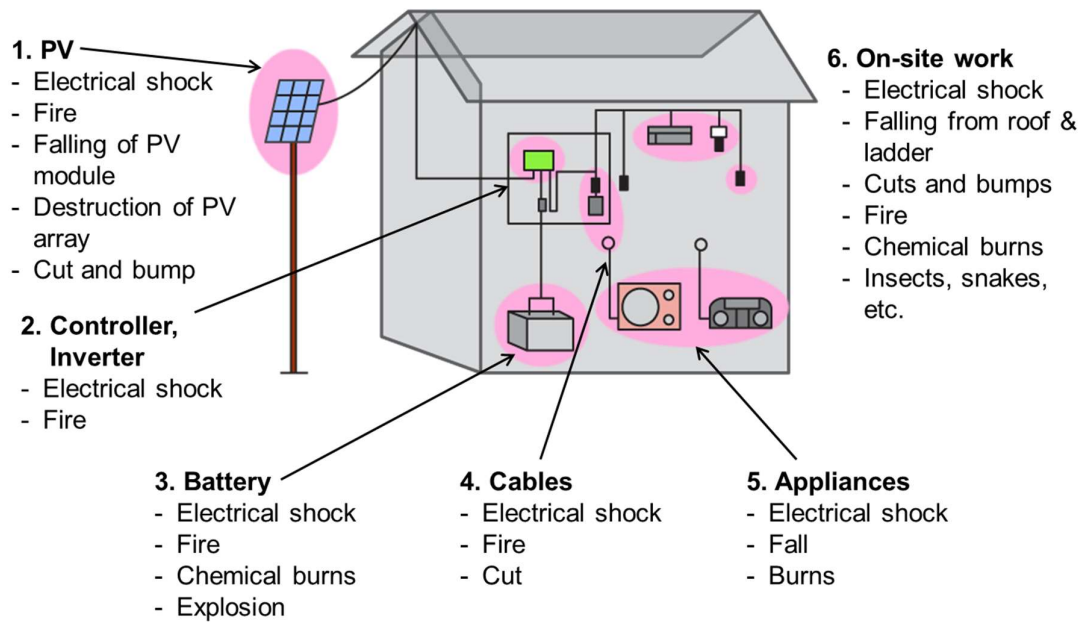


Fig. 11.9: Solar Home Systems – Safety Risks

Major Safety Hazards

1. Physical Hazard
2. Electrical Hazard
3. Chemical Hazard

1. Physical Hazards: Physical hazard is determined by the chemical's structural features. There are five types of physical hazards: explosive, flammable, oxidising, gases under pressure, and metal corrosive. These are then subdivided into different categories based on the level of danger, and each is assigned a unique hazard statement to identify it.

1.1. Explosive

If exposed to high temperature, heat, shock, and friction, it may explode.

- Avoid sources of ignition (sparks, flames, heat)
- Maintain your distance.
- Kept on protective clothing.



1.2. Flammable

Flammable if exposed to ignition sources, sparks, or heat. Some substances with this symbol may give off flammable gases in contact with water.

- Avoid ignition sources (sparks, flames, heat)
- Keep your distance
- Wear protective clothing



1.3 Oxidising

Can burn even without air, or can intensify fire in combustible materials.

- Avoid ignition sources (sparks, flames, heat)
- Keep your distance
- Wear protective clothing



1.4 Gas under Pressure

Contains gas under pressure. The gas released may be very cold. The gas container may explode if heated.

- Do not heat containers
- Avoid contact with skin and eyes



1.5 Corrosive

- May corrode metals.
- Keep away from metals



Physical Hazard – Personal Protection



Physical Hazard – Fall Protection

During construction, unprotected falls can lead to serious injury or even death:



Skylights must be protected so workers won't fall into them

Summary of physical hazards

- PV manufacturing and R&D provide a variety of physical safety problems throughout production and maintenance operations, in addition to chemical-related health and safety concerns:
- Equipment servicing, cleaning, adjustment, and/or repair exposes workers to a variety of hazardous energies, including electrical, hydraulic, and mechanical. To avoid electrocution, amputation, or crushing accidents, well-written hazardous energy control measures must be implemented and trained on. To prevent unintended contact by production and maintenance personnel, exposed belts, wheels, and other rotating machinery on conveyors or other production equipment must be properly guarded.

2. Electrical Hazard: An electrical hazard is a serious workplace hazard that can cause burns, electrocution, shock, arc flash/arc blast, fire, or explosions. We can protect ourselves by identifying these hazards and understanding how they occur. Although much of the public may think radiation from the sun is magically transformed into electricity that powers all types of equipment and devices, solar technicians know there is much more to it.

In PV, the current is "wild" and not limited by electronics, which has implications for hidden ground faults, and wire sizing, and is the impetus for the rapid shutdown. The control measures and best practices to mitigate risks will differ when working with PV versus any other kind of energy-generating resource.

Key points to remember

- Ensure that workers know how to use the electrical equipment safely
- Make sure enough sockets are available. Check that socket outlets are not overloaded by using unfused adaptors as this can cause fires
- Ensure there are no trailing cables that can cause people to trip or fall
- Switch off and unplug appliances before cleaning or adjusting them
- Ensure everyone looks for electrical wires, cables or equipment near where they are going to work and check for signs warning of dangers from electricity, or any other hazard. Checks should be made around the job, and remember that electrical cables may be within walls, floors, and ceilings (especially when drilling into these locations), etc
- Make sure anyone working with electricity has sufficient skills, knowledge, and experience to do so. Incorrectly wiring a plug can be dangerous and lead to fatal accidents or fires
- Stop using the equipment immediately if it appears to be faulty – have it checked by a competent person
- Ensure any electrical equipment brought to work by employees, or any hired or borrowed, is suitable for use before using it and remains suitable by being maintained as necessary
- Consider using a residual current device (RCD) between the electrical supply and the equipment, especially when working outdoors, or within a wet or confined place (see HSE's electrical safety at work site)

1. Shock or electrocution from energised conductors

An electrical hazard is just a serious workplace hazard that can cause burns, electrocution, shock, arc flash/arc blast, fire, or explosions. We can protect ourselves by identifying these hazards and understanding how they take place. Electrical shocks are typically caused by a short circuit resulting from corroded cables and connections, loose wiring, and improper grounding. Key places to look for these conditions in a PV system include the combiner box, PV source and output circuit conductors, and the equipment grounding conductor. The grounding conductor bonds all metallic components together

and eventually to the ground through the grounding electrode conductor and grounding electrode.

2. Arc faults that spark fires

Fire is always a potential hazard in any electrical system. Electrical arc faults, which are high-power discharges of electricity between two or more conductors, are one of the most common causes. The heat generated by this discharge can damage wire insulation, resulting in a spark or "arc" that can trigger a fire.

PV systems are susceptible to both series arc faults and parallel arc faults, which are caused by unintentional current flowing between two conductors, generally due to a ground fault.

3. Arc flash leading to explosions

Arc flash can occur in large-scale PV arrays with medium and high voltage levels. This is especially true when a technician is inspecting energised combiner boxes, which combine PV source circuits in parallel to boost current, and medium-to-high voltage switchgear and transformers for problems. An arc flash produces heated gases and concentrated radiant energy that can reach temperatures of 35,000° F (19,500° C)—four times the temperature of the sun's surface. It happens when an arc fault has a lot of energy, and it can happen in both DC and AC conductors.

3. Chemical: Photovoltaic refers to the direct conversion of solar radiance into electrical energy thanks to solar cells. Until now, solar cells have been generally made of silicon (a semiconductor).

During photovoltaic cell production, chemicals are used. The most dangerous ones are described below.

The doping operation of the cell issuer consists of bubbling a neutral gas in phosphoryl chloride (POCl₃), which is toxic and corrosive. Hydrofluoric acid (HF) baths are used for silicon engraving. To texturise the surface of silicon, we have to realise chemical attacks on the surface with soda (NaOH) and acids (hydrofluoric: HF, nitric: HNO₃, hydrochloric: HCl). The phosphoryl chloride (POCl₃), also called phosphorus oxychloride, is contained in glass bottles, which creates a risk of spill and therefore a risk of contamination for the people and the environment. On the other hand, the cells have little impact on the environment during their life and at the end of their life. They can be dismantled and basic materials (such as aluminium, glass, silicon, and electronics) can be reused or recycled. The main risks are in:

- Production areas (tanks filling, gates, maintenance),
- Goods reception areas (decanting areas),
- Storage areas.

Summary of chemical hazards: PV manufacturing and R&D process present a diverse range of chemical-related health and safety considerations during both production and maintenance operations:

- Pyrophoric, flammable, and/or toxic gases such as silane, phosphine, hydrazine, hydrogen, ammonia, and arsine, which are utilized in reactors to facilitate deposition processes, doping, and for other production-related processes. Worker exposures and chemical safety hazards associated with the storage, handling, and transport of these gases are ever-present.
- Mixtures of airborne metal dust, generated from cutting and scribing of solar cells with deposited metals (e.g., arsenic, cadmium, copper, indium, gallium, and selenium), may result in worker inhalation exposure.
- Nanoparticles used in PV manufacturing such as quantum dots suspended in ink, nanowires, and silver cells are made of various chemicals such as cadmium, silicon, cadmium telluride, and cadmium selenide. Handling nanoparticles in their raw (unbound) form can result in inhalation and/or dermal hazard.
- Various corrosive chemicals used to etch and clean PV components during manufacturing include hydrochloric acid, hydrofluoric acid, phosphoric acid, and sodium hydroxide.
- Abrasive cleaning methods are often used to manually clean reactors and other production equipment in CIS and CIGS (copper, indium, gallium, selenium) solar cell production operations, resulting in the potential for exposure to reactor chamber deposits and reactant residues.

Practical Exercise

1. Make a list of safety tools we used in solar installation.
2. Sketch a personal protective Equipment kit.

Know Your Progress

A. Fill in the blank

1. Workshop where tools andare used for making or repairing things.
2. PPE refers to the equipment which the user from health hazards orat work.
3. Wearing a helmet offers protection and can prevent
4. Theare the most complex and fragile parts of our body.

B. Multiple Choice Question

1. The welding mask's main function is to protect the eyes from the extremely
 - a. Bright light of a torch
 - b. The dark light of torch
 - c. Zig-zag current
 - d. None of These

2. Name of sound protection PPE kit
 - a. Ear Plugs
 - b. Ear Muffs
 - c. Electronic Ear Muffs
 - d. All of these
3. Respirators are a type of personal protective equipment designed specifically to protect the
 - a. lungs of the people
 - b. head of people
 - c. eyes of people
 - d. None of these
4. A facemask can minimize the risk of exposure to simple
 - a. Dust, Debris, and other harmful impurities
 - b. sun
 - c. chemical reaction
 - d. head injuries

C. Short Answer Question

Q.1 Explain the safety hazard and their types.

Q.2 Discuss about the PPE kit and its use.

Module 12: Documentation for Completion and Handover

This document outlines the necessary procedures and requirements for the completion and handover process. It provides detailed guidelines to ensure that all aspects of the project are finalised and that the transition to the client or end-user is smooth and efficient.

Session 1: Demonstrate the Working Principle of the Solar PV System

1. Demonstrate Start-up and Shutdown Procedures

Once a solar panel (PV) system is running, it doesn't need to be turned off and on regularly. However, the customer should turn off the system in certain situations, such as:

- i. If there are any problems with the inverters or batteries, like strange noises, overheating, or fumes.
- ii. If the customer notices voltage fluctuations in their electricity supply and doesn't know why.
- iii. If there is a safety issue with the PV system or the electrical wiring in the building.
- iv. If a service provider tells the customer to switch off the system.

Customers should have a simple block diagram to understand the system and know which switches to turn off or on. The diagram below shows the shutdown process in an easy-to-understand format.

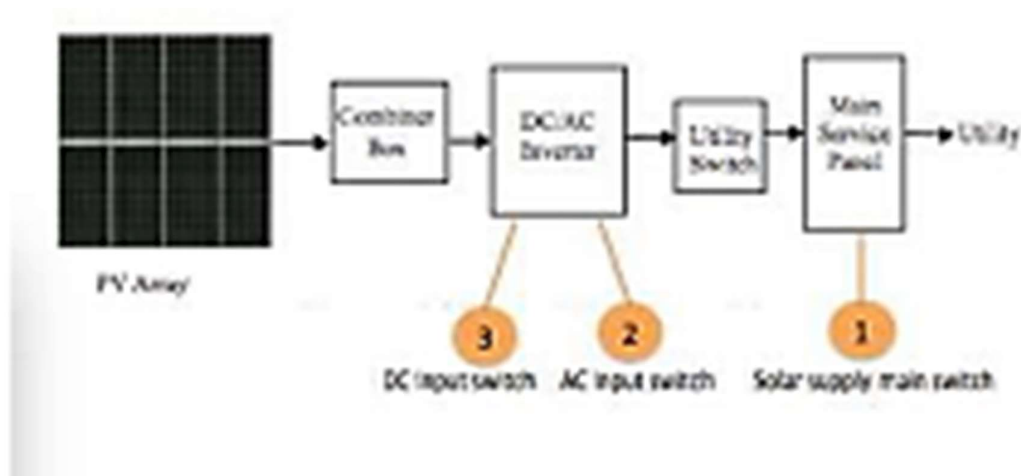


Fig. 12.1: Shut down sequence

2. Shut Down Procedure

- a) Turn off the main solar supply switch in the service panel.



b) Turn off the AC input or inverter switch on the solar inverter.



c) Turn off the DC input switch that connects to the solar array.



To start the system again, follow the steps in reverse order.

It's important to follow this shutdown sequence. The DC breaker has a higher chance of arcing compared to AC breakers. By switching off AC breakers first, you isolate the load and reduce current flow. This is safer and helps extend the lifespan of the protective devices in the circuit.

3. Explaining System Maintenance to the Customer

Your PV system works automatically and doesn't need your help for normal operation! However, to keep it performing well, it's important to clean the PV modules regularly. Here are some tips to help you with that.:



Fig. 12.2: Clean without stepping on the panels or placing heavy objects on them

4. What to Expect from the System

The system might perform differently in various weather, such as rain, fog, or sunshine. Be prepared to answer any questions customers may have. Here are some common ones:

A. How many backup hours can I expect?

- Explain how many backup hours the system can provide on a sunny day.
- Explain how many cloudy days it takes to fully discharge the batteries under normal use.
- Explain how fog can impact the backup hours.

B. How much will I save with this system?

- Explain that monthly output will change with the seasons and weather.

- b. Provide the estimated yearly savings on electricity based on the initial design and payback calculations from the design team.

C. How can I get service if there's a problem?

- a. Provide contact numbers for service calls.
- b. Provide contact numbers for emergencies, such as electric shock or fire.
- c. Explain the service costs.
- d. Explain which costs are covered by warranties and which are not.

D. How much will this system benefit me financially?

Be ready to discuss the monthly financial benefits. If the system includes batteries, calculate the daily energy use from the batteries. Use the following formula:

Energy = (Ampere-hour rating of the battery bank) × (Voltage of the bank) × (Depth of Discharge)

In an off-grid system, the solar array must supply all this energy since it is a free and renewable source. By using solar power, you can save money that would otherwise go towards backup energy sources like grid power or diesel fuel.

In a grid-tied system, solar power helps reduce the amount of grid power used. To estimate savings, multiply the average expected output from the solar array by the cost of grid power. Make sure to check the data collected during the site survey for accurate calculations.

Keep in mind that these methods provide approximate figures and do not account for other costs, such as loan payments for the solar system. For a precise calculation of financial benefits and payback time, consult an engineer or manager.

Check Your Progress

A. Multiple Choice Questions

1. When should a customer turn off their solar PV system?

- a) Every night before sleeping
- b) Only during maintenance or when advised by a service provider
- c) During sunny weather
- d) When electricity bills are high

2. What should be turned off first during the shutdown procedure of a solar PV system?

- a) DC input switch
- b) Solar inverter
- c) Main solar supply switch in the service panel
- d) AC input switch

3. Why should the AC breaker be turned off before the DC breaker?

- a) To increase system voltage
- b) To reduce current flow and prevent arcing
- c) To make the inverter run faster
- d) To increase the power output

4. What is the formula for calculating daily energy use from the batteries?

- a) $\text{Energy} = \text{Voltage} \times \text{Resistance}$
- b) $\text{Energy} = \text{Current} \times \text{Voltage} \times \text{Time}$
- c) $\text{Energy} = (\text{Ampere-hour rating}) \times (\text{Voltage}) \times (\text{Depth of Discharge})$
- d) $\text{Energy} = \text{Power} \times \text{Current} \times \text{Time}$

B. Fill in the Blanks

- 1. Customers should have a simple _____ to understand the system and know which switches to turn off or on.
- 2. The solar PV system works _____ and does not need help for normal operation.
- 3. Cleaning PV modules regularly helps maintain their _____.
- 4. In a grid-tied system, solar power helps reduce the amount of _____ power used.

C. Short Answer Questions

- 1. List any two situations when the customer should shut down the solar PV system.
- 2. What is the correct order of the shutdown procedure for a solar PV system?
- 3. Why should customers avoid stepping on solar panels during cleaning?
- 4. What factors can affect the performance of a solar PV system?

SESSION 2: HAND OVER DOCUMENTATION ON THE USE OF THE SYSTEM

Hand over documentation and explain the importance of each document to the customer, as listed in the table below:

Table 12.1: Important documents and their significance

	Document	Purpose
1.	Layout Diagram (see Fig. 12.3 below)	This diagram shows where each component is located in the customer's installation. It helps engineers or technicians during maintenance or troubleshooting.
2.	Single Line Diagram (See Fig. 12.4 below)	This diagram displays the system design. It is useful for engineers or technicians when they perform maintenance or troubleshooting.
3.	Approvals and Permits (varies by state and distribution company) - Related to subsidies - Related to grid connection - Related to structural integrity	- A certified chartered engineer may need to approve building structural integrity. - Subsidy application documents vary based on state government processes. - Keep the subsidy approval document, if received. - The local utility must approve any connection to the grid for a grid-tied system. Make sure this approval is ready for renewal at the right time.
4.	Product Documentation - Keep invoices for all purchased products. - Store the ratings and data sheets for all products. - Warranties of all product	Hold onto warranties for all products, as these are essential for obtaining replacements when a product fails.
5.	Service Documentation - Keep the invoice from the installation and maintenance provider along with their contact details. - Keep the service contract with the provider, which should outline: - How often will scheduled maintenance happen? - What maintenance procedures are included in the contract? - What will be the response time for service outages? - What system problems will cost the customer extra?	This documentation ensures you receive the right level of service.

Objective:

To recognise various handover documents and explain their importance to the customer.

Materials Required:

- Sample copies of Layout Diagram, Single Line Diagram, Product Invoice, Warranty card, and Service contract
- Chart paper and markers

Procedure:

1. Divide students into small groups.
2. Provide each group with sample documents.
3. Ask them to identify the purpose of each document.
4. Each group prepares a short presentation explaining how each document helps during maintenance or service.

Expected Outcome: Students will be able to identify key system documents and explain their significance to the customer during handover.

Check Your Progress**A. Multiple Choice Questions****1. What is the purpose of the Layout Diagram in a solar PV system?**

- a) It shows the financial benefits of the system
- b) It shows where each component is located in the installation
- c) It explains how to calculate energy output
- d) It provides details of the product warranty

2. The Single Line Diagram is mainly used to:

- a) Explain the installation cost
- b) Represent the system's electrical design
- c) Display the cleaning schedule of panels
- d) Track monthly energy output

3. Which document ensures the customer gets proper maintenance and support service?

- a) Product documentation
- b) Layout diagram
- c) Service documentation
- d) Approval and permit

4. Which of the following is not part of the Approvals and Permits documentation?

- a) Subsidy application document

- b) Grid connection approval
- c) Inverter operation manual
- d) Structural integrity certificate

B. Fill in the Blanks

1. The _____ diagram helps engineers or technicians locate each component during maintenance or troubleshooting.
2. The _____ diagram shows the system's electrical design for technical understanding.
3. A certified _____ engineer may need to approve the building's structural integrity for the installation.
4. The _____ documentation includes warranties, invoices, and product data sheets.

C. Short Answer Questions

1. Why is the Layout Diagram important for the customer?
2. What key approvals are required under "Approvals and Permits"?
3. What information should be included in Service Documentation?
4. Why should customers keep warranties and product data sheets safely?

MODULE 13: CUSTOMER RELATIONSHIP

A strong customer relationship is the foundation of every successful solar business. It is not enough for a technician to install a solar PV system correctly. Also, they must ensure that the customer understands the system, feels satisfied, and trusts the service provider.

Session 1: Building Customer Relationship and Communication

When a customer invests in a solar PV system, they are often making a long-term commitment. The system will operate for 20–25 years, and during this time, the customer will rely on the installer for guidance, maintenance, and technical support. Therefore, maintaining a positive and professional relationship is essential for both the customer's satisfaction and the technician's reputation.

What is Customer Relationship?

Customer relationship refers to the process of building trust, communication, and understanding between the service provider (technician or company) and the customer. It involves listening to customer needs, offering appropriate solutions, and ensuring continuous support even after the installation is complete. In the solar industry, this relationship begins before installation (during consultation and design) and continues after installation (through maintenance and service visits).

Why is it Important?

Customers who receive clear explanations and honest advice feel more confident about investing in solar systems. Trust helps in long-term association and positive word-of-mouth. When customers understand how their system works and how it benefits them, they feel satisfied and valued.

A happy customer often recommends the technician or company to others. This helps expand business opportunities without extra marketing cost. Transparent communication prevents misunderstandings about cost, performance, or maintenance. If the customer follows the maintenance guidance given by the technician, the system works efficiently and lasts longer.

A technician who communicates politely, provides complete documentation, and offers post-installation services earns respect and credibility in the market.

Key Elements of Good Customer Relationships

This table explains technical terms used in documents in a way that is easy to understand. It also details the purpose of these terms related to documentation.

Table 13.1: Key Elements of Good Customer Relationships

Element	Description
Communication	Clear explanation of system components, cost, and benefits in simple language.
Transparency	Honest discussion about pricing, payback, and limitations of the system.
Responsiveness	Quick and helpful replies to customer queries or service requests.
Courtesy and Respect	Maintaining polite behaviour and a positive attitude.
Reliability	Fulfilling promises on time, such as installation schedules and maintenance visits.
After-Sales Service	Regular maintenance and performance checks even after installation.

Example Scenario

Suppose a customer is planning to install a 3-kW rooftop solar system. The technician should:

- Visit the site and understand the customer's electricity needs.
- Explain how much energy the system will generate and how much money it will save.
- Provide information about available subsidies and warranty conditions.
- After installation, show how to read the energy meter and maintain the panels.
- Stay available for post-installation service calls.

Such communication not only makes the customer happy but also strengthens the technician's professional image and helps attract new clients.

Informing the Customer about Various Components of the System

A key part of building customer trust and satisfaction is ensuring that the customer understands their solar PV system. A well-informed customer is confident in their investment, follows maintenance guidelines, and can use the system efficiently. This section explains how a technician should introduce and explain the components of a solar PV system to a customer in a clear and simple manner.

Why It Is Important

- Customers need to know what each component does and how it contributes to generating electricity.
- Proper understanding reduces confusion, prevents misuse, and improves safety.
- Explaining components builds confidence in the technician and the quality of the system.

2. Main Components of a Solar PV System

Table 13.2 highlights each component, such as solar panels, inverters, mounting systems, and batteries, providing insights into how they work together to harness solar energy effectively. Additionally, it addresses common questions and concerns, offering clear explanations that facilitate informed decision-making for potential buyers.

Table 13.2: Key Elements of the Main Components of a Solar PV System

Component	Purpose / Function	Customer-Friendly Explanation
Solar Panels (PV Modules)	Convert sunlight into Direct Current (DC) electricity.	"These panels capture sunlight and turn it into electricity that powers your home."
Inverter	Converts DC electricity from the panels into Alternating Current (AC) used by appliances.	"This device changes the electricity into the form your appliances can use."
Battery (if included)	Stores excess electricity for use during the night or power cuts.	"It keeps electricity ready for you even when the sun is not shining."
Mounting Structure	Supports the solar panels and holds them at the correct angle.	"This frame keeps the panels steady and facing the sun for maximum energy."
Cables and Junction Boxes	Connect the panels, inverter, and load safely.	"These wires safely carry electricity from the panels to your home."
Energy / Net Meter	Measures the electricity produced and consumed.	"This meter tracks how much electricity you are generating and using. Extra power goes to the grid."

3. How to Explain Components Effectively

1. **Use Simple Language:** Avoid technical jargon. For example, say "stores energy" instead of "battery storage capacity in ampere-hours."
2. **Show Physical Components:** Let the customer see panels, inverter, and meter. Hands-on demonstration helps understanding.
3. **Use Diagrams or Layouts:** A small layout or schematic can clearly show the connection between panels, inverter, and grid.
4. **Explain Benefits Alongside Components:** Link each part to customer benefits, e.g., "The battery ensures uninterrupted power supply."
5. **Answer Questions Patiently:** Encourage customers to ask questions about the system and respond clearly.

Example Scenario

A technician installs a 3-kW rooftop solar system for a residential customer. During the handover:

- The technician shows the panels on the roof, explaining how they capture sunlight.
- The inverter is displayed, and its role in powering household appliances is described.

- The battery and meter are demonstrated, showing how stored electricity is used and surplus energy is credited.
- A simple diagram of the system connections is provided as a reference.

By doing this, the customer feels confident in operating and maintaining the system.

Tips:

- Always highlight safety features, such as proper earthing and circuit breakers.
- Explain maintenance requirements, like cleaning panels periodically.
- Encourage the customer to monitor system performance via the energy meter or mobile app if available.
- Make sure the customer knows who to contact in case of issues; this builds trust and long-term satisfaction.

Delivering Documentation and Customer Handover

A key part of customer relationship management in solar PV installations is the proper handover of documents and guidance after the system is installed. Providing clear documentation ensures that the customer knows how to operate the system safely, maintain it effectively, and claim warranty or subsidies if needed.

1. Importance of Documentation

Having the proper documentation is essential for ensuring that customers feel secure and informed regarding their investment. Local authorities often require specific permits and approvals for both rooftop and ground-mounted systems. These documents not only guide customers on the operation, cleaning, and maintenance of their systems, but they also serve as proof for warranty claims. Furthermore, in the event of system upgrades, repairs, or even property resale, these documents provide crucial official records.

2. Key Documents to Deliver

Table 13.3 provides a customer-friendly explanation of technical terms found in documents and their purposes related to documentation.

Table 13.3: Key Documents to Deliver

Document	Purpose	Customer-Friendly Explanation
Layout Diagram & Single Line Diagram (SLD)	Shows placement of panels, inverter, and wiring connections.	"This diagram shows how your solar system is connected from panels to your house."
Operation & Maintenance (O&M) Manual	Step-by-step instructions for using and maintaining the system.	"Follow this guide to ensure your solar system works efficiently for many years."
Project Photographs	Record of the installation process and completed system.	"These photos show how the system was installed on your property."

Permits and Approvals	Legal compliance and government approvals.	"These documents confirm that your system meets all local rules and regulations."
Warranty Certificates	Proof of the manufacturer's guarantee for panels, inverter, and batteries.	"If any part of the system fails, you can claim replacement or repair under warranty."
Job Completion Report	Confirms installation is complete and tested.	"This form records that your system is installed correctly and working perfectly."

3. Handover Process

1. **Explain Each Document:** Take the customer through the purpose and usage of every document in simple terms.
2. **Demonstrate System Operation:** Show how to read the energy meter, inverter display, and battery status (if applicable).
3. **Answer Customer Questions:** Encourage the customer to ask any questions about system operation, performance, or safety.
4. **Obtain Customer Signature:** After explaining all documents, ask the customer to sign the **handover form or job completion report** to confirm understanding.
5. **Provide Contact Information:** Share technician or service center details for **post-installation support**.

Example Scenario

After installing a 3-kW rooftop solar system for Mr. Sharma:

1. The technician hands over the layout diagram and SLD.
2. Shows the O&M manual and explains daily operation and cleaning.
3. Shares project photos and warranty certificates.
4. Demonstrates how to check inverter readings and the energy meter.
5. Collects Mr. Sharma's signature on the job completion form and provides contact information for post-installation support.

This ensures that Mr. Sharma understands his system, knows how to maintain it, and feels confident in using it safely.

Explaining Location Choice to Customers

A technician should:

1. **Conduct a site survey** to check sunlight, shade, and roof condition.
2. **Explain the reasoning** behind the selected location in simple terms, e.g., "This part of the roof receives the most sunlight during the day, ensuring maximum energy production."

3. **Show the customer the installation site** physically and with a diagram if needed.
4. **Discuss maintenance access** and safety features.

This transparency ensures that the customer trusts the system's performance and understands its placement.

Example Scenario

Customer: Mrs. Singh

- House has a sloped rooftop partially shaded by a tree.
- Technician surveys the site and selects the **southern section of the roof** without shading.
- Panels are mounted at a **25° tilt**, ensuring **maximum sunlight exposure**.
- Technician explains to Mrs. Singh why the remaining roof sections were not chosen and shows easy access paths for cleaning.

How to Communicate Post-Installation Support to Customers

1. **Explain the Services Clearly:** Let the customer know what routine checks and maintenance will be done.
2. **Provide a Schedule:** For example, quarterly inspection visits or annual panel cleaning.
3. **Share Contact Information:** Give details of the service technician or customer support helpline.
4. **Offer Remote Support:** If monitoring apps or online dashboards are available, guide the customer on usage.
5. **Follow Up:** Make at least one follow-up visit or call within the first few months after installation to ensure system performance.

Example Scenario

Customer: Mr. Kumar

- After installing a 5 kW solar rooftop system, the technician assures Mr. Kumar that:
 - Panels will be cleaned twice a year.
 - Inverter will be checked annually.
 - Any faults will be addressed within 48 hours.
 - Monitoring app will alert Mr. Kumar about system performance.
- Mr. Kumar receives a **contact card** with the technician's phone number and email for service requests.

This reassures Mr. Kumar that he will always have support, giving him confidence in the system.

Check Your Progress**A. Multiple Choice Questions**

1. **Which of the following is the primary purpose of building a strong customer relationship in solar PV installation?**
 - a) To sell more products quickly
 - b) To ensure customer trust, satisfaction, and long-term support
 - c) To avoid technical training for the technician
 - d) To reduce installation time
2. **Which element is NOT listed as a key part of good customer relationships?**
 - a) Communication
 - b) Transparency
 - c) Profit maximization
 - d) After-Sales Service
3. **What is the main function of an inverter in a solar PV system?**
 - a) Store energy for later use
 - b) Measure electricity generated and consumed
 - c) Convert DC electricity from panels into AC electricity for appliances
 - d) Support solar panels physically
4. **Why is delivering proper documentation after installation important?**
 - a) It makes the installation process faster
 - b) It ensures customer confidence, legal compliance, and guides maintenance
 - c) It helps in buying more solar panels
 - d) It is only needed for warranty purposes

B. Fill in the Blanks

1. Customer relationship refers to the process of building _____, communication, and understanding between the service provider and the customer.
2. The _____ converts Direct Current (DC) electricity generated by solar panels into Alternating Current (AC) used by household appliances.
3. Providing a clear _____ after installation ensures the customer knows how to operate the system safely, maintain it effectively, and claim warranty if needed.
4. Showing the customer the location of solar panels and explaining the reasoning behind it helps build _____ in the system's performance.

C. Answer the Following Questions

1. Explain why building a strong customer relationship is important in the solar industry. Include at least three benefits for both the customer and the technician.
2. Describe the main components of a solar PV system and explain in simple terms how a technician should communicate their functions to a customer.
3. Outline the proper handover process for a solar PV installation, including documentation and customer guidance steps. Why is this process critical for customer satisfaction?
4. Discuss the importance of site survey and location choice for solar panel installation. How should a technician explain these decisions to the customer to ensure trust and transparency?

SESSION 2: DEMONSTRATION OF JOB CARD AND SOP

A Job Card and Standard Operating Procedure (SOP) are essential tools for professional solar PV installation and maintenance. They ensure that all work is organised, safe, and consistent. Demonstrating these to the customer and team builds trust and ensures quality service.

1. A Job Card serves as a comprehensive document that captures essential details of a solar photovoltaic (PV) project. It includes the following information:

- Customer details
- System specifications, such as capacity, type, and components
- Dates and locations of installation
- Assigned technician along with tasks carried out
- Results from inspections and testing
- Additional remarks and approvals

The purpose of a Job Card is multi-faceted. It helps track work progress, provides an official record for warranty and maintenance purposes, and ensures technicians adhere to standard procedures throughout the installation process.

2. What is an SOP (Standard Operating Procedure)?

A Standard Operating Procedure (SOP) serves as a comprehensive, step-by-step guide detailing how specific tasks should be carried out during installation, maintenance, or troubleshooting. The purpose of an SOP is to guarantee that every technician adheres to established safety protocols, employs the proper procedures, and upholds the system's overall quality and efficiency. Some examples of tasks covered in an SOP include:

- Conducting inspections of the roof or ground structure to assess suitability

- Installing solar panels at the appropriate tilt and orientation for optimal performance
- Ensuring proper connections between the inverter and the battery
- Testing the system's performance thoroughly before final handover to ensure reliability

By following an SOP, technicians can enhance safety and ensure consistency in their work.

3. Demonstration Process

1. **Explain the Job Card:** Show the customer all sections – customer details, system specs, installation dates, and signatures.
2. **Walk Through the SOP:** Demonstrate step-by-step tasks performed during installation and testing.
3. **Highlight Safety Measures:** Point out earthing, insulation, and personal protective equipment (PPE) used.
4. **Sign-Off:** After inspection, the customer or supervisor signs the Job Card to confirm that installation is complete and satisfactory.

Example Scenario

Customer: Mrs. Patel

- Technician shows the **Job Card** with system capacity (3 kW), installation date, and technician name.
- SOP checklist is reviewed to show stepwise installation: roof inspection, panel mounting, wiring, inverter installation, testing, and final handover.
- Mrs. Patel signs the Job Card after the demonstration, and the technician provides a copy for her records.

This process builds customer confidence and ensures accountability.

ACTIVITIES

Activity 1: Customer Demonstration Role-Play

- **Objective:** Practice explaining solar PV components, operation, and documentation to a customer.
- **Procedure:**
 1. Divide students into groups of two (technician and customer).
 2. Technician demonstrates the system layout, inverter operation, and Job Card details.
 3. “Customer” asks questions about system benefits, operation, and maintenance.

4. Swap roles and repeat.
- **Learning Outcome:** Students learn how to communicate technical information in a clear, professional, and confident manner.

Activity 2: Job Card and SOP Preparation

1. **Objective:** Prepare a complete Job Card and SOP for a sample 3 kW rooftop solar installation.
2. **Procedure:**
 1. List all components, tools, and installation steps.
 2. Fill in a Job Card template with customer name, system details, installation date, and technician name.
 3. Prepare an SOP checklist covering safety, installation, and testing steps.
3. **Learning Outcome:** Students understand documentation requirements and the importance of following SOPs for safety, efficiency, and customer satisfaction.

Check Your Progress

A. Multiple Choice Questions

1. **What is the primary purpose of a Job Card in solar PV installation?**
 - a) To sell additional solar components
 - b) To track work progress, maintain official records, and ensure adherence to procedures
 - c) To calculate electricity generation
 - d) To train new customers
2. **Which of the following is included in a Job Card?**
 - a) Customer details, system specifications, assigned technician, inspection results
 - b) Local government rules only
 - c) Only the technician's personal notes
 - d) Company financial statements
3. **What is the main objective of an SOP (Standard Operating Procedure) in solar PV work?**
 - a) To provide discounts to customers
 - b) To guide technicians step-by-step, ensuring safety, quality, and consistency
 - c) To measure electricity production
 - d) To advertise solar PV services

4. During the demonstration process of Job Card and SOP, which of the following should be highlighted?

- a) Safety measures, earthing, PPE, and system testing
- b) Company marketing strategy
- c) Payment collection process only
- d) Customer's electricity bills

B. Fill in the Blanks

1. A Job Card captures essential details of a solar PV project, including customer details, system specifications, assigned technician, and _____ from inspections and testing.
2. An SOP serves as a _____, step-by-step guide detailing how specific tasks should be carried out during installation, maintenance, or troubleshooting.
3. Highlighting _____, insulation, and personal protective equipment (PPE) during demonstration ensures safety awareness for both customers and technicians.
4. The final step in the demonstration process is _____ on the Job Card by the customer or supervisor to confirm installation completion and satisfaction.

C. Answer the Following Questions

1. Explain the purpose and importance of a Job Card in solar PV installation. Include the types of information it records and how it helps technicians and customers.
2. What is an SOP in the context of solar PV systems? Describe its role in maintaining safety, consistency, and quality during installation and maintenance.
3. Describe the step-by-step process of demonstrating a Job Card and SOP to a customer. Why is this demonstration important for building customer trust?
4. Discuss the key safety measures that should be highlighted during the demonstration of a Job Card and SOP. How do these measures ensure both technician and customer safety?

Module 14: Employability Skills

For this unit, please visit the link below and download the provided study material.

Employability Skills – I (Available in English and Hindi)

<https://www.psscive.ac.in/publications/textbooks/j144c9?language=english>

ANSWER KEY

MODULE 01: INTRODUCTION TO SOLAR ENERGY

SESSION 1: INTRODUCTION TO ENERGY

Fill in the blank	Multiple Choice Question
1. Energies.	1. A
2. Geothermal, Ocean	2. A
3. Solar power	3. A
4. Photovoltaic (PV)	4. D
	5. A

SESSION 2: SOLAR ENERGY

Fill in the blank	Multiple Choice Question
1. renewable energy	1. D
2. Photovoltaic cells	2. A
3. solar collectors, radiators	3. A
4. Tubing, insulated tank	4. C
	5. C

SESSION 3: SOLAR PHOTOVOLTAICS (PV) TECHNOLOGY

Fill in the blank	Multiple Choice Question
1. Calculators	1. C
2. Light, electricity	2. A
3. Silicon	3. A
4. Photovoltaic effect	4. A
	5. C

SESSION 4. SOLAR POWER GENERATION AND APPLICATION

Fill in the blank	Multiple Choice Question
1. PV array	1. A
2. DC power	2. A
3. Inverter	3. A
4. 278 KWh	4. A
5. Energy	5. A

SESSION 5: GOVTS' INITIATIVES/SCHEMES AND PROGRAMMES (PM SURYA GHAR, PM KUSUM, SOLAR PARKS, ETC.)

Fill in the blank	Multiple Choice Question
1. 2 MW	1. B
2. 40%	2. D
3. 100 GW	3. B
4. International Solar Alliance (ISA)	4. C

Module 2: Introduction of PV Installer

Session 1: Role and Responsibilities of Solar Panel Installation Technician

Fill in the blank	Multiple Choice Question
1. Sunlight	1. D
2. local regulations	2. B
3. Installation site	3. B
4. Profession	4. A

Module 03: Basics of Solar Energy and Electrical Concepts

Session 1: FUNDAMENTALS OF SOLAR ENERGY

Fill in the blank	Multiple Choice Question
1. Sun	1. B
2. Pyranometer	2. B
3. 6000°C	3. A
4. Insolation	4. C

SESSION 2: FUNDAMENTALS OF ELECTRICITY

Fill in the blank	Multiple Choice Question
1. Electric current	1. C
2. Voltage	2. C
3. Ohm (Ω)	3. B
4. 3,600,000 joules	4. B
5. Inverter	5. B

SESSION 3: TERMINOLOGY AND DEFINITIONS EXPLAINED

Fill in the blank	Multiple Choice Question
1. Wiring	1. B
2. Schematic	2. B
3. structural	3. C
4. project	4. C

Module 4: Site Survey for Installation of Solar PV System

Session 1: Understanding Customer Needs in Solar PV Installation

Fill in the blank	Multiple Choice Question
1. Site survey	1. B
2. Load	2. C
3. Load Profile	3. B
4. Sizing	4. B

Session 2: Key Methods for Gathering Customer Requirements

Fill in the blank	Multiple Choice Question
1. Customer	1. C
2. Walkthrough	2. C
3. Reading	3. B
4. Shading	4. B

MODULE 5: BASICS OF SOLAR PHOTOVOLTAIC SYSTEMS AND ITS COMPONENTS

SESSION 1: SOLAR POWER SYSTEM AND ITS COMPONENTS

Fill in the blank	Multiple Choice Question
1. 1HP -15 HP,	1. A
2. 1-3HP,	2. C
3. 900-1000	3. C
4. Maximum Power Point Tracking (MPPT)	4. B

SESSION 2: THE SOLAR PANEL AND ITS COMPONENTS

Fill in the blank	Multiple Choice Question
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1. Photovoltaic	1. A
2. Thin film	2. A
3. 25 years	3. C
4. Solar radiation.	4. A

Session 3: Earthing and Lightning Protection

Fill in the blank	Multiple Choice Question
1. lightning	1. B
2. ground	2. C
3. shortest	3. B
4. bonded	4. C

Module 6: Interpretation of Drawings, Material Handling and Storage of Components on Site

Session 1: Prepare Bill of Materials

Fill in the blank	Multiple Choice Question
1. sunlight	1. B
2. appliances	2. C
3. AC	3. B
4. Quantity	4. C

Session 2: Procurement of the Solar PV System Components

Fill in the blank	Multiple Choice Question
1. Bill of Materials (BOM)	1. B
2. PWM (Pulse Width Modulation), MPPT (Maximum Power Point Tracking)	2. B
3. UV, weather	3. C
4. Bureau of Indian Standards (BIS)	4. D

SESSION 3: INSTALL CIVIL & MECHANICAL PARTS OF SOLAR PV SYSTEM

Fill in the blank	Multiple Choice Question
1. Grade beam	1. B
2. Pitched	2. C
3. Aluminum	3. C
4. Penetrating	4. B

SESSION 4: INSTALL PHOTOVOLTAIC MODULE

Fill in the blank	Multiple Choice Question
1. licensed	1. B
2. sunlight	2. B
3. negative socket	3. B
4. spill	4. C

MODULE 7: TOOLS FOR SOLAR PV SYSTEM INSTALLATIONS

SESSION 1: MECHANICAL AND GENERAL TOOLS

Fill in the blank	Multiple Choice Question
1. Tough Steel	1. A
2. Screw drivers	2. A
3. Hammer	3. A
4. Fine-toothed saw	
5. Solar installation	
6. Nipper	
7. Drilling small holes	

SESSION 2: ELECTRICAL, SAFETY, MARKING, AND CIVIL TOOLS

Fill in the blank	Multiple Choice Question
1. Analog Multimeter	1. A
2. earth electrode	2. A
3. Very low	3. A
4. insulation resistance (IR) test	4. C
	5. D

MODULE 8: INSTALLATION OF ELECTRICAL OF A SOLAR PV SYSTEM
Session 1: Prepare for Solar Installation

Fill in the blank	Multiple Choice Question
1. solar work zone	1. C
2. harness	2. C
3. continuity	3. B
4. condition	4. B

SESSION 2: INSTALL ELECTRICAL COMPONENTS

Fill in the blank	Multiple Choice Question
1. vertically	1. B
2. DC disconnects	2. C
3. vented	3. C
4. cool	4. B

Session 3: Install Conduits and Cables

Fill in the blank	Multiple Choice Question
1. live	1. B
2. thinner	2. B
3. continuous	3. C
4. positive (+), negative (-)	4. C

SESSION 4: GET THE GROUNDING SYSTEMS INSTALLED

Fill in the blank	Multiple Choice Question
1. fault	1. B
2. 1.5	2. B
3. System design	3. C
4. bonded	4. B

MODULE 9: TEST & COMMISSION SOLAR PV SYSTEM
SESSION 1: OVERALL SYSTEM INSPECTION

Fill in the blank	Multiple Choice Question
1. tested	1. B
2. shadows	2. C
3. polarity	3. B
4. 1.265	4. C

SESSION 2: UNINTENTIONAL ISLANDING FUNCTIONALITY TEST

Fill in the blank	Multiple Choice Question
1. grid	1. B
2. two (2)	2. B
3. sixty (60)	3. D
4. inverter	4. C

MODULE 10: OPERATION AND MAINTENANCE OF SOLAR PV POWER SYSTEM

SESSION 1: CLEANING AND TESTING OF SOLAR PANEL MAINTENANCE
Fill in the blank

1. voltage, current, and resistance
2. Amperes
3. protected enclosure for electrical wiring.
4. Continuity

MODULE 11: MAINTAIN PERSONAL HEALTH AND SAFETY AT THE PROJECT SITE
SESSION 1: PERSONAL PROTECTIVE EQUIPMENT
Fill in the blank

1. Machines
2. Protects, safety risks
3. Head injuries
4. Eyes

Multiple Choice Question

1. A
2. D
3. A
4. A

MODULE 12: DOCUMENTATION FOR COMPLETION AND HANDOVER
SESSION 1: DEMONSTRATE THE WORKING PRINCIPLE OF THE SOLAR PV SYSTEM
Fill in the blank

1. block diagram
2. automatically
3. performance
4. grid

Multiple Choice Question

1. B
2. C
3. B
4. C

SESSION 2: HAND OVER DOCUMENTATION ON THE USE OF THE SYSTEM
Fill in the blank

1. Layout
2. Single Line
3. Structural
4. Product

Multiple Choice Question

1. B
2. B
3. C
4. C

MODULE 13: CUSTOMER RELATIONSHIP
Session 1: Building Customer Relationship and Communication
Fill in the blank

1. trust
2. inverter
3. documentation
4. trust

Multiple Choice Question

1. B
2. C
3. C
4. B

Session 2: Demonstration of Job Card and SOP
Fill in the blank

1. results
2. comprehensive
3. earthing
4. sign-off

Multiple Choice Question

1. B
2. A
3. B
4. A

Glossary

Alternating Current (Ac)	A type of electrical current, the direction of which is reversed at regular intervals or cycles.
Ampere (Amp)	A unit of electrical current or rate of flow of electrons.
The angle of Incidence	The angle that a ray of sun makes with a line perpendicular to the surface
Array	Photovoltaic cells which are then grouped together to make solar panels.
Battery	Two or more electrochemical cells enclosed in a container and electrically interconnected in an appropriate series/parallel arrangement to provide the required operating voltage and current levels
Battery Capacity	The maximum total electrical charge, expressed in ampere-hours, which a battery can deliver to a load under a specific set of conditions
Battery Cell	The simplest operating unit in a storage battery.
Battery Life	The period during which a cell or battery is capable of operating above a specified capacity or efficiency performance level. Life may be measured in cycles and/or years, depending on the type of service for which the cell or battery is intended
Charge Controller	A component of a photovoltaic system that controls the flow of current to and from the battery to protect it from over-charge and over-discharge.
Conductor	The material through which electricity is transmitted, such as an electrical wire, or transmission or distribution line.
Crystalline Silicon	A type of photovoltaic cell made from a slice of single-crystal silicon or polycrystalline silicon
Deep Discharge	Discharging a battery to 20% or less of its full charge capacity.
Electric Current	The flow of electrical energy (electricity) in a conductor, measured in amperes.
Gigawatt (GW)	A unit of power equal to 1 billion watts; 1 million kilowatts, or 1,000 megawatts.
Load	The Demand on an Energy-Producing System
Ohm	A measure of the electrical resistance of a material equal to the resistance of a circuit in which the

	potential difference of 1 volt produces a current of 1 ampere.
Parallel Connection	A way of joining solar cells or photovoltaic modules by connecting positive leads together and negative leads together; such a configuration increases the current, but not the voltage.
Photoelectric Cell	A device for measuring light intensity that works by converting light falling on, or reach it, to electricity, and then measuring the current; used in photometers
Photovoltaic (PV) Effect	The phenomenon that occurs when photons, the “particles” in a beam of light, knock electrons loose from the atoms they strike.
Resistance (R)	The property of a conductor, which opposes the flow of an electric current

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