DRAFT STUDY MATERIAL

Solar Panel Installation Technician

(Job Role)

Qualification Pack: Ref. Id. SGJ/Q0101 and Ref. Id ELEQ590

Sector: Skill Council for Green Jobs (SCGJ)
and
Electronics Sector Skills Council of India (ESSCI)

Grade XI

PSS CENTRAL INSTITUTE OF VOCATIONAL EDUCATION, SHYAMLA HILLS, BHOPAL, M.P., INDIA

Preface

Vocational Education is a dynamic and evolving field, and ensuring that every student has access to quality learning materials is of paramount importance. The journey of the PSS Central Institute of Vocational Education (PSSCIVE) toward producing comprehensive and inclusive study material is rigorous and time-consuming, requiring thorough research, expert consultation, and publication by the National Council of Educational Research and Training (NCERT). However, the absence of finalized study material should not impede the educational progress of our students. In response to this necessity, we present the draft study material, a provisional yet comprehensive guide, designed to bridge the gap between teaching and learning, until the official version of the study material is made available by the NCERT. The draft study material provides a structured and accessible set of materials for teachers and students to utilize in the interim period. The content is aligned with the prescribed curriculum to ensure that students remain on track with their learning objectives.

The contents of the modules are curated to provide continuity in education and maintain the momentum of teaching-learning in vocational education. It encompasses essential concepts and skills aligned with the curriculum and educational standards. We extend our gratitude to the academicians, vocational educators, subject matter experts, industry experts, academic consultants, and all other people who contributed their expertise and insights to the creation of the draft study material.

Teachers are encouraged to use the draft modules of the study material as a guide and supplement their teaching with additional resources and activities that cater to their students' unique learning styles and needs. Collaboration and feedback are vital; therefore, we welcome suggestions for improvement, especially by the teachers, in improving upon the content of the study material.

Deepak Paliwal

(Joint Director)

Date: 25 Aug 2024

PSSCIVE, Bhopal

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Module 1	INTRODUCTION TO SOLAR ENERGY

Module Overview

This module introduces the fundamental concepts of energy, covering various forms like kinetic, potential, thermal, and electrical energy. Students will distinguish between renewable and non-renewable energy sources, setting the foundation for sustainable energy practices.

The module then explores solar energy, focusing on its origin, significance as a renewable resource, and the principles of harnessing it. Students will also examine the environmental benefits and factors affecting solar energy efficiency.

Examines into photovoltaic (PV) technology, explaining how sunlight is converted into electricity. It covers the components of a solar PV system, types of solar cells, and practical applications across different sectors.

Explore solar power generation, current trends in the industry, technological advancements, and global adoption. The session also addresses challenges like energy storage and intermittency, concluding with discussions on the future potential of solar energy.

This module aims to provide students with a comprehensive understanding of solar energy and its relationship with various forms of energy. It lays the foundation for exploring how solar energy can be converted into different forms, emphasizing the integration of science and technology in various practical applications. Students will gain insights into the principles, technologies, and practices necessary for harnessing solar energy effectively in the context of sustainable energy solutions.

Learning Outcomes

After completing this module, you will be able to:

- Describe the basic concept of about energy, photovoltaic energy, and the basic of electricity.
- Describe the use of solar energy and its application
- Explain the Solar PV Technology
- Discuss the Solar Power generation and current trend
- Describe the basic principles of how solar energy is harnessed.
- Discuss the advantages of solar energy, including its abundance, sustainability, and environmental benefits.

- Understand the role of solar energy in reducing dependence on fossil fuels and combating climate change.
- Identify the key factors that influence the efficiency of solar energy systems, such as location and sunlight availability.
- Explain the basic principles of photovoltaic (PV) technology and how it converts sunlight into electricity.
- Identify the main components of a solar PV system, including solar panels, inverters, and batteries.
- Discuss the applications of solar PV technology in residential, commercial, and industrial settings.
- Understand the process of solar power generation from sunlight to electricity.
- Discuss the various methods of solar power generation, including photovoltaic.
- Explore the future potential of solar energy in contributing to global energy needs and sustainability goals.

Module Structure
Session 1: Introduction to Energy
Session 2: Solar Energy
Session 3: Solar PV Technology
Session 4: Solar Power Generation and Current Trend

SESSION 1: INTRODUCTION TO ENERGY

Role and Responsibilities of Solar Panel Installation Technician

A Solar Panel Installation Technician is an important Job role in the energy sector, for operating solar plant used for electricity generation. The Solar Panel Installation Technician is responsible for the installation of the solar panel system, Gather materials required for installation and maintenance of the solar panel system. 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 mouting of solar panels at 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.
- Deliver quality work as per standards despite constraints.
- Ensure customer satisfaction and get a feedback on standards of work

INTRODUCTION TO ENERGY

Energy is the hub of life. The *capability to do work is known as Energy* which is measured in joules and the *rate of doing work is called Power* which is measured in watts (w). The Law of conservation of energy states that energy can neither be created nor destroyed but it can be transformed from one form to another. Any physical activity in this world, whether carried out by human beings or by nature, is caused due to the flow of energy from one form to the other. The word *'energy'* itself is derived from the *Greek* word 'en-ergon, which means 'in-work' or 'work content'. The work output of any system depends on the energy input to the system.

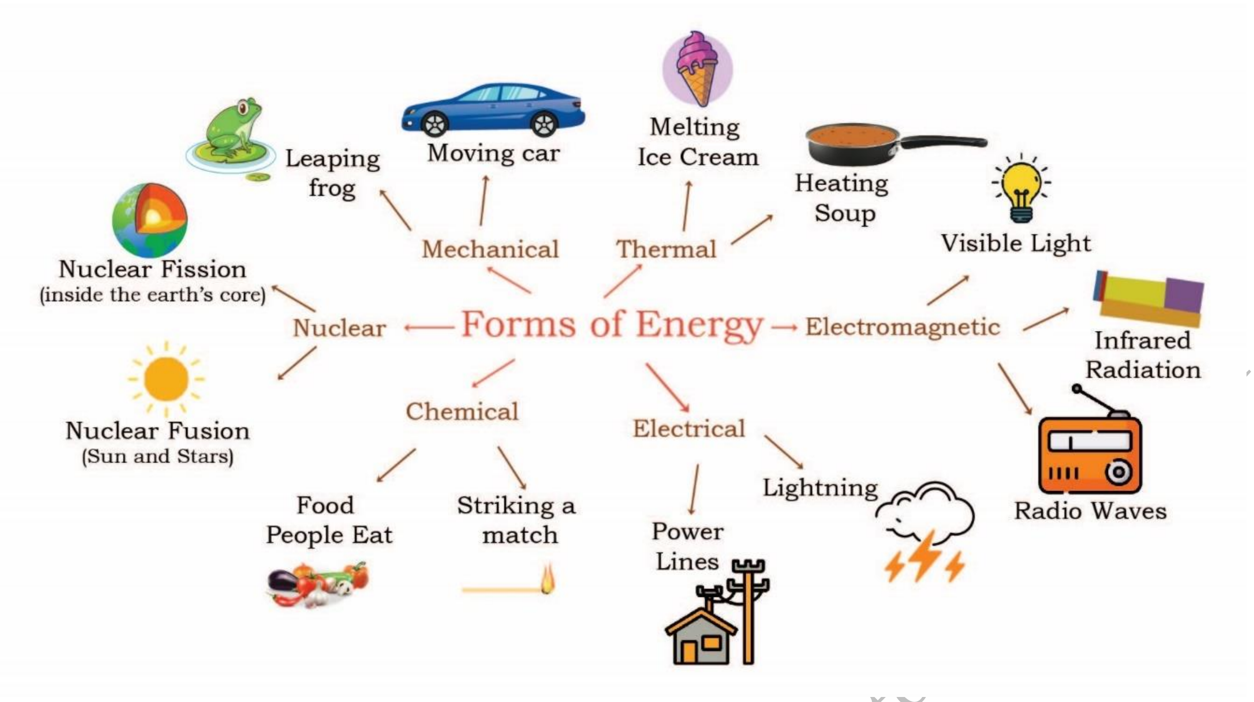


Fig. 1.1 Form of energy

Energy can be classified into 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

1. 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.

2. 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,

3. 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.

4 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 those 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.

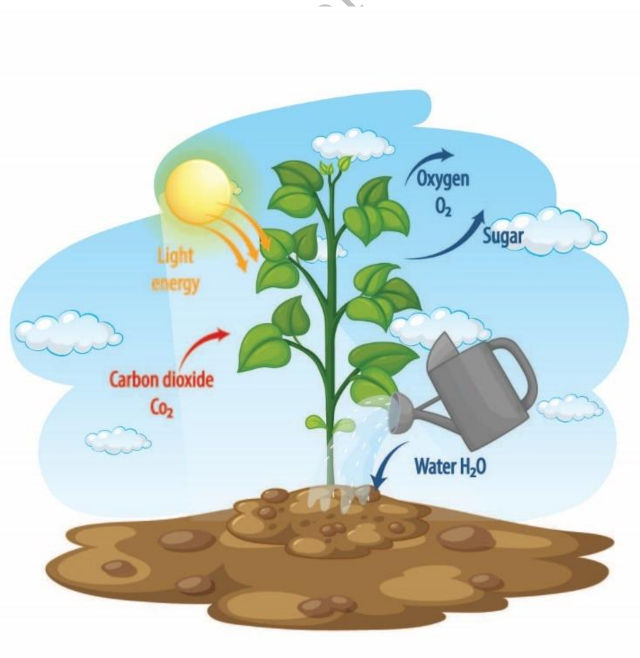


Fig. 1.2 Photosynthesis process

Sun rays heat the ocean water and thus various wind speeds are generated. Solar power is worth considering for its sustainable, renewable, and emissions-reducing qualities.

Modern Solar power systems for homes and industries use systems use photovoltaic (PV) to collect the sun's energy. "*Photo" means "produced by light" and "voltaic" means "electricity produced by the chemical reaction*". Photovoltaic cells use solar energy to produce a chemical reaction that produces electricity. Each cell contains a semiconductor (a semiconductor is a solid substance that allows heat or electricity to pass through it or along it in particular conditions), generally, silicon, germanium, and gallium arsenide are used. Most commonly, silicon semiconductors are used because of silicon of various forms (like single-crystalline, multi-crystalline, or thin-layer), with impurities (either boron or phosphorus) diffused throughout and covered with a silk screen. Cells are linked together by a circuit and frame into a module. Semiconductors allow the electrons freed from impurities by the sun's rays to move fast and into the circuit, producing electricity.

Commercial residential PV modules range in power output from 10 watts to 400 watts, in a direct current. A PV module must have an inverter to change the direct current (DC) electricity into alternating current (AC) energy to be usable by electrical devices and compatible with the electric grid. PV modules can also be used in solar power plants. The method of utilization of solar energy is presented as shown in Fig. 1.3.

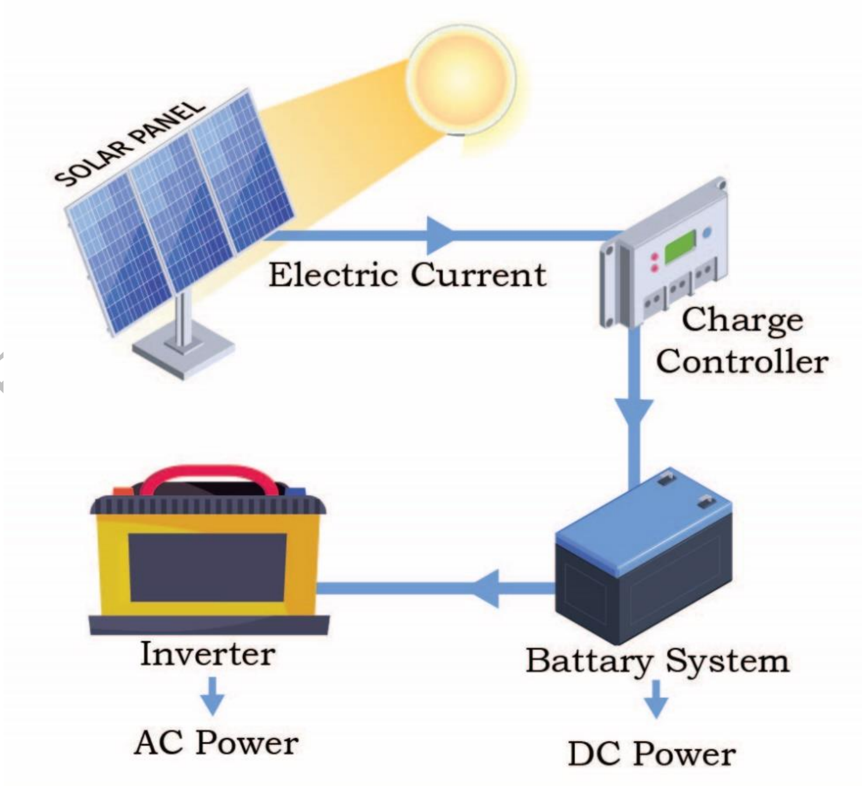


Fig. 1.3 Solar energy generation system through the solar panel

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.

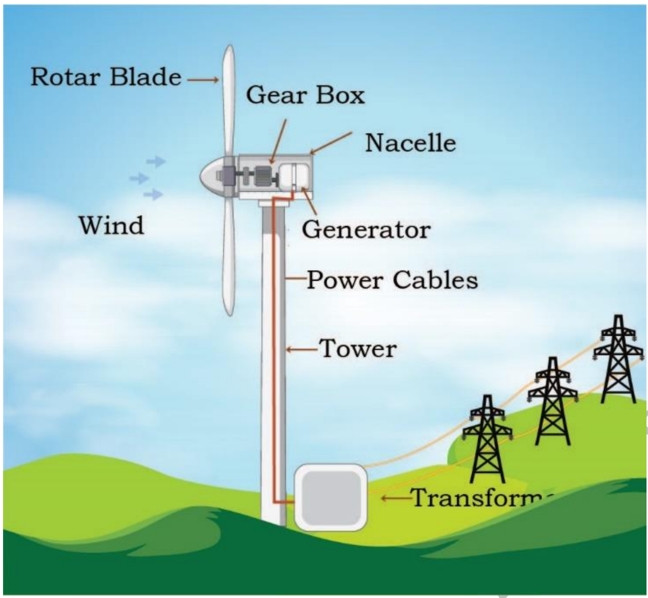


Fig. 1.4 Wind energy generation system through wind turbine

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

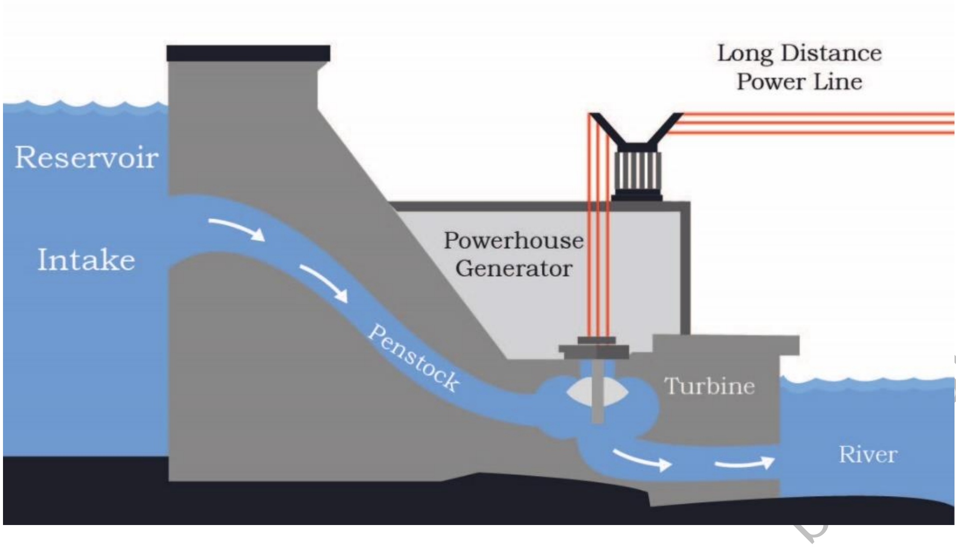


Fig. 1.5 Hydro-electric energy generation system through the hydro-electric dam

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.

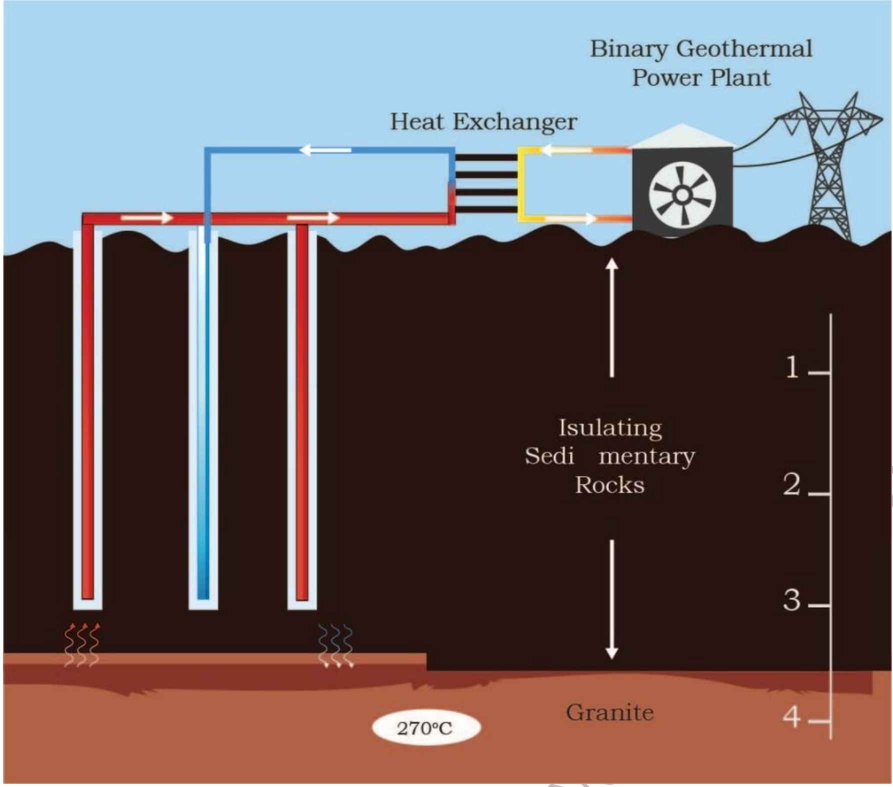


Fig. 1.6 Geothermal energy generation system

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.

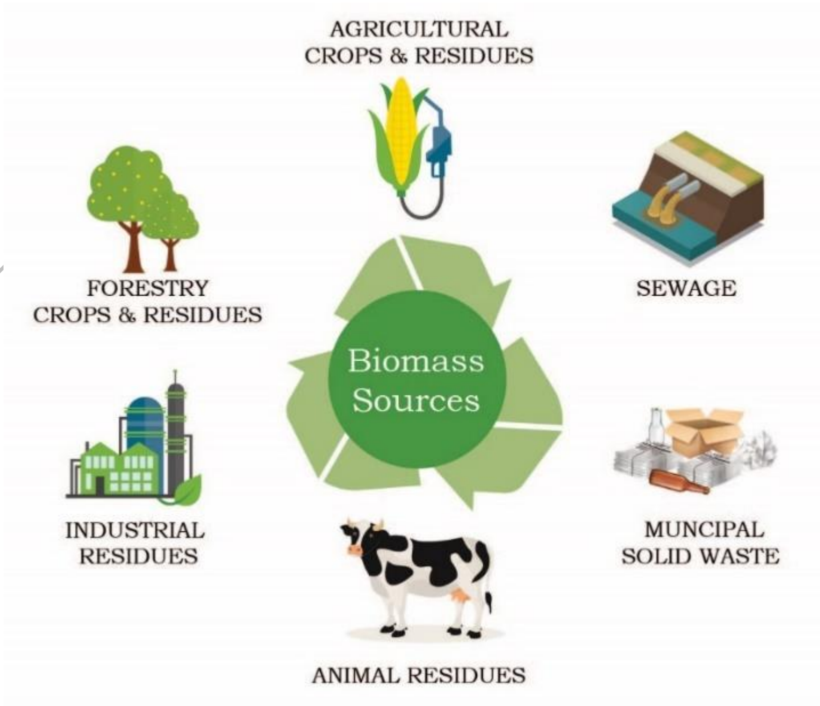


Fig. 1.7 Biomass energy generation system

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.

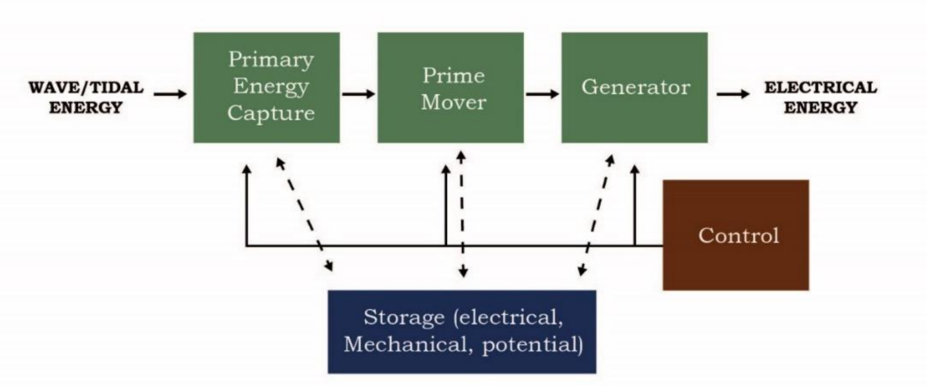


Fig.1.8 (a) Flow diagram of tide/wave energy use

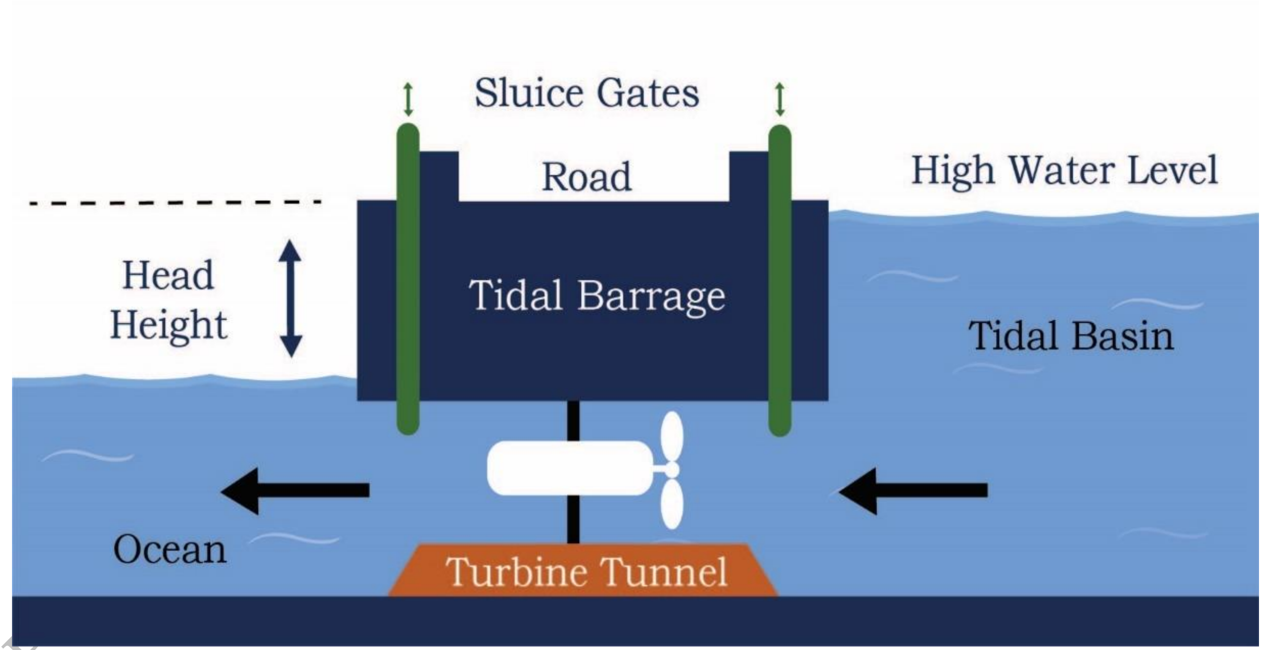


Fig. 1.8 (b) Tide/Wave Energy Use

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

SESSION 1

Practical Exercise

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 include ....and ....energies. **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

D. Match the columns

1. Fossil fuels	Renewable
2. Wind energy	Non-renewable
3. Silicon	Solar energy
4. Nuclear fusion	Solar cells

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/m^2, 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

(1) 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.

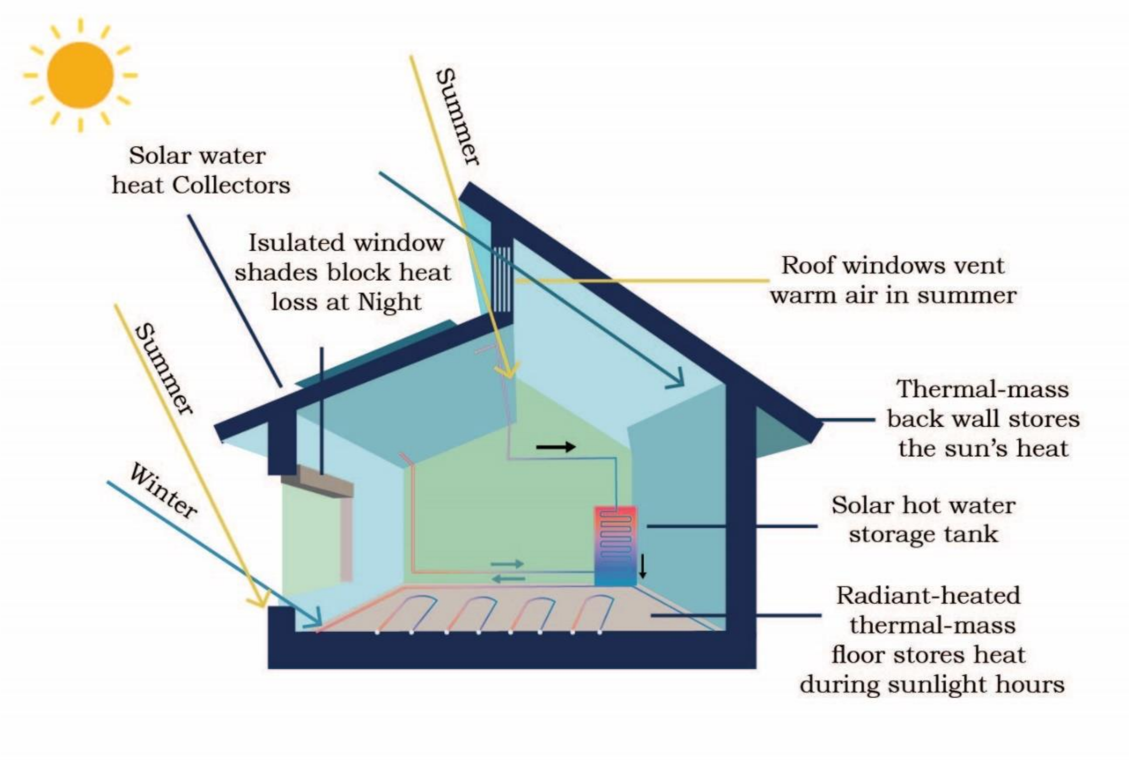


Fig. 1.9 Solar Space Heating System

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.

(2) 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.

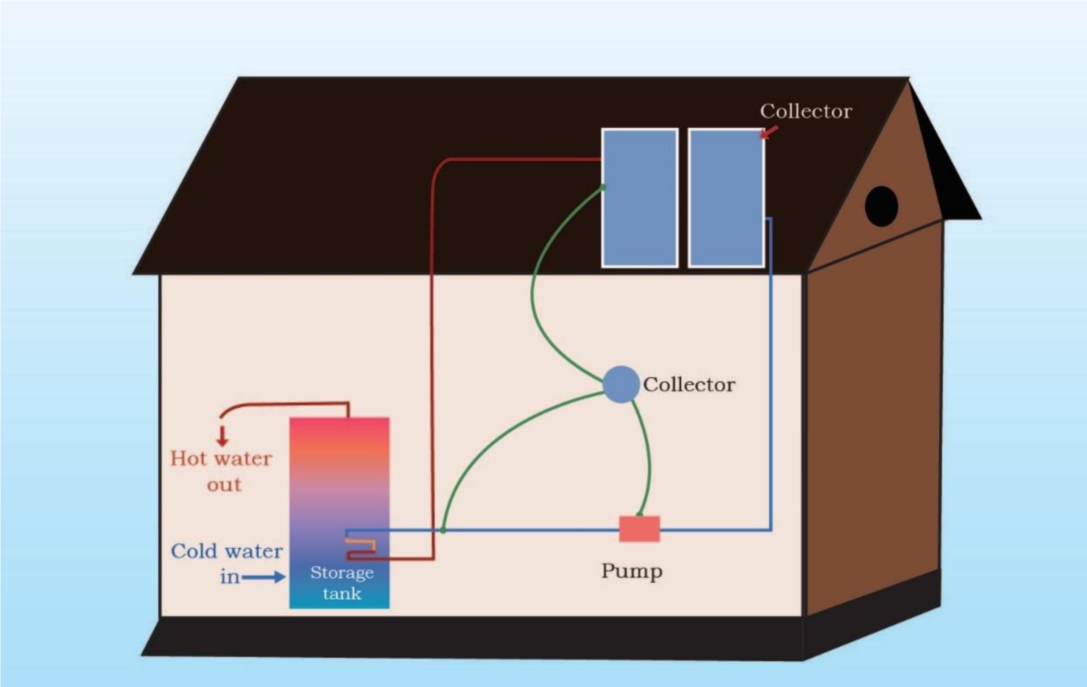


Fig. 1.10 Solar water heating system

(3) 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.

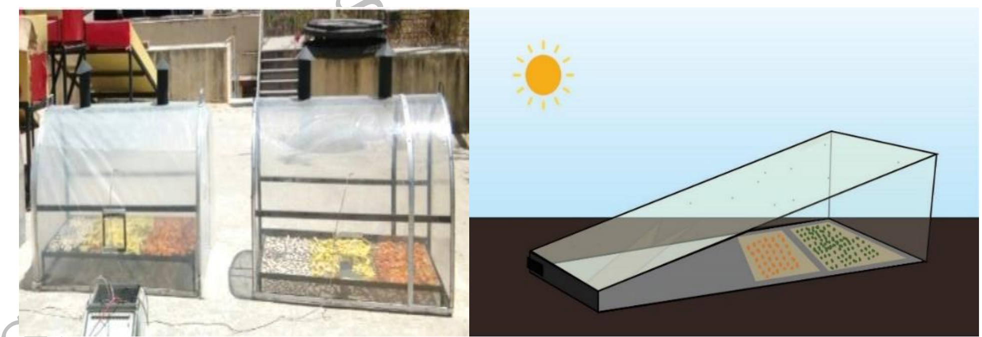
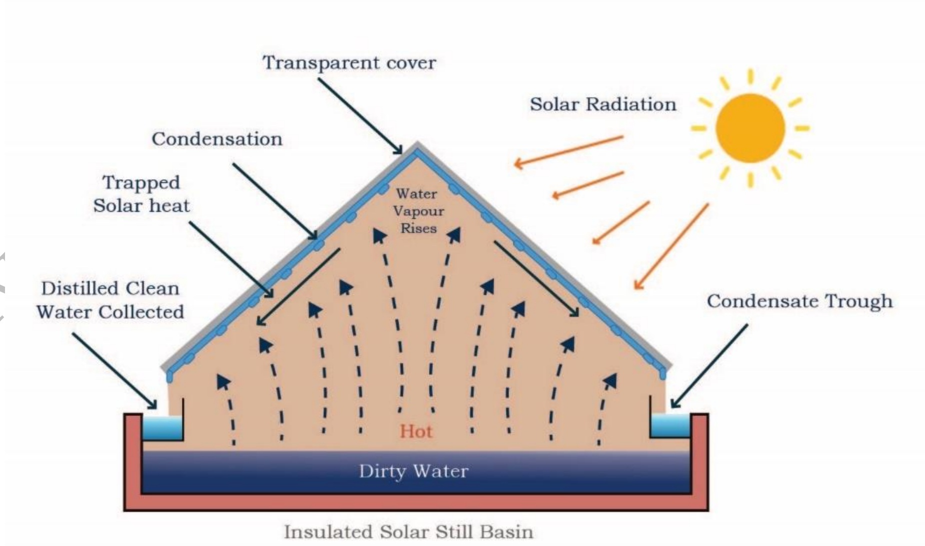


Fig. 1.11 Solar dryer system

(4) 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

(5) 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.

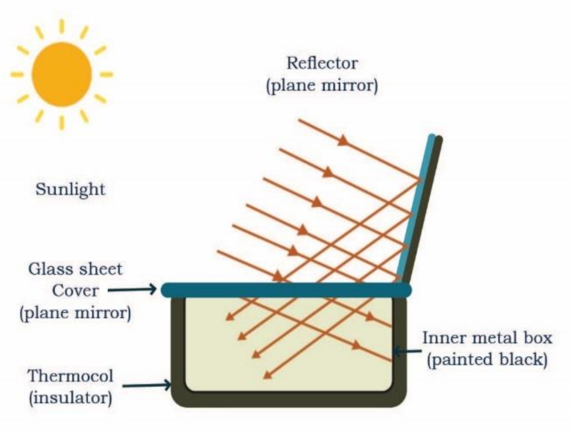


Fig. 1.13 Solar cooker

(6) 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.

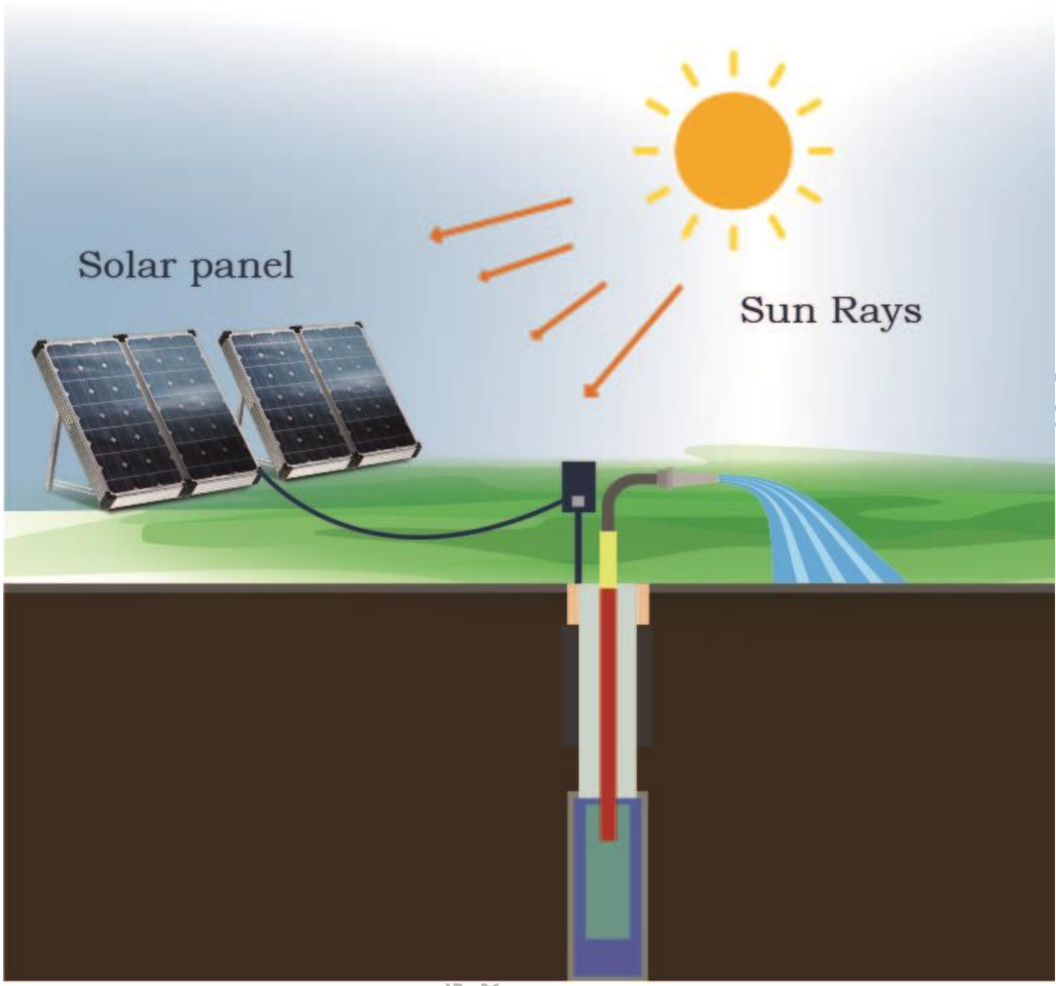


Fig. 1.14 Solar water pumping

SOLAR RADIATION

The sun radiates about 3.8 x 10^{26} Watts of power in all directions. Out of this about **1.7 x 10^{17} Watts** is received by the earth. The average solar radiation outside the earth's atmosphere is 1.35 kW/m^2 varying from 1kW/m^2 to 1.40 kW/m^2 (January- December).

` The Earth receives solar energy from the Sun in the form of solar radiation. These radiations comprising of 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 (O_3) layer absorbs 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. 1.15.

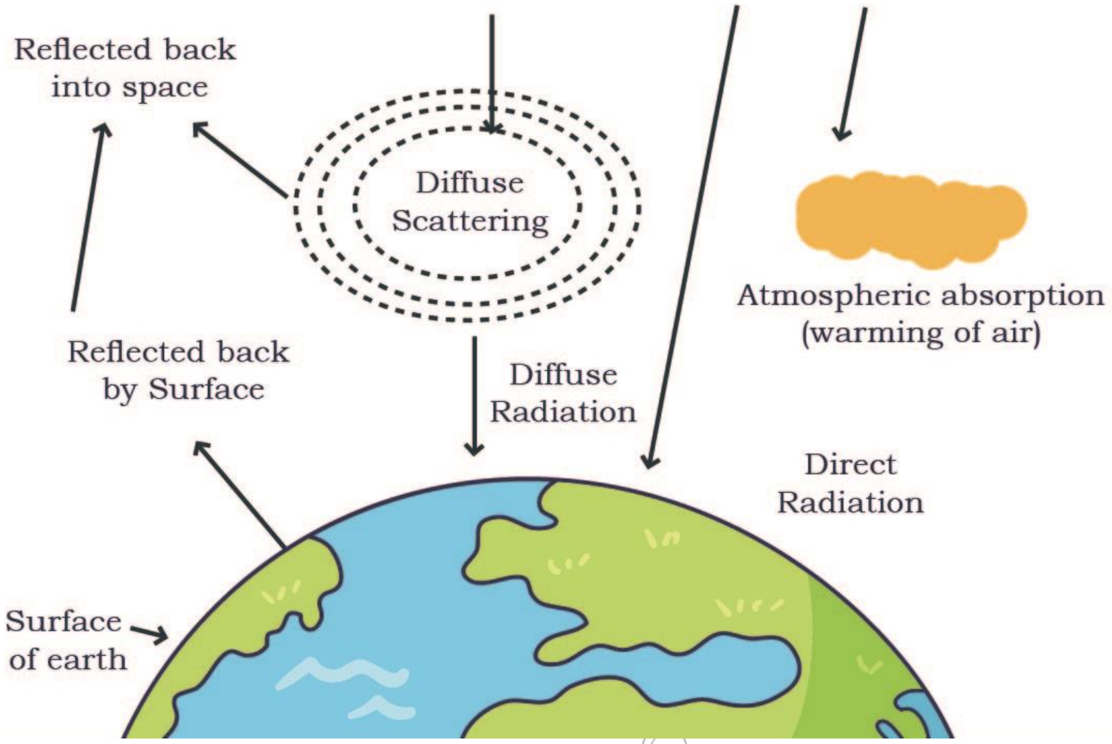


Fig. 1.15 Direct, diffuse and total radiation

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:

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

SESSION -2

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., through ....and hot air registers. **solar collectors, radiators**

4. The collector ....is connected by a pipe to an ....that 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.

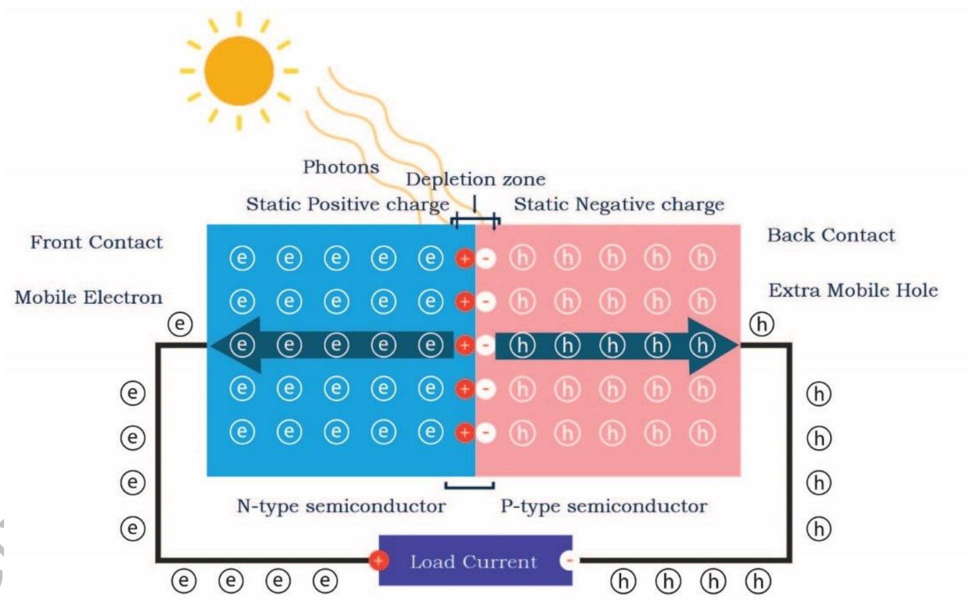


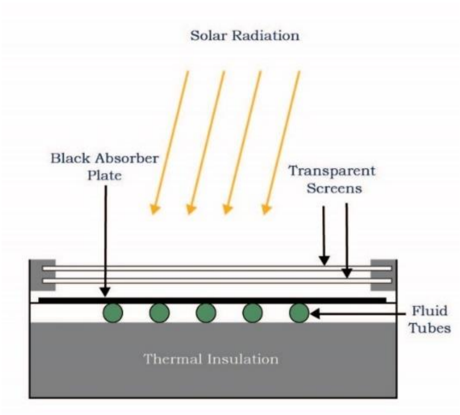
Fig 1.16 Photovoltaic effect

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.

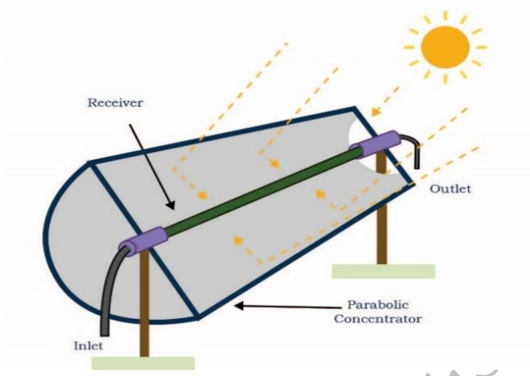
Photovoltaic and Photovoltaic Cells

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 ou tputs 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.

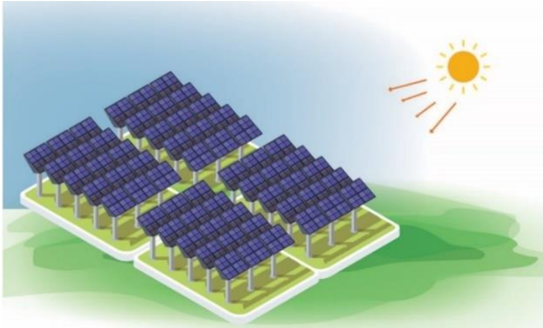


Fig. 1.19 Solar energy generation unit

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.

FUNDAMENTAL 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

When electrons inside any material move, flow of electricity takes place. This flow is called current. It is measured in ampere.

Voltage

In an electrical circuit, the current flows only when there is a voltage source. Voltage is the force pushing electrons through the wire.

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 workdone.

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= 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:

Electrical Energy (E) = Power (P) x Duration of Energy usage (T)

= Power (Watt) x Time (hour)

E (Wh) = P (W) x T (h)

Power = Energy / Time

SESSION 3

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” means ......and “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) 2 watts
   b) 10-watt
   c) 12-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

1) **National Institute of Solar Energy**
2) National Institute of Science Energy
3) Neutral Intensity of Solar Energy
4) none of these

5. the efficiency of solar cells is about

1) 10%
2) 25%
3) **15%**
4) 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 CURRENT TREND

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/m^2/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 .

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 watt (W) = 1 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.

1KJ (Kilo Joule) = 1000J

1MJ (Mega Joule) =1000KJ=1000000J

1GJ (Giga Joule) =1000MJ=1000000000

Various units of electrical energy:

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

Energy (Joule)= Power (Watt)×Time (Second)

1 Joule =1W×1s

1KW= 1000 Watt

1hour (h)= 3600 seconds (sec)

Thus,

1 Kw×h= 1000W×3600sec= 3600000Ws=3600000J=3600KJ

1 KWh Energy = 1 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

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.

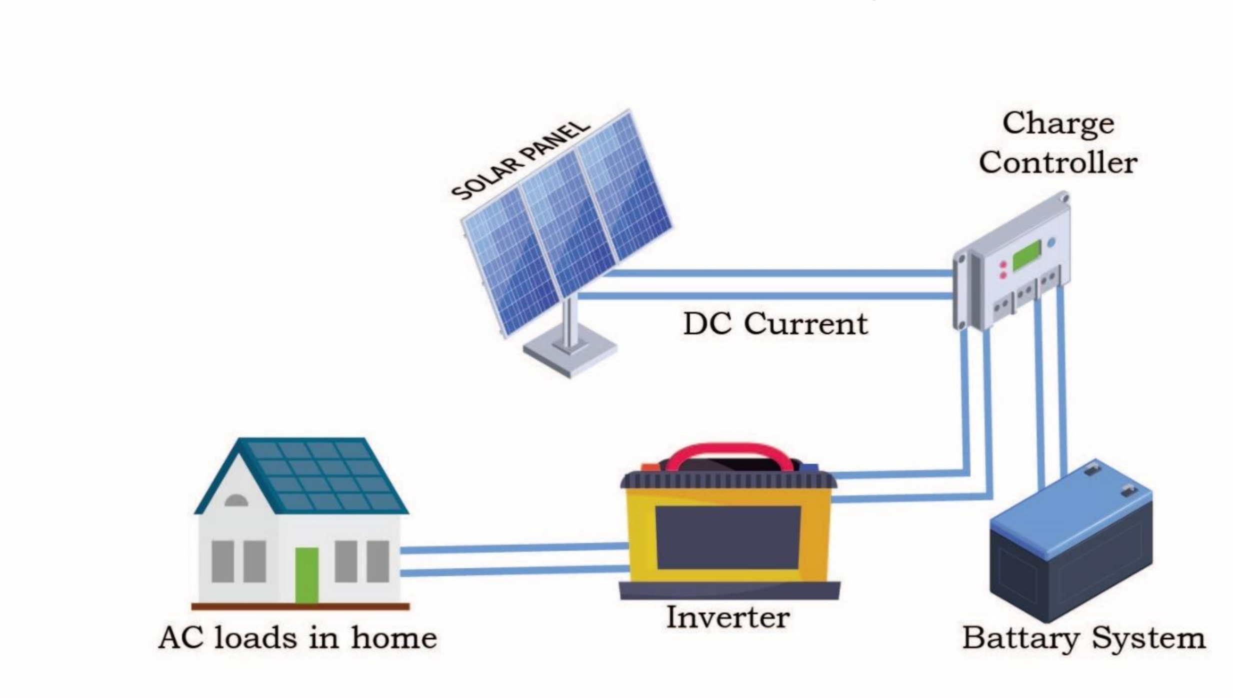


Fig. 1.20 off-grid system

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.

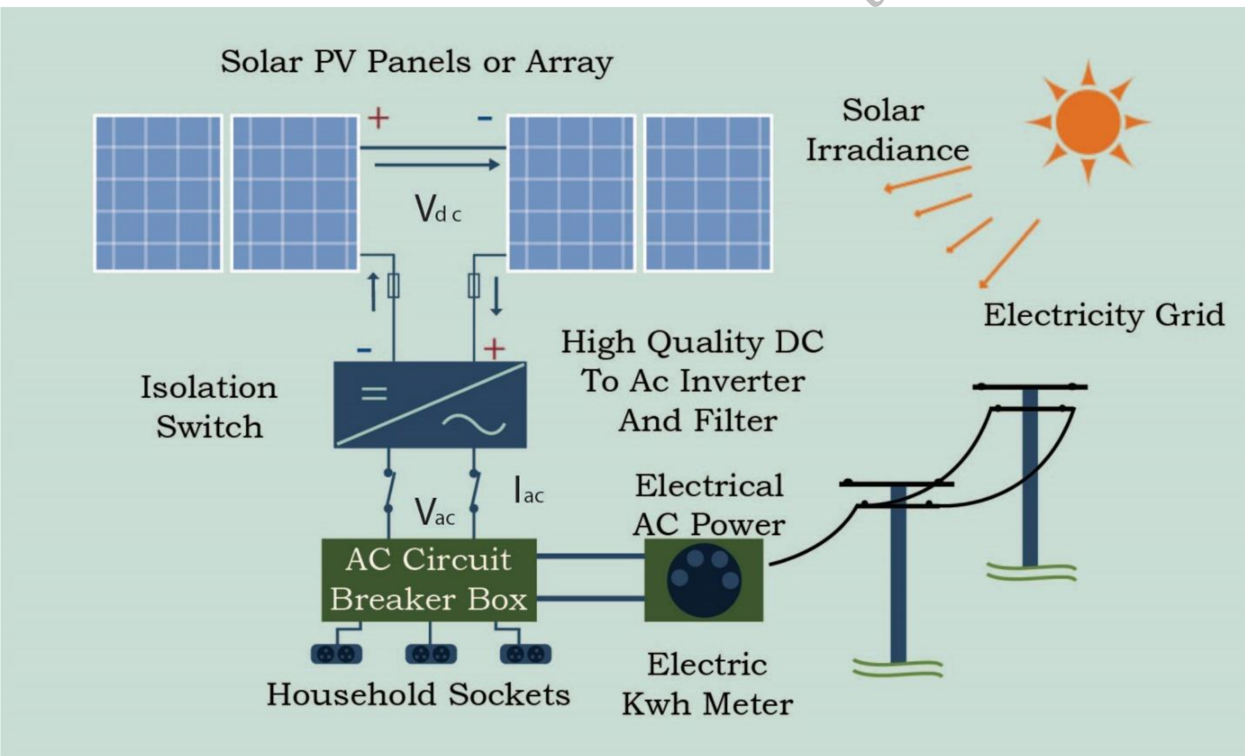


Fig. 1.21 Grid-connected solar power plant

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 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. ower is among the very critical component 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.

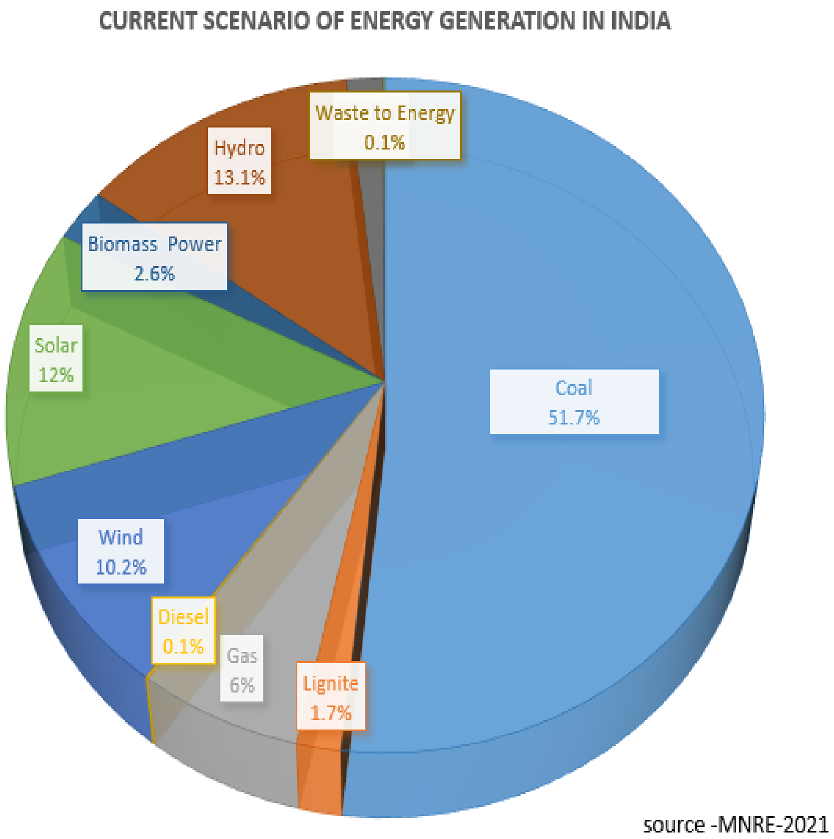


Fig. 1.22 Energy generation in India

National Institute of Solar Energy has assessed the Country's solar potential of about 748 GW assuming 3% of the waste land 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 percent 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 percent 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.

SESSION 4

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?

Module 2	Major Components of Solar Power System

Module Overview

This module provides an in-depth understanding of the essential components that make up a solar power system. Students will learn about the functions, characteristics, and integration of these components to effectively convert solar energy into usable electricity. The module will cover the following key elements:

Solar Panels (Photovoltaic Modules), Different types of solar panels, including monocrystalline, polycrystalline, and thin-film, along with their advantages and applications. The role of inverters in converting the direct current (DC) generated by solar panels into alternating current (AC) for use in homes and businesses. Different inverter types, including string inverters, micro inverters, and hybrid inverters. Mounting Systems in securing solar panels to rooftops, ground mounts, or other structures. The role of batteries in storing excess solar energy for use during periods of low sunlight or at night. Understanding how battery storage systems integrate with solar power systems and grid connections to optimize energy use.
Charge Controllers Maximum Power Point Tracking (MPPT) charge controllers. Cabling and Electrical Components
Wiring: The role of cabling in connecting solar panels, inverters, batteries, and other system components.

By the end of this module, students will have a comprehensive understanding of the major components that make up a solar power system. They will learn how these components work together to harness solar energy, convert it into electricity, and store or distribute it for various applications. This knowledge will provide a strong foundation for designing, installing, and maintaining efficient solar power systems.

Learning Outcomes

- Describe the Solar Panel System and its types
- Identify the solar panel and its types
- Explain the mounting structure and their different types
- Describe the power conditioning unit
- Able to explain inverter and its types
- Able to explain features of battery energy storage unit
- Identify the different cable connection

- Explain the importance of earthing systems and their types
- Explain the different types of conduit used in cable

Module Structure

SESSION 1: SOLAR POWER SYSTEM AND ITS COMPONENTS

Introduction

A solar power system, alsoknown 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.

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 summarized 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 purpose. 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 are able to automatically isolate from the grid (known as islanding) and continue to supply some power during ablackout.

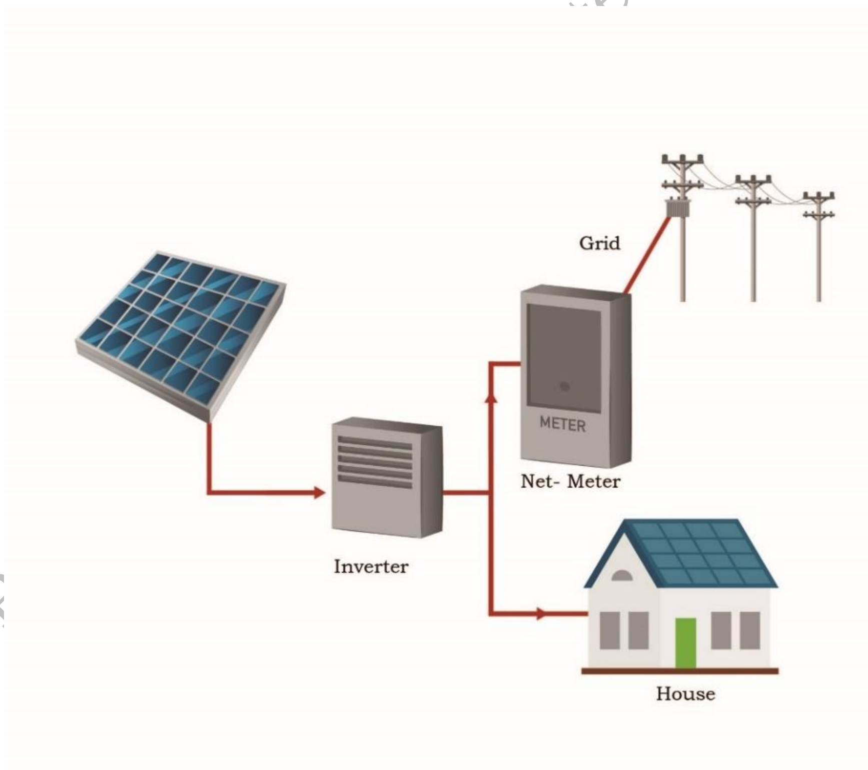


Fig.2.1 In an on-grid system,

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.

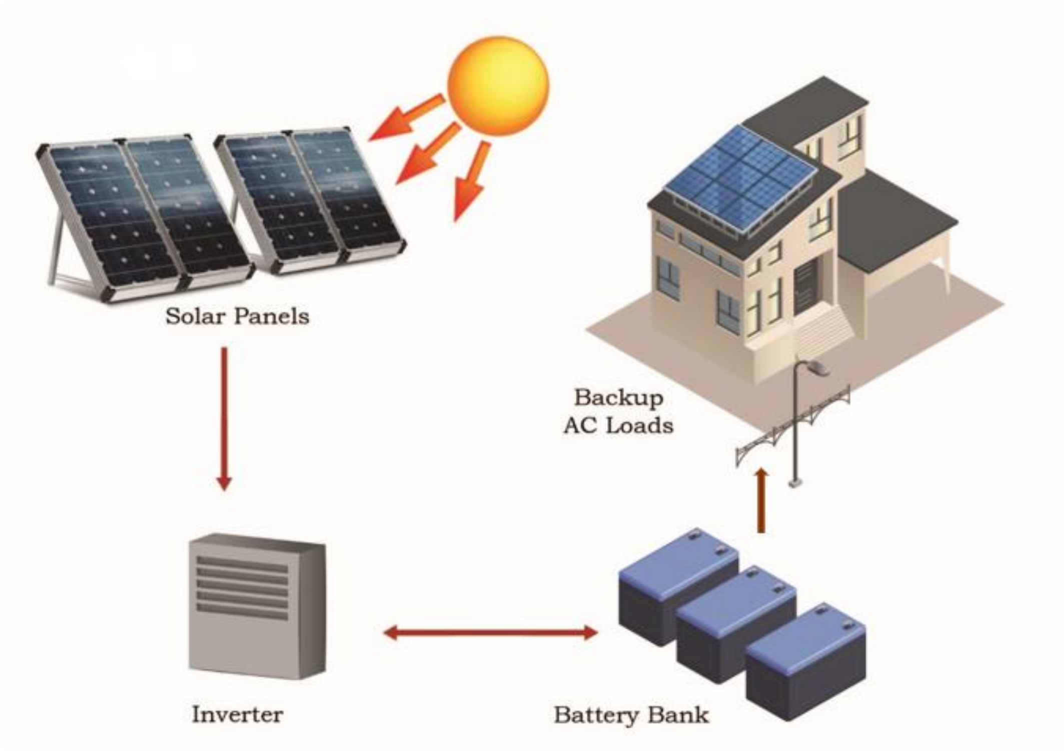


Fig.2.2 Off-Grid Solar System

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 more costly.
- 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).

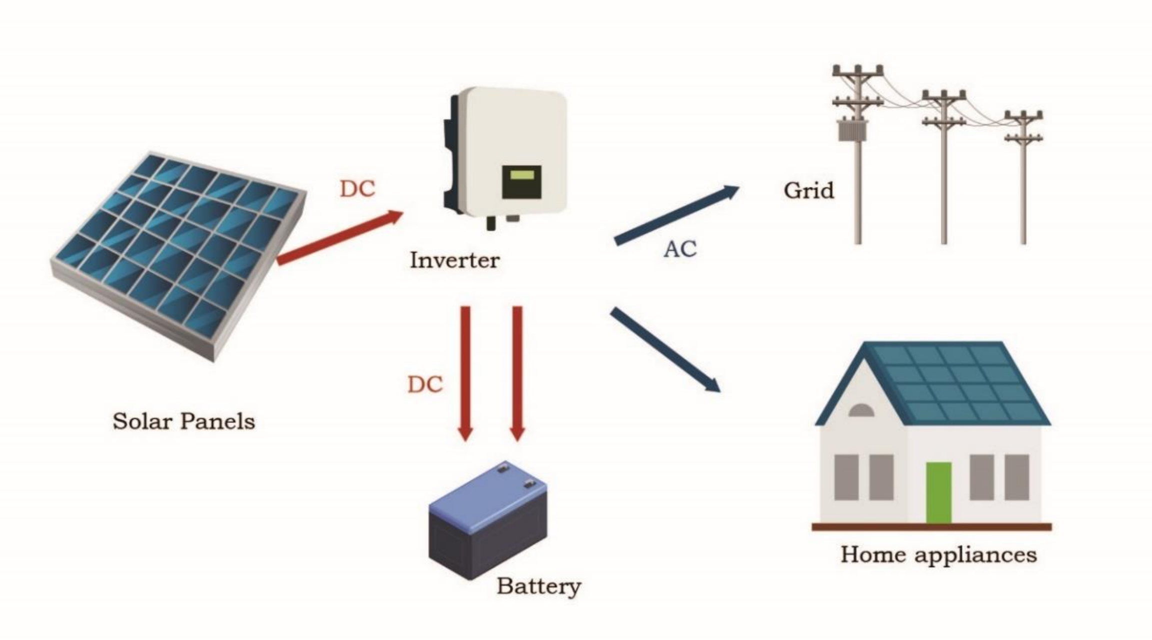


Fig.2.3 Hybrid solar system

- The battery bank. 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.

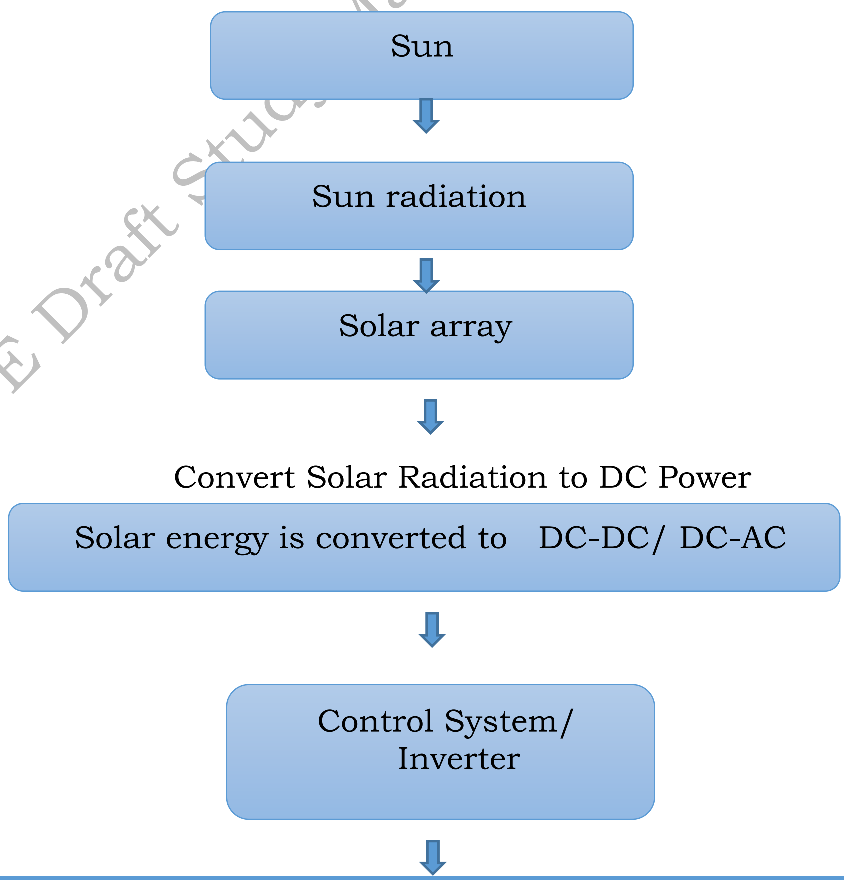
- The meter and the electricity grid. Depending on how your hybrid system is set up and whether your utility allows it, once your batteries are fully charged excess solar power not required by your appliances can be exported to the grid via your meter. When your solar system is not in use, and if you have drained the usable power in your batteries your appliances will then start drawing power from the grid.

Conclusion: 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 there are fewer components that 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, investors, solar charge controller , DCDB/ACDB, structure , earthing , lighting arrester , and sometimes a solar battery also.

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



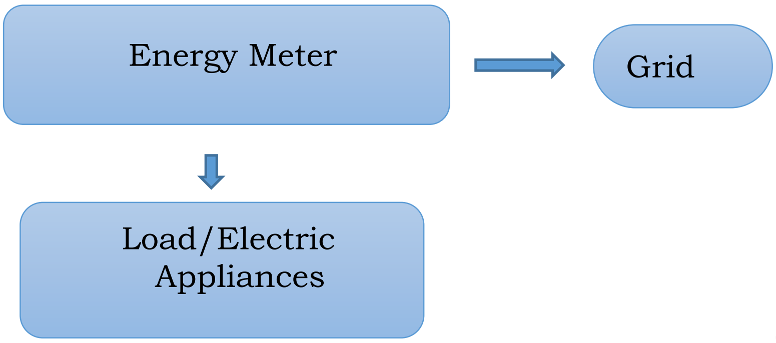


Fig. 2.4 Principle of a solar power system

SESSION 1

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

Answer 1.a, 2.c, 3.c, 4.b

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.

Answers 1. (2-15) HP, 2. 1-3HP, 3. MPPT

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 the single solar cells. These solar panels are available in the power rating range from 1 watt to 700 watts. With 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.

1.1 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 varieties 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.

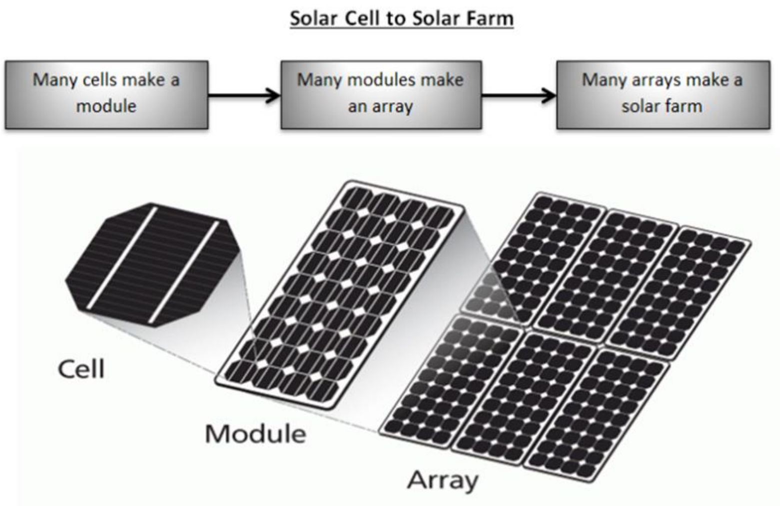


Fig. 2.5 PV Cell, Module, Array

Photovoltaic Panel/module: Photovoltaic Panel 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.

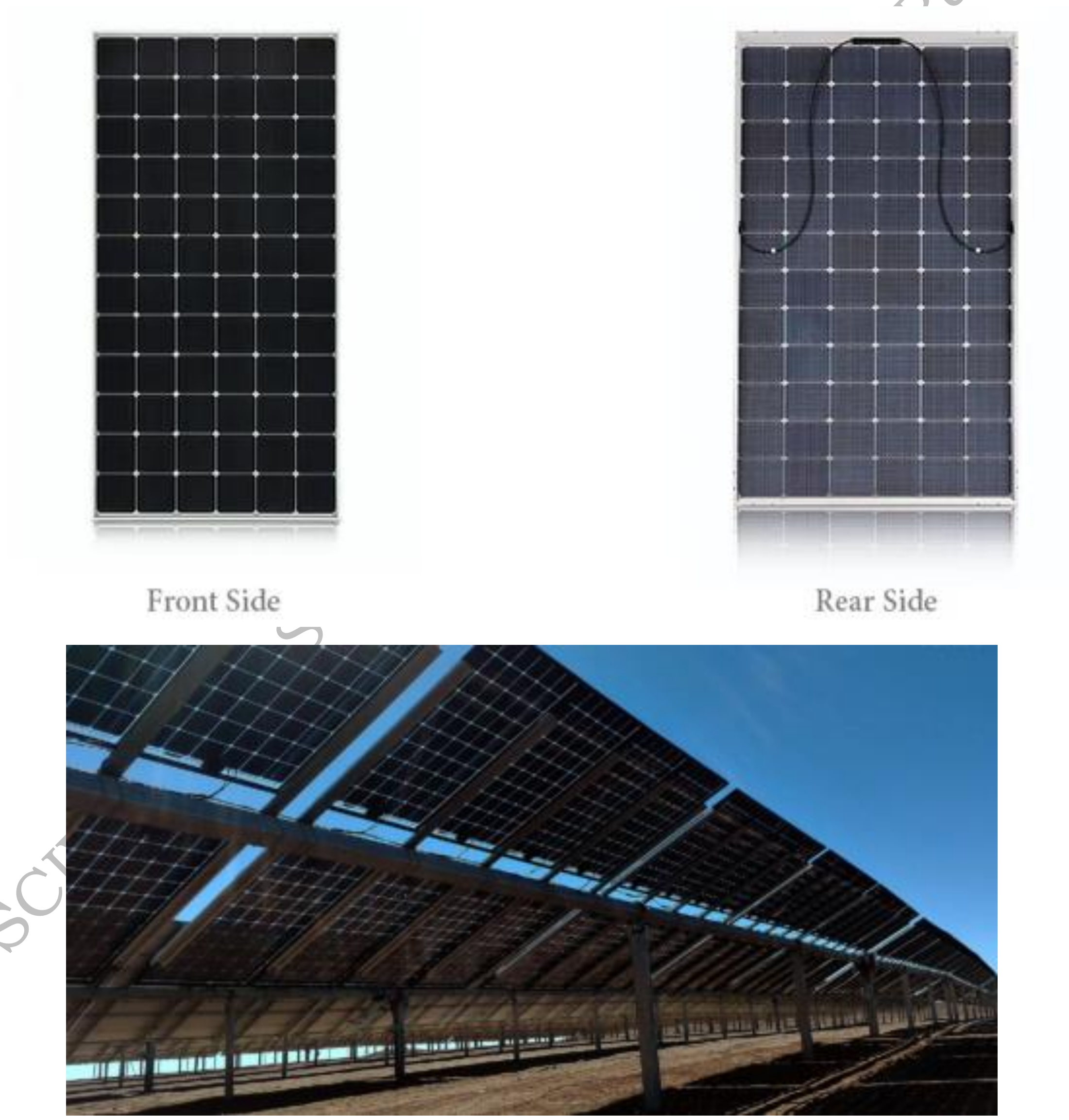


Fig. 2.6 Bifacial Solar PV Panel

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 2.7

Fig. 2.8 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. 2.9 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. 2.10 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.

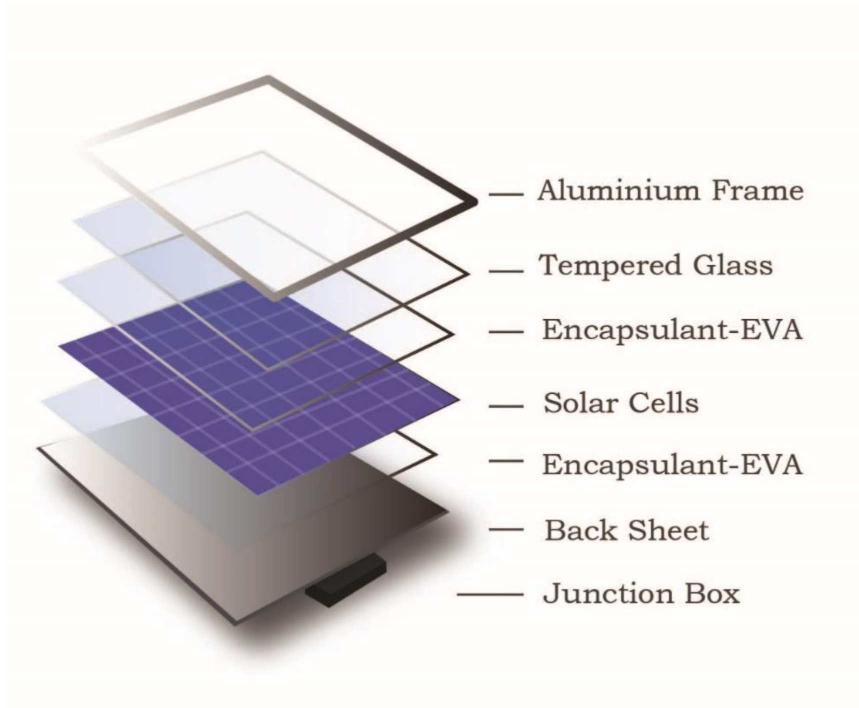


Fig. 2.11 Solar Photovoltaic cell layer

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. 3.1 Comparison of Different Types Of PV Modules

TYPE OF PV Cell	Module efficiency	Surface area needed for 1 KWp(Power)	Advantages	Disadvantages
Bifacial Solar PV Panel	20 Plus %	5-6m²	-Less Area Required, -Highly Standardised,	Very Expensive
Monocrystalline silicon	15-19 %	7-9 m²	- Most Efficient PV Modules - Easily Available On The Market - Highly Standardised	-Expensive - Waste Of Silicon In The Production Process
Polycrystalline silicon	13-16 %	8-9 m²	- Less Energy And Time Needed For Production Than For Monocrystalline Cells (Lower Costs) - Easily Available On The Market - Highly Standardised	-Slightly Less Efficient Than Monocrystalline Silicon Modules
Thin film: Copper indium diselenide (CIS)	10-12 %	9-11 m²	- Higher Temperatures And Shading Have a Lower Impact On Performance - Lower Production Costs	- More Space For The Same Output Needed
Thin film: Cadmium telluride (CdTe)	9-11 %	11-13 m²	- Higher Temperatures And Shading Have a Lower Impact On Performance - Highest Cost-Cutting Potential	- More Space For The Same Output Needed
Thin film:(Amorphus silicon (a-Si))	6-8 %	13-20 m²	- Higher Temperatures And Shading Have a Lower Impact On Performance - less silicon is needed for production	- More Space For The Same Output Needed

Session 2

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

Answer 1.a, 2.a, 3.c, 4.a

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.

Answer 1. Photovoltaic 2. Thin film 3. 25 years, 4. Solar radiations.

C. Short answers Questions

1. A typical solar PV cell is a multi-layered unit consisting of?

2. How does Solar PV Panel Works?

3. What is Photovoltaic Principle explain.

4. Different types of solar Panels differentiate between them.

D. Practical Exercise:

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

SESSION 3 – SOLAR PANEL MOUNTING STRUCTURE

Mounting structures are the strength of a solar power plant as they provide support to modules. These support structures raise solar panels at appropriate angles to ensure that they receive maximum solar irradiation. Module mounting structures are made of three types of materials. They are Hot Dip Galvanized Iron, Aluminium, and Mild Steel (MS). In galvanizing zinc coating is applied to iron or steel to prevent it from rusting. In solar PV module mounting structure, iron is used for galvanizing process.

1.1 Types of Solar Panel Mounting Structure

1. Rooftop Mounting Structure
2. Tin Shed Mounting Structure
3. Ground Mounted Structure

1. **Rooftop Mounting Structure:** In a rooftop mounting system, solar PV panels will be installed on the roof of any building. It can either be any residential building or any commercial/industrial building. In a rooftop mounting system, the roof on which the solar array will be installed can be of two types.

a) Standard Rooftop Mounting Structure:

In rooftop solar installations, we have three techniques to mount the solar panels. All the techniques are applicable on all types of roofs except ballasted mounting system on the tin shed. Because it is hard to fix solar panels on the shed by using concrete.

Fig. 2.12 Standard Rooftop Mounting Structure:

Railed Mounting System

In railed mounting structure, solar panels are fixed on several rails through a set of clamps. These rails are made of Aluminium. The rails are attached properly to your roof by using a drill and nut bolts. This is the most common type of mounting the panels.

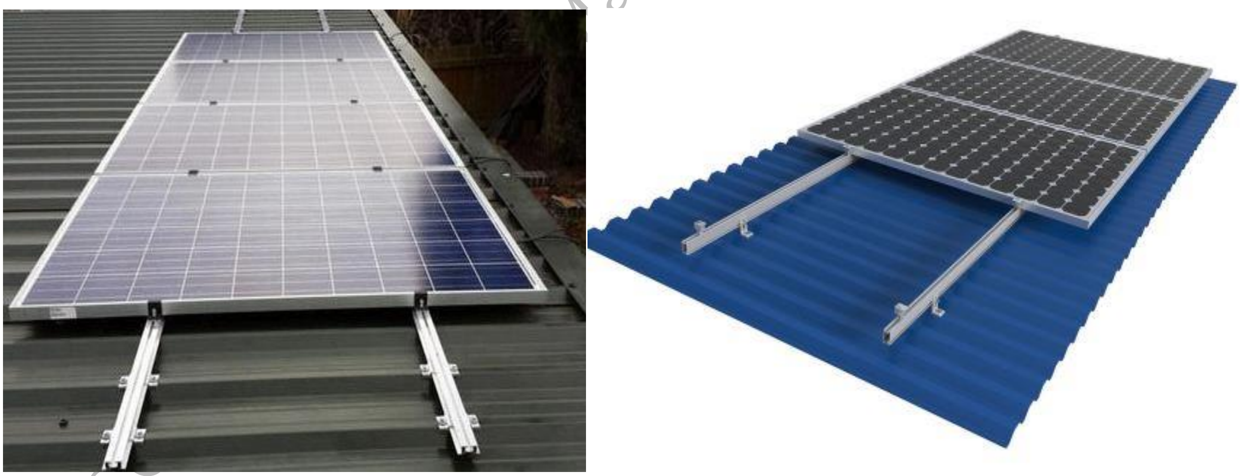


Fig. 2.13 Railed Mounting System

Rail-less/Ballasted Mounting System

Rail less mounting system is also known as ballasted mounting system. In this technique, rails are not used to fix the solar panels. Instead of using the rails, the solar panels are directly fixed with the roof by using hardware. The hardware is further attached with the roof through nut bolts strongly. This is a cost-effective method of installation.

Fig. 2.14 Ballasted Mounting System

Shared Rail Mounting System

The shared rail mounting system is very similar to the railed system. The basic difference between the two is the number of rails that will be used for mounting. In railed mounting system,4 rails are used to fix 2 rows of solar panels. While in shared rail system only 3 rails will be used to mount 2rows of solar panel. The middle rail will be shared by both rows.

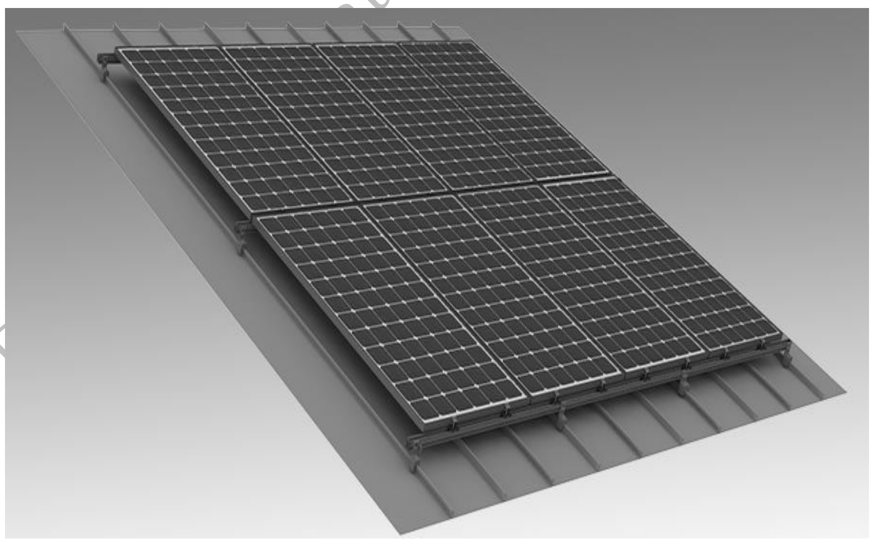


Fig. 2.15 Shared Rail Mounting System

b) **Elevated Mounting Structure**: In an elevated solar panel structures, solar panels are installed at a height of 12 to 15 ft. There will be a little room-type space behind the mounting structure. It is also an almost common type of mounting structure.

Fig. 2.16 Elevated Mounting Structure

2. Tin Shed Mounting Structure:

In the tin shed solar mounting system, the solar panels are fixed on the shed of your house. The tin shed solar structures are the cheapest of all types of solar mounting structures

Fig.2.18 Tin Shed Mounting Structur

3. Ground Mounted Structure:

In a ground mount solar system, the solar panels are installed on the ground. The land where the solar structure is getting installed could be parks, playgrounds, agricultural land, etc. generally ground mounting solar structure as discussed below.

Foundation Mounting Structure: This is the most common type of ground mounting structure. In this system, the land will be excavated to put the vertical pipes surrounded by a concrete foundation. The land is strong enough to hold the mounting structure or not, it finalizes after the site analysis by the solar experts.

Fig. 2.19 Foundation Mounting Structure

Ballasted Mounting Structure: If the soil is not suitable for drilling or excavation, the best solution is to use a ballast mount system. Ballast mounting consists of a pre-cast concrete block anchored to the ground. In ballasted solar mounting structures, precast concrete block anchors will be used. Your solar structure will be fixed by using cementing materials.

Fig. 2.20 Ballasted Mounting Structure

Pole Mounting Structure: Ideal for a small solar system, especially for residential purposes, the pole mounting structure functions on a simple foundation that is a pole:

Single Pole Mounting Structure: In a single pole mounting system, a simple steel pole with a concrete anchor will be fixed on the ground. The solar panels will be installed on this pole.

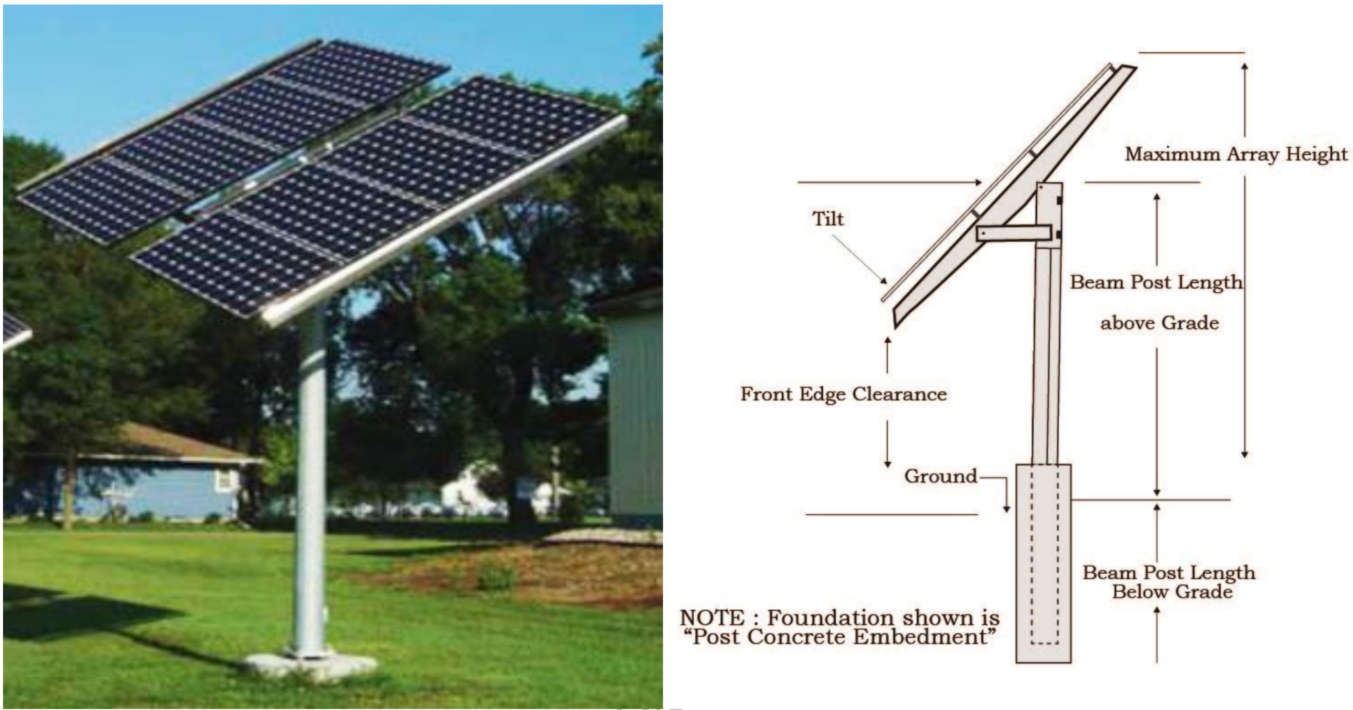


Fig. 2.21 Pole Mounting Structure

Multi Pole Mounting Structure: In a multi-pole mounting structure, several poles are used in a single horizontal line. The solar panels will be installed on these poles.

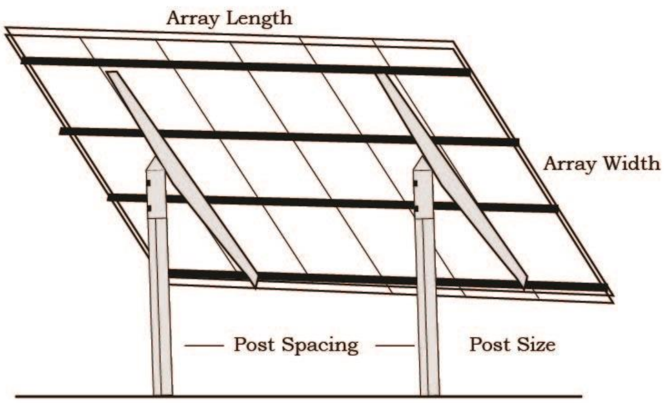


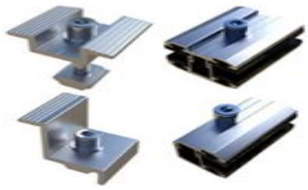
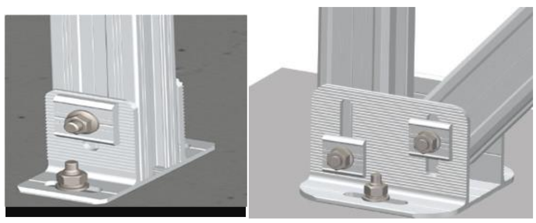
Fig. 2.22 Multi Pole Mounting Structure

Material of mounting structure

A good mounting structure can not only bear the weight of solar modules but can also withstand extreme weather conditions like storms and floods. A variety of materials ranging from wood to polymers have been used to create strong and durable mounting structures for solar panels. Stainless steel has been the popular choice in most cases.

Stainless steel, aluminium, and galvalume are the primary materials used in solar mounting structures in India. Given the plant location and life cycle, stainless steel has traditionally been the most cost-effective option. However, recent trends show increased utilization of aluminum in a hot dip galvanised state along with steel for better protection against rust formation.

Table no. Miscellaneous components are used to make the solar structure.

S.No	Parts name	Uses	Diagram
1	Rail	Solar mounting system	
2	L foot	Tin Roof PV Mounting System	
3	Clamp /Mid clamp/ End clamp	Holding Panel to Purlin or rail	
4	Spring Nut	Fastening	
5	Earth clamp/ Leg cap	Join earth and leg of solar structure	
7	Different type Screw	Fastening	

Session 3

CHECK YOUR PROGRESS

A. Multiple Choice Questions.

1. Which material is not used in the mounting Structure?

a. Wood b. Aluminium c. Mild Steel. d. all of these

2. In solar Street light which type of mounting system is used?

a. blasted mounting b. rack and rails. C. Pole mounting d. ground Mounting.

3. In Coastal Areas which type of material could be used in the mounting structure?

a. Iron b. Aluminium c. Galvanized metal d. None of these

4. Mounting Structure used for:

a. inverter b. battery c. Solar Panel d. charge controller.

Answers 1.a, 2.c, 3.c, 4.c

B. Fill in the blanks

1. In roof ____________ type of mounting structure used.

2. For MW solar Power plant ____________ type of mounting structure used.

3. In blasted type mounting structure Concrete block of _________ grade is used.

4. In elevated solar panel structure, solar panels are installed at a height of__________.

Answers 1. Blasted 2. Ground Mounting 3. M20 4. 12 to 15 ft.

C. Short answers QUESTIONS

1. What Mounting structure?

2. Types of mounting Structure?

3. What is an elevated Mounting Structure?

4. Mounting Structure for coastal areas?

D. Practical Exercise

Installation of mounting Structure at different angles as per design, and also measure their area and candidate able to understand drawing of Mounting structure.

Session 4: Power conditioning Unit

PCU means Power Conditioning Unit is a Unit of Solar PV power System that consists of Controllers (MPPT Charge Controller) switches, inverters, etc. This Unit Controls the Power and let the battery charge and also gives power to loads to run accurately without any fault or interruption. the PCU intelligently optimizes battery charging and power to load among Solar, Battery, and Grid power.

In other words, the PCU is the heart of the system and ensures the life of the battery and optimum usage of the system. The inverter will convert the DC energy into alternating energy to meet the conventional load demand for the predetermined period. It will also take care of the initial surge current required for inductive loads. The capacity of the Inverter will always be double the size of the load demand.

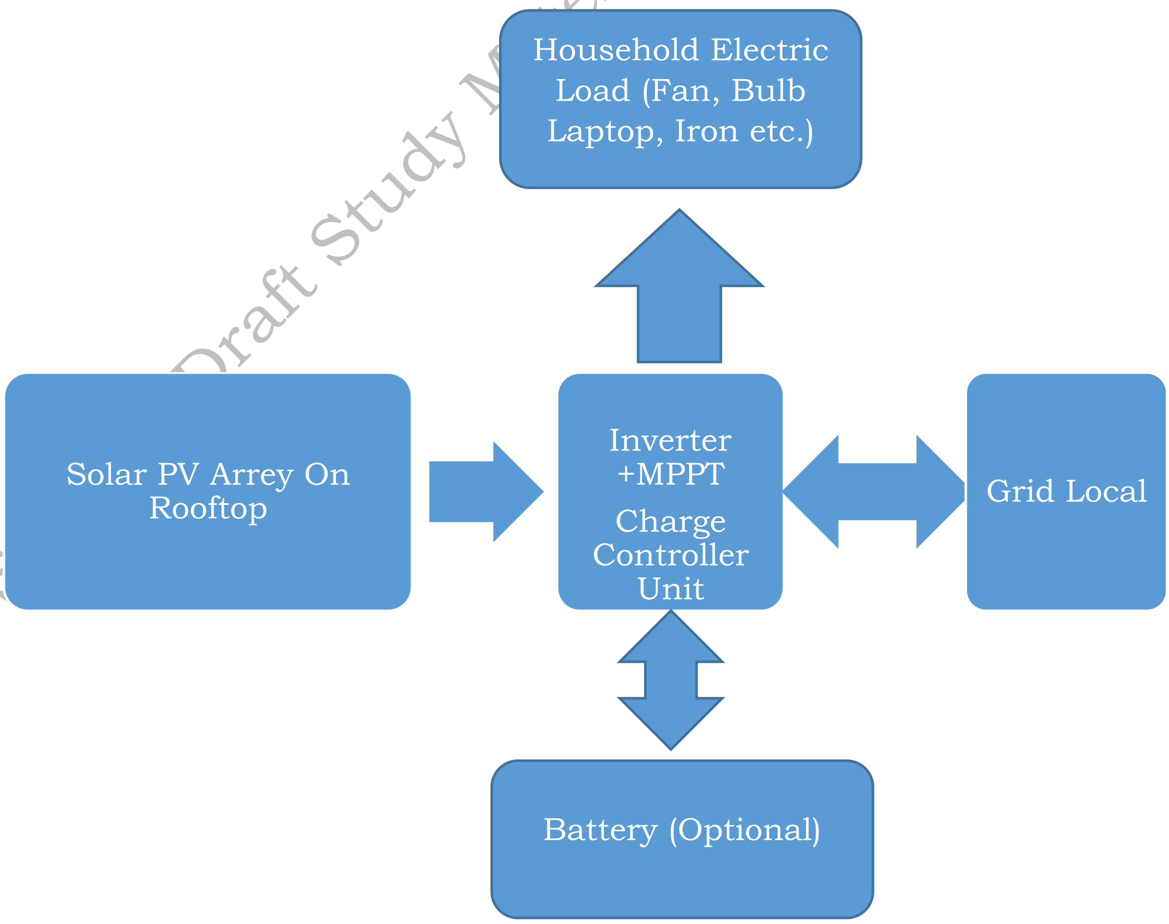


Fig.2.23 solar Power Conditioning Unit

Main Components of Power Conditioning Unit

Grid Charger:

It is an auxiliary charger in a Solar PCU. It charge's the battery from the grid when solar is not available. Different type of chargers is available in the market. Some inverters are even bi-directional and have the ability to charge the battery in the reverse direction from the grid.

Inverter: it is the heart of the solar PCU. This part is responsible for converting the DC voltage from the battery to AC power to the output. Different technologies exist for the inverter. In the transformer-based inverter, the dc-ac inversion happens at the low voltage of the battery, and then it is stepped up using a transformer. This technology is being replaced by High efficiency switched mode power supply (SMPS) based inverters around the world. The SMPS is used to transform the DC to high voltage DC and it is then inverted.

MPPT Charge Control: The sole purpose of the MPPT controller is to convert the solar energy collected by the photo voltaic panels to charge the battery. Convert the voltage of the solar panel to the battery level. Here the panel voltage is independent of the battery voltage level, the panels are operated at its peak power point. Hence utilization of the panel is maximized. This is used for larger systems and this is costlier than PWM (Pulse Width Modulation) type.

Battery: The battery stores the solar charge for use by the inverter. On a normal day, solar energy keeps varying depending on cloud formation, shadow and time of day, etc. The loads connected to the inverter will also be having its own variations in loading patterns. Hence it is very essential to have a battery backup to act as a buffer and for storage of electricity produced through solar.

Control Algorithm: This is the part that distinguishes a solar PCU from an ordinary inverter Plus solar charger. This is the part that controls the priority and optimally selects which is the source of charging solar or grid or both. It also selects the source of ac output to be either from the inverter or from the grid.

Some Indicators are available on the PCU for obtaining the system status at any given point in time.

- ON/OFF charging algorithm:
  Full current from PV at near full charge in the battery leads to overcharging and electrolyzing battery acid with loss of water
- charging algorithm:
  To avoid overcharging the battery, the current is tapered if the battery is close to full charge, the charge controller uses high-frequency solid state switches
- Constant Voltage charging algorithm:
  Current from PV is tapered when the battery is close to being fully charged The charge controller uses non-PWM methods
- Maximum Power Point Tracking:
  MPPT control and DC-DC conversion dynamically adjust the operating point of the PV array towards its maximum power point to improve battery-charging performance Constant

Session 4

CHECK YOUR PROGRESS

A. Multiple Choice Questions.

1. PCU Stands for

a. Power circulating Unit b. Power controlling Unit c. Power cloning unit d. Power Conditioning Unit.

2. Most Efficient Charge Controller

a. MPPT Charge Controller b. PWM Charge Controller c. Shunt Charge Controller d. None of these

3. Charge Controller Used for

a. For Battery charging b. for battery protection c. prevention from overcharging d. All of the above

Answers 1. D, 2. A, 3. D

B. Fill in the blanks.

1. MPPT Stands for ______________________.

2. PWM Stands for ______________________.

3. Charge Controller rate in ________________.

Answers 1. Maximum Power Point Tracker 2. Pulse width modulation 3. Ampere

C. Short Answers Questions.

1. What is PCU?

2. What is a Charge controller?

3. Types of charge Controllers?

4. Difference Between MPPT and PWM charge Controller?

D. Practical

Identify different types of charge controllers and practice their connections with batteries, solar panels, and inverters.

SESSION 5 - INVERTER

A solar inverter or PV inverter is a type of electrical converter which converts the variable direct current output of a photovoltaic solar panel into a utility frequency alternating current that can be fed into a commercial electrical grid or used by a local, off-grid electrical network. The solar inverter is an important interface between the solar PV module and load. It is depending on whether the battery used in the PV System is used or not. Solar power inverters have special functions adapted for use with photovoltaic arrays, including maximum power point tracking and anti-islanding protection.

Classification Solar inverter

TYPES OF INVERTERS

Stand-Alone Inverters or off-grid inverters: these types of inverters are not connected to the grid. It is used in isolated systems where the inverter draws its DC energy from batteries charged by photovoltaic arrays.

Grid interactive inverters or Grid-Tie Inverters: they have special circuitry to match inverter output voltage and frequency with that of the grid. Grid-tie inverters are designed to shut down automatically upon loss of utility supply, for safety reasons. They do not provide backup power during utility outages.

Battery Backup Grid Tie Inverters: it is special inverters that are designed to draw energy from a battery, manage the battery charge via an onboard charger, and export excess energy to the utility grid. These inverters are capable of supplying AC energy to selected loads during a utility outage and are required to have anti-islanding protection.

Intelligent hybrid inverters: manage photovoltaic array, battery storage, and utility grid, which are all coupled directly to the unit. These modern all-in-one systems are usually highly versatile and can be used for grid-tie, stand-alone or backup applications but their primary function is self-consumption with the use of storage.

Solar Micro-Inverters:

A solar micro-inverter is an inverter designed to operate with a single PV module. The micro-inverter converts the direct current output from each panel into alternating current.

CHECK YOUR PROGRESS

A. Multiple Choice Questions.

1. Inverter Converts

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

2. In the On grid system which type of inverter is used?

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

3. Full Form of VFD.

a. Various formula drive b. variable frequency drive c. Variable formula drive. d. None of these.

Answers 1. C,2. B,3. b

B. Fill in the blanks.

1. Anti-islanding feature is required for the ___________ inverters.

2. __________ Used to convert single phase DC to 3 Phase AC current.

3. Inverter Rate in __________.

Answer 1. Grid tie inverter, 2. VFD,3 KVA, or VA

C. Short Answers Questions.

1. Explain the Working of the inverter?

2. Types of inverters, explain them.

3. Specifications of different types of inverters?

4. Why inverter Rate in KVA not in KW explain?

D. Practical

Study of different types of inverters and their connections.

SESSION 6: Battery

Electric energy storage in the form of batteries may be required if there is no other supply. For storing electrical energy for nighttime applications and for when the electricity is more than the generation of electricity.

A "battery" consists of one or more voltaic cells (electrochemical cells) connected in series or parallel, and to provide a steady DC voltage at the battery's output terminals.

The chemical reactions in a battery produce a flow of electrons through an electric circuit, generating an electric current that can be used to power devices.

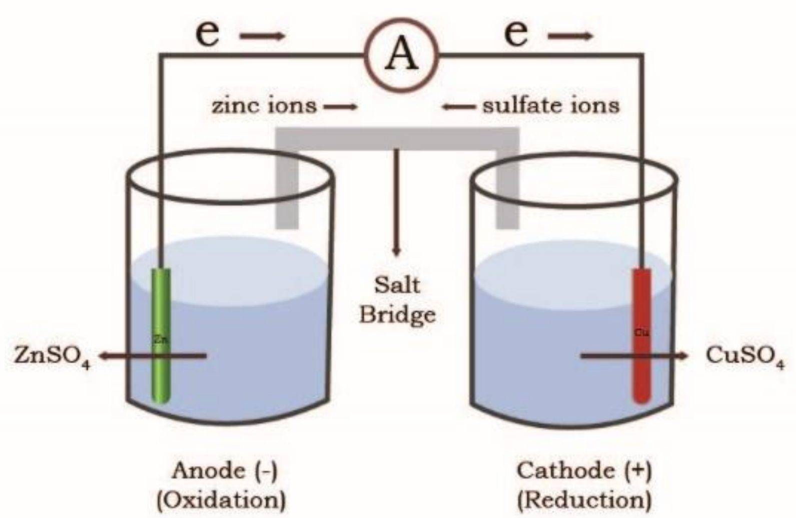


Fig. 2.24 A typical single unit of an electrochemical cell

Working of battery- a battery consists of two or more units of electrochemical cells (voltaic cells) connected in parallel or series. It is called an electrochemical cell because it deals with chemical or electrical energy. A single unit of an electrochemical cell consists of two half cells shown in the above fig. two half cells are electrically connected to each other by a salt bridge. The electrodes in the two half-cut cells are different metals. In each half-cut cell, a chemical reaction occurs at the metal electrode. The operation of the cells involves two chemical reactions.

a) Oxidation:

$$reducing\ \ agent \rightarrow product + e^{-}(loss\ of\ electron)$$

b) Reduction:

$$Oxidant +\ e^{-}\ \ \rightarrow product\ (gain\ of\ electron)$$

Both reactions takes place at the time of charging and discharging. While charging reaction takes place negative terminal at the negative terminal (cathode)and reduction takes place at the positive terminal (anode) during discharging

COMPONENTS OF BATTERY:

I. Anode: anode, the terminal or electrode from which electrons leave a system. In a battery or other source of direct current, the anode is the negative terminal, but in a passive load, it is the positive terminal.

II. Cathode: cathode, negative terminal or electrode through which electrons enter a direct current load, such as an electrolytic cell or an electron tube, and the positive

III. Electrolyte: An electrolyte is a substance that conducts electricity when dissolved in water.

IV. Salt Bridge: A salt bridge is a device used in an electrochemical cell for connecting its oxidation and reduction half cells wherein a weak electrolyte is used. In other words, a salt bridge is a junction that connects the anodic and cathodic compartments in a cell or electrolytic solution. The main function of a salt bridge is to help maintain electrical neutrality within the internal circuit.

Battery performance can be evaluated along several different metrics:

- **Battery Terminal Voltage (Volts)** is the difference in electric potential between cathode and anode. Which is practical terms being the driving force with which electrons are transported through the circuit.
- **Current (amperes)** is the amount of electric charge (directly proportional to the number of electrons) per unit of time flowing through the external circuit.
- **Power (watts)** is the product of the voltage and current, the rate at which electrical energy can be discharged.

$$Battery\ Power\ (Watt) = Terminal\ Voltage(V) \times Current\ Drawn(A)$$

- **Capacity (ampere-hours)** is the amount of stored charge that is usable during battery operation. It impacts the time over which a battery can deliver a steady supply of power and is used to evaluate the length of time a battery can keep a device running.

$$capacity(C) = Current\ (A) \times Hour(h)$$

- **Batteries lose** their cycling capacity over time due to self-discharge, which is when local electrochemical reactions unrelated to generating electricity in the external circuit occur in the battery cell. These local electrochemical reactions reduce the potential difference across the electrodes, resulting in the less driving force for the flow of electrons during battery operation. It can also result in a depletion of the usable capacity of the battery over time.
- **Volumetric energy density** is the amount of energy measured in Watt-hours per unit of volume measured in litters. The higher the volumetric energy density, the smaller a battery needs to be for the same given total amount of energy.
- **Specific energy density** is the amount of energy per unit of weight measured in kilograms, meaning that the higher the specific energy the lighter the battery.

- **Cycle life** is the number of times a battery can be charged and discharged before it fails to meet its defined requirements, for example, having at least 80% of the original discharge capacity.
- **The charge rate** is the speed with which a battery is charged relative to the battery's capacity.

State of Charge and Depth of Discharge

State of Charge (SoC), is used to describe the percentage of the battery's full charge.

In practical application, all the charges stored in the battery cannot be used for running load only some percentage of the total charge stored can be used.

The percentage of total charge that can be used for connected load is referred to as the depth of discharge (DoD).

State of Charge (SOC) describes the level of charge of an electrical battery, in relation to the battery's full capacity. SOC is a percentage so it is having no unit and is expressed in the range from 0% to 100%. Depth of discharge (DOD) is a different form used to express the level of charge, as DOD is the inverse of SOC (100% DOD means empty; while 0% means fully charged). SOC is mainly used while discussing the battery's current state, while DOD is used more when discussing battery's lifetime after repeated use.

$$\boldsymbol{SOC}\,(\%) = \mathbf{100\%} - \boldsymbol{DOD}(\%)$$

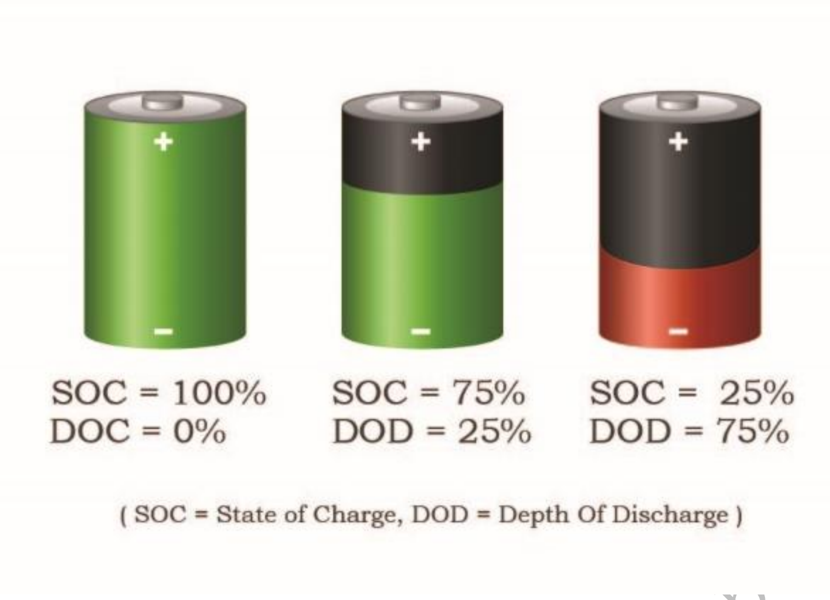


Fig. 2.25 State of Charge and Depth of Discharge

Charging Rate/ Discharging Rate or /C-Rating of battery

The charge and discharge rates of a battery are represented by C-rates. The capacity of a battery is commonly rated at 1C, meaning that a fully charged battery rated at 1Ah should provide 1A for one hour. The same battery discharging at 0.5C should provide 500mA for two hours, and at 2C it delivers 2A for 30 minutes. Losses at fast discharges reduce the discharge time and these losses also affect charge times.

$$C-rating \ = \frac{Capacity(Ah)}{No.of\ hour\ \ for\ full\ discharge\ or\ charge\ (t)}$$

A C-rate of 1C is also known as a one-hour discharge; 0.5C or C/2 is a two-hour discharge and 0.2C or C/5 is a 5-hour discharge. Some high-performance batteries can be charged and discharged above 1C with moderate stress. Table 1 illustrates typical times at various C-rates.

***Example**: The capacity of a battery is 100Ah. determined the C-rating of the battery for 1,2,5,10,20,40,50 and 100 hours of charging?*

Solution: *C-rating calculated in the table using the formula*

$$C-rating \ = \frac{Capacity(Ah)}{No.of\ hour\ \ for\ full\ discharge\ or\ charge\ (t)}$$

Table no.3.2 calculating the c rating using the above formula

Battery Capacity (Ah)	No. Of Hour of Charging (t)	Current Required (A)	C-Rating
100	1	100/1= 100	C
100	2	100/2= 50	C/2
100	5	100/5= 20	C/5
100	10	100/10= 10	C/10
100	20	100/20= 5	C/20
100	40	100/40= 2.5	C/40
100	50	100/50= 2	C/50
100	100	100/100= 1	C/100

In the market, many types of batteries are used while designing of solar PV systems comprises batteries, one of the problems often faced is a proper choice of battery from many available batteries. This problem can be simplified by making a list of minimum requirements, conditions, and limitations. The typical rechargeable batteries tabulated in table no….. the lead acid battery performs very well, all factors (factors like cost, availability, temperature, cycle, charge-discharge cycle) make lead acid batteries a good choice for PV Applications.

Table no.3.4 Typical Value of a Rechargeable Cell

Battery Type	**Voltage Per Cell (Volts)**	**Efficiency Charge/Discharge %**	**Self-Discharge %/Month**	**Cycles (Number)**	**Life (Year)**	**Voltage Per Cell (Volts)**
Lead Acid	2.1	70-92	3-5	<800	3-4	2
Nicad (Nikil Cadmium)	1.2	70-92	20	1500	3-5	1.2
Nickel Metal Hydride	1.2	60-70	30	500-1000	2-4	3.7
Lithium Ion	3.6	80-90	5-12	1200	3-4	3.7
Lithium Ion Polymer	3.7	80-90	5-10	500-1000	2-4	3.3

CHECK YOUR PROGRESS

A. Multiple choice Question.

1. Battery is a.__________

a. Storage Device b. Charging Device c. converter d. None of these

2. Battery Should be kept in which area.

a. in Ventilated area b. dust-free area c. moisture-free area d. All of the above

3. DOD stands for_______

a. Dead of discharge b. depth of discharge c. state of charge d. none of these

4. Battery used in the solar PV system.

a. Lithium-ion Battery b. Zinc Battery c. lead acid Battery d. Nickle ion Battery

Answer 1.a,2. d,3. b,4.c

B. Fill in the blanks

1. Convert stored _____________ into electrical energy.

2. SOC Stands for _______________.

3. Battery rates in ________________.

4. Life of a lead acid battery ____________years.

Answer 1. Chemical Energy,2. State of charge,3. Ampere hour,4. 5 years

C. Short answers Questions.

1. what is Battery?

2. Write the Battery types and their characteristics advantages and disadvantages.

3. What are DOD and SOC?

4. Working Principle of battery.

D. Practical Exercise

Battery maintenance and visual inspection and measurement of their electrical parameter.

SESSION 7 CABLE CONNECTIONS

7.1 Cables and Wires:

In a solar PV system, Cables and wires are used for electricity supply from one place to another and also connect different components of the system.

Cable- A cable is, generally, two or more wires running together or bonded, twisted, or braided together. They are mostly insulated to offer better protection than just wires. Cables are largely employed in power transmission, and to carry electricity and telecommunications signals. There are many types of cables, such as twisted pair cable, coaxial cable, multi-conductor cable, and fiber optic cable.

Wire- A wire is a single conductor strand or a group of conductor strands, sheathed in a jacket of insulation to prevent the conductors from making unwanted contacts. Wires are generally used to carry electricity and telecommunications signals.

Table no. 3.5 **Difference between Wires and Cables**

Difference between Wires and Cables		
	Wires	**Cables**
Classification	Single conductor	Two or more conductors
Uses	To allow mechanical loads, to carry electricity and telecommunications signals. Also used in heating, jewelry, clothing, mesh, automotive or industrial manufactured parts, pins, needles, fish hooks, and bulbs.	To allow power transmission, to carry electricity and telecommunications signals.
Types	1. Solid wire 2. Stranded wires	1. Twisted pair cable 2. Multi conductor cable 3. Coaxial cable

		4. Fiber optic cable
Advantages	Solid wires offer low resistance, thus, perfect for use in higher frequencies. Stranded wire shows higher resistance to metal fatigue.	Higher strength, heavy-duty, and insulated.

Cable and Wires Selection Would be based on the Conductivity of wires, in the solar system, we use copper wires for connection because they have less resistance as compared to other metal wires. The two common conductor materials used in residential and commercial solar installations are copper and aluminum. Copper has a greater conductivity than aluminum, thus it carries more current than aluminum at the same size.

Types of wire

1. Single-stranded
2. Multi- stranded
3. Single-core
4. Multi-core

Fig. 2.26 Wire

Fig. 2.27 Cable

Single Core Wires are less used in Solar PV systems if there is any crack in the core of the wire the possibility of disconnection is more.

Multicore Wires are mostly used in solar PV Systems as they have multiple cores of wire so there is less possibility of disconnection and the connection will be long-lasting also.

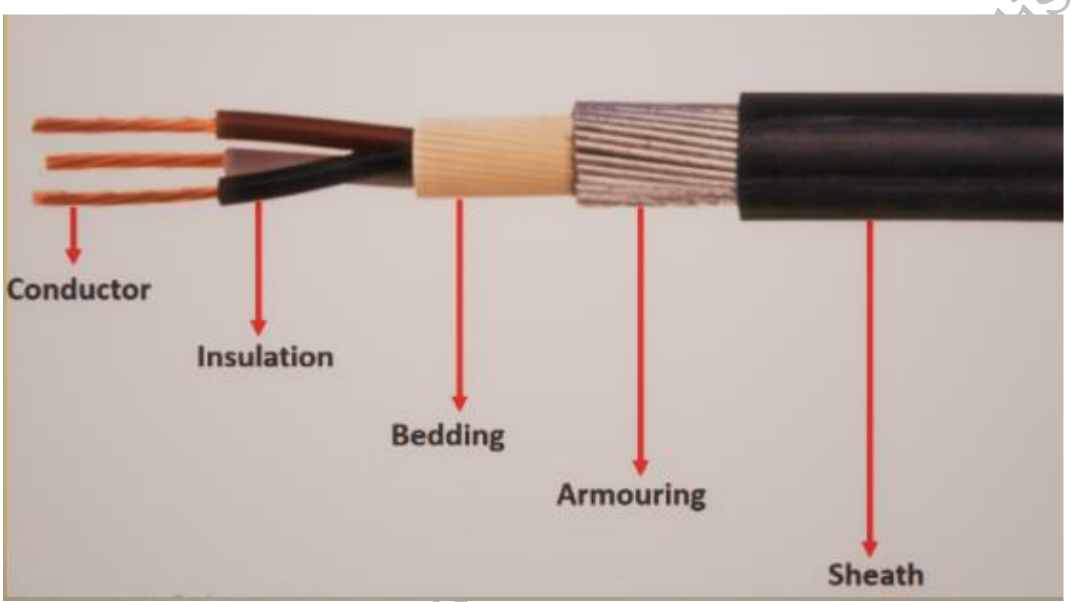


Fig.2.28 Construction of the cable

In a solar PV System two types of cables and Wires are used:

DC Wires: The DC wire is used in places where self-generation of power takes place like solar panels or batteries. The DC wires are mostly double insulated because it is mostly used for outdoor applications. The current carrying capability of the DC cable is better than the AC cable.

This type of cable is thick as DC current has to flow through it,2.5Amp current flow through the diameter of 1sq. mm, wire approx.

AC Wires: Electrical wires used for domestic as well as industrial purposes are known as AC wires. These wires are used in AC current equipment, 5-amp current flows through 1 sq. mm wire approx.

The AC cables will be single insulated while the DC cables are double insulated. The copper wire in the DC wire is the tinned copper wire which is to protect the wire from rust and other environmental hazards. The thickness of the DC cable strands will be smaller than the AC cables.

As we all know that Solar PV system generates power from the sun so the wire which we are using in the solar PV system should be insulated and protected from ultraviolet rays as well as weather.

Distribution Box:

A distribution board (also known as panel board, breaker panel, electric panel, DB board, or DB box) is a component of an electricity supply system that divides an electrical power feed into subsidiary circuits while providing a protective fuse or circuit breaker for each circuit in a common enclosure. Normally, the main switch, and in recent boards, one or more residual-current devices (RCDs) or residual current breakers with overcurrent protection (RCBOs) are also incorporated. generally, AC Distribution and DC distribution boxes are used in solar PV system

DC Distribution Box (DCDB): DC Distribution box is used to distribute the DC cable to the inverter two-pole DC disconnect switch is used to isolate the PC array from the inverter. It is a parallel combination of DC MCB, DC SPD, and inverter (I/P) and it is used to Switch off/on any emergency/service.

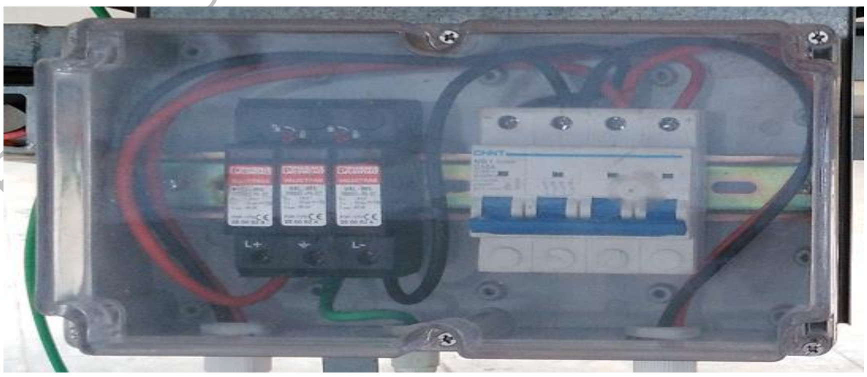


Fig. 2.29 DC Distribution Box

AC Distribution Box (ACDB):

The ACDB receives AC power from the solar inverter and directs it to AC loads / LT panels. ACDB is an important part of the SPV system as it provides extra protection to the system in case of failures on the load side. A provision can also be made in ACDB to monitor the consumption of power from SPV Power Plant. It is a parallel combination of AC MCB, AC SPD, and inverter(O/P) and it is used to Switch off/on any emergency/service.

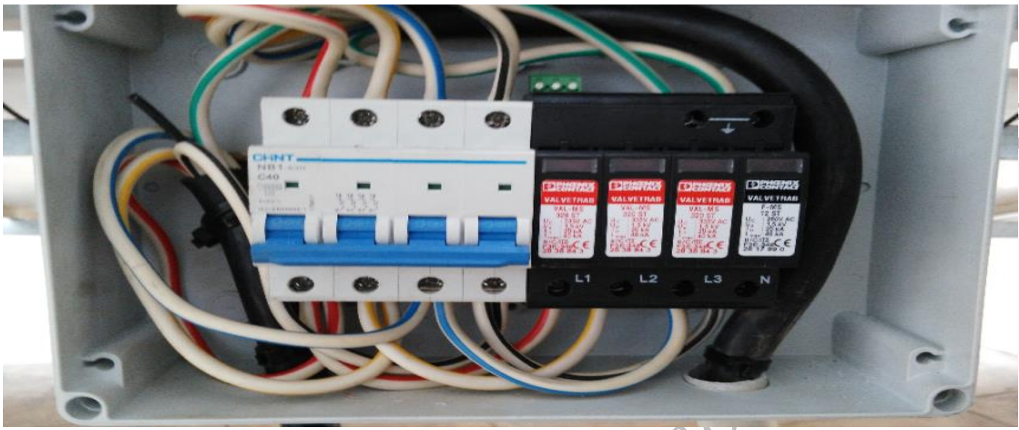


Fig. 2.30 AC Distribution Box

MCB (Miniature Circuit Breakers): The MCB is an electromechanical device that switches off the circuit automatically if an abnormality is detected. The MCB easily senses the overcurrent caused by the short circuit.

Fig.2.31 MCB

SPD (Surge Protective Devices):

Surge Protective Devices (SPD) are used to protect the electrical installation, which consists of the consumer unit, wiring, and accessories, from electrical power surges known as transient overvoltages.

They are also used to protect sensitive electronic equipment connected to the installation, such as computers, televisions, washing machines, and safety circuits, such as fire detection systems and emergency lighting. Equipment with sensitive electronic circuitry can be vulnerable to damage by transient overvoltages.

The effects of a surge can result in either instant failure or damage to the equipment only evident over a longer period. SPDs are usually installed within the consumer unit to protect the electrical installation but different types of SPD are available to protect the installation from other incoming services, such as telephone lines and cable TV. It is important to remember that protecting the electrical installation alone and not the other services could leave another route for transient voltages to enter the installation.

Fig. 2.32 Surge Protective Devices

FUSE: for Protection is by using fuses or circuit breakers. Fuses and circuit breakers are used to protect the wiring from getting too hot and also protect all devices connected to the system from catching fire or getting damaged if a short circuit occurs. They are not necessary for the system to run properly, but we always recommend using fuses or circuit breakers for safety purposes.

IP (INGRESS PROTECTION RATING):

Ingress Protection rating (or just IP rating), is an international standard (IEC 60529) used to rate the degree of protection or sealing effectiveness in electrical enclosures against the intrusion of objects, water, dust, or accidental contact. It corresponds to the European standard EN 60529.

The IP code always consists of the letters IP (Ingress Protection) followed by two digits and an optional letter. The two digits and the last letter indicate the classified protection below.

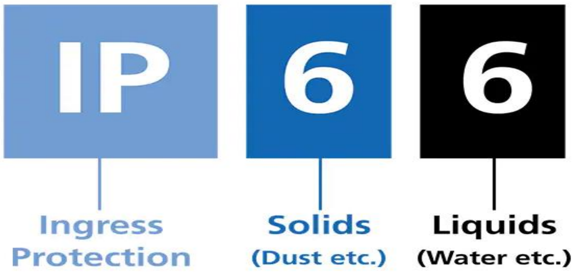


Fig. 2.33 IP Code

First digit: Solids protection

The first digit following the IP indicates the level of protection of enclosed equipment against ingress of solid foreign objects, and against people accessing hazardous parts such as electric conductors.

Second digit: Liquids protection

The second digit following IP in the code rating shows the level of equipment protection inside the enclosure against water ingress.

Conduits: Conduits are nothing but a cover or pipe for the protection of wires. An electrical conduit is a tube used to protect and route electrical wiring in a building or structure. Electrical conduits may be made of metal, plastic, fiber, or fired clay. Most conduit is rigid, but flexible conduit is used for some purposes.

Conduit is generally installed by electricians at the site of installation of electrical equipment. Its use, form, and installation details are often specified by wiring regulations.

Plastic Conduits

Metal Conduit

Fig. 2.34 Plastic Conduits and Metal Conduits

Conduit Glands: Conduit glands are ideally suited for use where many wires are to be passed through a single panel port or System.

Fig. 2.35: Conduit Glands

Lugs: Lugs are used with proper wire connection and by using this there is less possibility of leak current.

Aluminum lugs copper lugs

Fig. 2.36: Aluminum lugs and copper lugs

Conduits Clip: A conduit clip can be used anywhere that a surface-mounted conduit. Apply for fixing the conduits, with screw on the bottom to fix on wall or ceil, Applicable for joint together for multiple conduits, U type is easy to clip and unfasten.

Cable Tie: a fastener consisting of a thin, flexible nylon strap with a notched surface, one end of which is threaded through a locking mechanism at the other.

Fig. 2.37: Cable Tie

MC4 Connector: Multi-contact 4 or MC4 connectors are used to connect solar PV panels.

Fig.2.38: MC4 Connector

CHECK YOUR PROGRESS

A. Multiple Choice Question

1. Which type of wire is used in a solar PV system?

a. Copper wire multi core b. copper single core c. Aluminium wire d. steel wire

2. MC4 Connectors used in

a. Solar PV system b. home wiring c. pump connection d. batter connections.

3. SPD Stands for__________

a. surge protection device b. safety protection device c. safety precaution device

answers 1. a,2. a,3. a

B. Fill in the Blanks

1.MCB Stands for_____________.

2.MCB and SPD Rate in __________.

3.MC4 Stands for_____________.

Answer 1. Miniature circuit breaker 2. Ampere 3. Multi-Contact 4

C. Short Answers Questions.

1. applications of wire and conduits.

2. Explain MC4 Connectors

3. Explain MCB and SPD and their importance.

4. Uses of the lug and other accessories?

D. Practical Exercise

Identify different types of wires, connectors, and accessories

SESSION 8: Earthling System and Its Types

Earthing system in an electrical circuit is for safety purposes. The earthing system provides an alternative path for high and dangerous currents to flow to the earth so that the problem of electric shock and damage to equipment does not occur. The metallic connection between electrical machines and devices with the earth plate, commonly known as the earth electrode, through a thick wire of low resistance to provide safety is known as earthing. Metallic parts of the equipment are earthed and if the equipment's insulation fails there will be a dangerous current present on the surface of the equipment. This may cause a short circuit and the fuse will blow off immediately

Earthing

Earthing means the connection of non-current carrying parts (metallic parts) of electrical apparatus to the earth to discharge electrical energy without any danger. Earthing is done by connecting the appliance or machinery to the earth by a good conductor known as an earth electrode. Earthing is done to save human life from the danger of electrical shock, in case a human body comes in contact with a live wire. If earthing is done correctly and the metallic part comes in contact with a live wire, it will be discharged into the earth. In this condition, due to zero potential of the earth, a large amount of the current flows to the earth. If the current exceeds the limiting value of the fuse, it blows off, or the MCB trips and cuts off the supply from the appliance.

8.1.1 Application:

In Substations for safety purposes.

In residential homes for the safety of equipment and protection from shock.

In Industries for protection from any Electrical Hazards.

In Solar inverter and System.

8.1.2 Procedure and Components used:

Grounding or earthing is done because of protection from damages, in earthing or grounding a pit of around 4-5 feet is dug and the component used is mentioned Below:

- a grounding plate,
- ground joint
- grounding wires.

Different Terms used in Electrical Earthing

(a) **Earthing**: The proper electrical contact between electrical installation and the earth is known as earthing.

(b) **Earthed:** When an electrical machine, appliance, or wiring is connected to the earth through an earth electrode, it is known as earthed.

(c) **Earth electrode:** A pipe or plate buried in the earth for the discharge of electricity is known as an earth electrode.

(d) **Earthing lead:** The conducting wire or conductive strip connected between the earth electrode and electrical installation and machine is called the earthing lead.

(e) **Earthing resistance:** This is the resistance between the earth electrode and the earth in ohms.

8.1.3 Types of Earthing:

1. **Rod Earthing**: In this Grounding or earthing system a rod is used for grounding. In this type of earthing system 12.5 mm diameter of a solid rod of copper or, 16 mm diameter of a solid rod of galvanised iron are fitted vertically into the earth not less than 2.5 meters on the earth's surface.

Fig. 3.44 Rod Earthing

2. **Pipe Earthing:** In this Method Instead of a plate or rod pipe is used for grounding, this is depending upon soil quality a condition. It is cheaper and the best form of earthing. In this type of earthing a hollow pipe of 38 mm diameter and 2.5-meter-long GI is placed underground and covered with charcoal and salt.

Fig. 3.45 Pipe Earthing

3. **Plate Earthing**: This is the most common method of Grounding and a metal plate is used for grounding. In this type of earthing system, a plate of either copper with dimensions 60cm×60cm×3.18mm or galvanised iron (GI) of dimensions 60cm×60cm×6.35mm is buried vertical in the earth pit which should not be less than 3 meters from the surface of the ground.

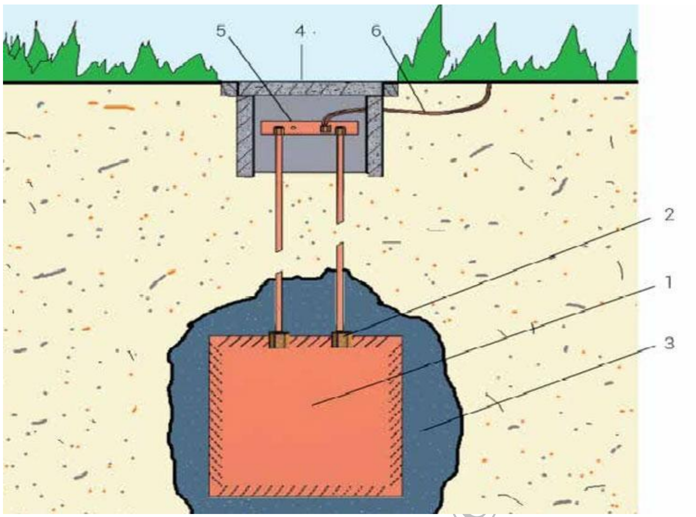


Fig. 3.46 Plate Earthing

3. **Chemical Earthing:** This is the modern era Earthing technique used by technicians now a day where instead of coal salt etc. chemicals are used in earthing or Grounding Processes.

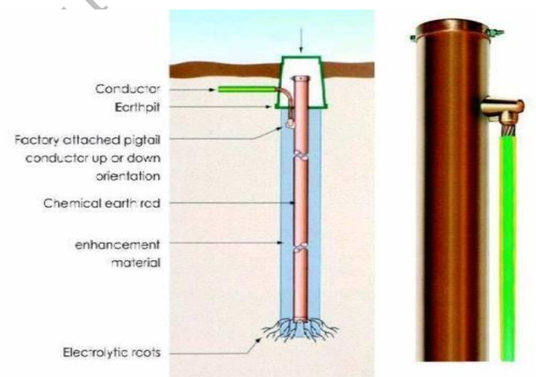


Fig. 3.47 Chemical Earthing

8.2 Lighten Arrestor – Lightning generates voltage surges in different ways and they directly hit on your house. It can strike the wiring of the circuit within the walls of the house. Lightning can hit an object close to your home to cause a surge like the ground or a tree. So it plays an important role to protect the electrical devices and traction installation from surges. The proper protection for this device is very necessary to check the normal power supply.

The principle of the lightning arrester was first discovered by Benjamin Franklin in 1749, who in the subsequent years developed his invention for household application.

8.2.1 What is Lightning Arrester?

Definition: The circuit which is protected from the strokes of lightning with the help of a protection device is known as a lightning arrester. Here the lightning strikes are nothing but surges with high transient voltage, arcs of isolation, spark, and surge currents because of lightning, etc. These devices are used to protect the power systems by forwarding the high voltage surges in the direction of the ground.

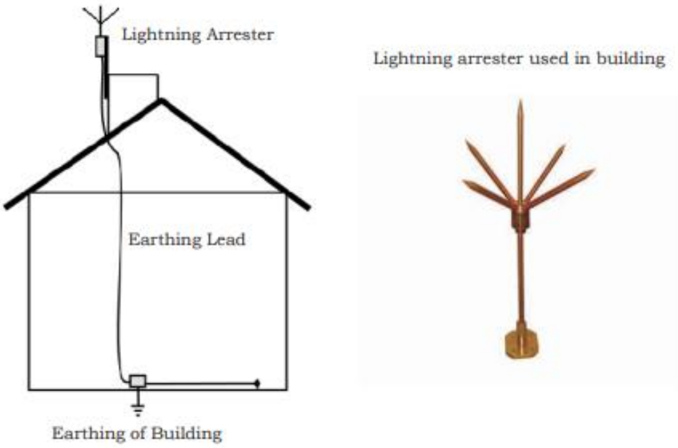


Fig. 3.48 Lightning Arrester

8.2.3 Working Principle

The lightning arrestor working principle is, that once the voltage surge travels throughout the conductor then it reaches the location of the arrestor where it is installed. So it will break down the insulation of the lightning arrestor for a moment, so voltage surge can be discharged toward the ground. Once the voltage of the system falls under the fixed value, then the insulation will be restored among the ground & conductor. Further, the current flow toward the ground will be stopped.

8.2.4 Types of Lightening Arrestor

Horn Gap Arresters

As per the name, this arrestor has two metal rods in horn-shaped. The arrangement of these metal rods can be done around a small air gap.

Multi-Gap Arresters

These types of arresters are designed with a sequence of metal cylinders that are insulated and divided through air gaps with each other. In the sequence of cylinders, the primary cylinder is connected to the electrical line, whereas the remaining cylinders are connected to the ground by series resistance.

Valve-Type Arresters

These kinds of arresters are applicable to electrical systems that are high-powered. These devices include two main parts like a sequence of spark gaps as well as a series of non-linear resistor discs.

Pellet-Type Arresters

The designing of these arresters can be done with glass tubes that are filled with lead pellets. These are finished from an inside of lead peroxide coated through the lead oxide

8.4.5

Advantages:

The advantages of a lightning arrestor are:

- Property damage can be reduced from strokes of lighting.
- Outdoor equipment of the substation can be protected
- Avoid damage to lines
- Outlet surges can be avoided
- Electromagnetic interference
- Simple to use

Disadvantages: The **disadvantages of lightning arrestors** are

- It occupies more space

- The installation cost is high.

CHECK YOUR PROGRESS

A. Multiple Choice Question

1. Effect on earth soil resistance when moisture Content in the soil.

a. increase b. Decrease c. do not affect d.none of the above

2. Grounding is provided for.

a. for equipment safety b. Personnel safety c. Both A and B d.none of the above

3. Earth wire or ground wire made up of

a. copper b. aluminium c. iron d. Galvanized steel

4. Which of the following is the protective device against lightning overvoltages?

a. Rod gaps b. Surge absorbers c. Horn gaps d. All of the above

Answer 1.b, 2.c, 3.d, 4.d

B. Fill in the Blanks

1. Distance between two earthing pits would be _____________.
2. Device protects from strokes of lightening is called _____________.
3. Lightening Arrestor installed on _______________.

Answer 1. 3 Meters, 2. Lightening Arrestor, 3. Roof.

C. Short Answers Questions

1. What is earthing and its types?

2. What is Lightening Arrestor, advantages and disadvantages?
3. Types of lightning Arrestors.
4. Working Principle of Earthing and lightening Arrestor.

D. Practical Exercise

Identify components used in ground and installation of lightening arrestor, installation of earthing, and lightening Arrestor.

Module 3	Tools for Solar PV systems Installations

Module Overview

This module a brief guide to the essential tools required for the installation of Solar PV systems. Students will become familiar with the specialized tools and equipment needed to ensure safe, efficient, and effective installation practices. Key topics include: Basic Electrical Tools like Multimeter, Wire Strippers and Crimpers, Screwdrivers and Pliers. Safety Equipment Insulated Gloves and Safety Goggles Harnesses and Ladders, Measurement and Alignment Tools, Solar Pathfinders, Inclinometers, Tape Measures Compass and GPS Devices.

This module equips students with the knowledge of the essential tools required to install solar PV systems, ensuring they are prepared to work efficiently and safely in the field.

Learning Outcomes

- Identify and describe the various mechanical tool
- Identify and describe the various electrical tool
- Describe the various safety tool
- Identify and use the different marking tool
- Identify and use the civil tool used in the solar system
- Describe the different electrical parameters

Module Structure

Session 1: Mechanical and General tools

Session 2: Electrical, Safety, Marking and Civil Tools

Session 3: Electrical Parameters and Solar PV System

MODULE 3: 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 specialized 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.

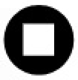
SESSION 1: MECHANICAL AND GENERAL TOOLS

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 3.1 Screwdriver

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

Table no.3.1 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.3.2 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 3.3 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 3.4 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.

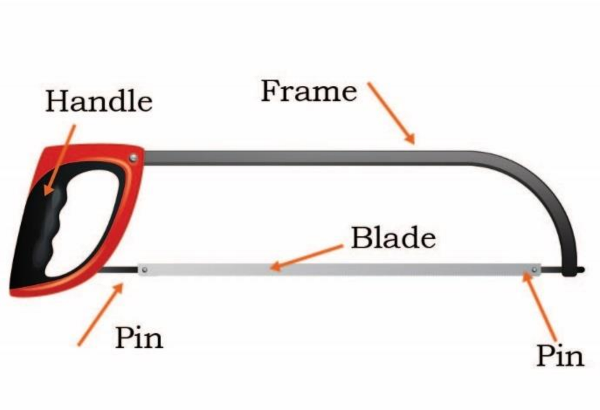


Fig 3.5: Hacksaw

(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 3.6 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.3.7: 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.3.8: 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.

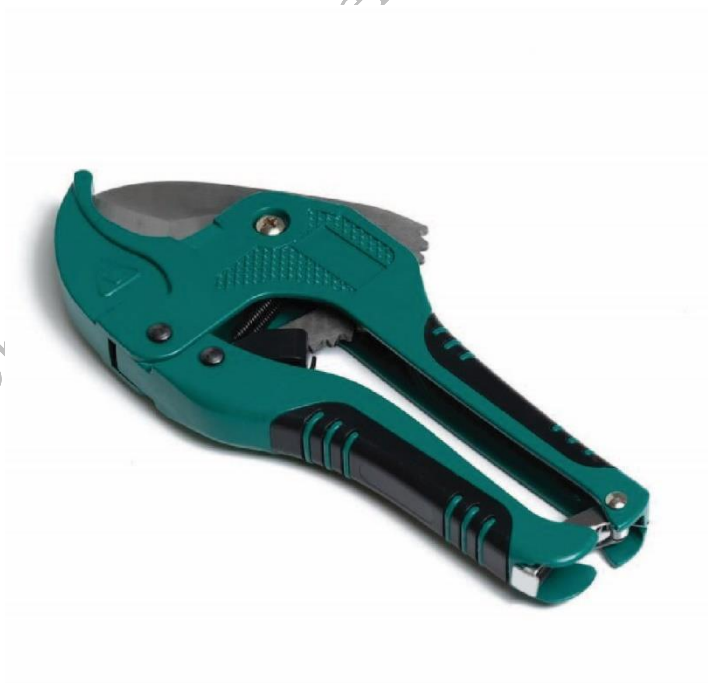


Fig.3.9 Pipe cutter

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.3.10: 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.3.11 Pliers

l) Crimping tool

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

Fig.3.12 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.3.13 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.3.14 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.

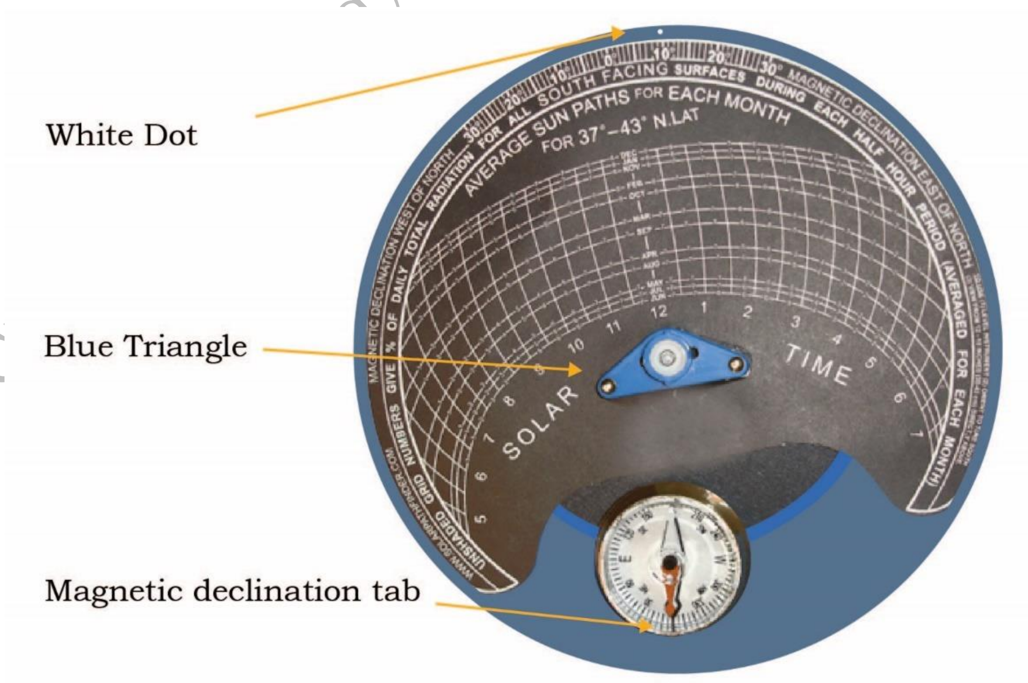


Fig. 3.15 Sun path Finder

SESSION -1

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. **Tough steel**
2. Electrical ....offer faster operation and comfort to operators. **Screwdrivers**
3. A .... is a tool that delivers a blow to an object. **Hammer**
4. A hacksaw is a..........., originally and principally for cutting metal. **fine-toothed saw**
5. Try-square implement used to check and mark right angles in .... work. **solar installation**
6. A.......... is a tool used to "nip" or pull-out small amounts of a hard material? **Nipper**
7. A gimlet is a hand tool for ...., mainly in wood, without splitting. **drilling small holes**

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.3.16 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.3.17 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.3.18 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/m²) from the hemispherical (1800) view. The instrument measures global (direct +diffuse) solar radiation within a wavelength range of 0.3 µm to 3 µm.

Fig.3.19 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.3.20 Solar Power Meter

(f) Pyrheliometer A pyrheliometer measures the direct component of solar irradiance, which is important when installing concentrating collectors.

Fig.3.21 Pyrheliometer

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

Fig. 3.22 Clamp Meter

SAFETY TOOLS FOR SOLAR INSTALLATION

Safety & Protective Equipment:

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
- Electrocution 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. 3.2 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. 3.23 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.

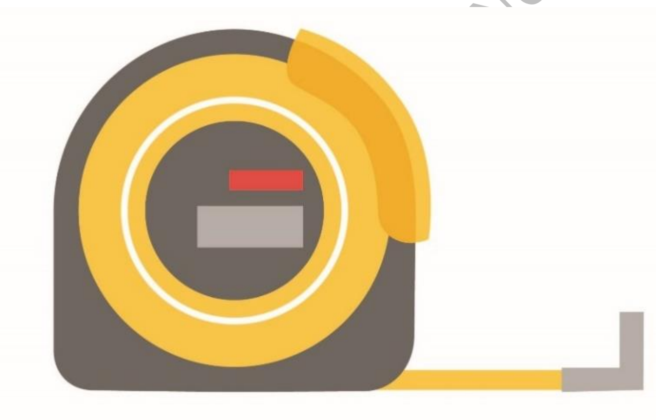


Fig. 3.24 Measuring Tape

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. 3.25: 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. 3.26: Plumb bob

d. Try Square: An implement used to check and mark right angles in solar installation work.

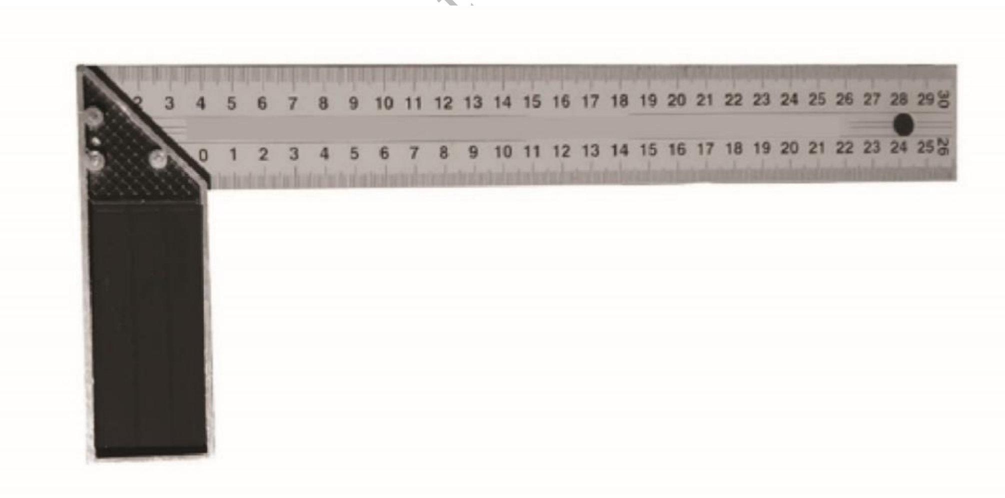


Fig. 3.27: Try Square

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.3.28 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.3.29 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.3.30 Pickaxe

(b) Spud

It is made of iron pointed at one side for making holes in the soil.

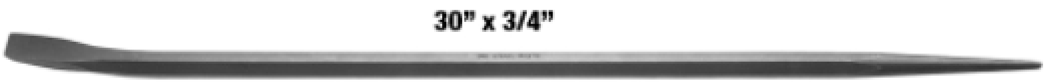


Fig.3.31 Spud

(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.3.31: 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 3.32: 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. 3.33: Tractor post hole digger

f. Crowbar

It is a hand tool used to pull two objects apart.

Fig.3.34 Crowbar

SESSION 2 Electrical, Safety, Marking, And Civil Tools

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.

SESSION 2

Check your progress

A. Fill in the blank

1................. uses a micro-ammeter with a moving pointer to display readings. **Analog Multimeter**

2. All the equipment of the power system is connected to the earth through the .... **earth electrode**

3. The resistance of the earth is............. **Very low**

4. Electrical resistance tester instrument is used for an........... **insulation resistance (IR) test**

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 c. Analog

2. Handheld portable Solar power meters are also used as.

a. Pyranometer b. Multimeter c. Rotameter c. Electrometer

3. A pyrheliometer 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. Match the columns

1. Crowbar	Marking Tool
2. Solar Compass:	Pull Two Objects Apart
3. Clamp Meter	Measure the Current
4. Center punch	Navigational Instrument

D. 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.

SESSION 3 ELECTRICAL PARAMETERS AND SOLAR PV SYSTEM

We use electricity in our daily life without electricity it is very difficult to live. so we need to know some electrical parameters. As a solar pump technician, one should know all parameters/terminology related to electricity.

Electrical Parameters of Electricity

Electricity is the Flow of Electrons. Electricity uses in our daily life but many of us do not know its basic terms and people find it difficult to learn about electricity main terms of electricity are as follows-

Current (I)

The flow of electrons (amount of charge) through a wire is called current. The SI unit of current is Ampere (A).

$$current(I) = \frac{charge(Q)}{time(t)}$$

1 Ampere means 10^{18} electrons flow in one second in a wire

Voltage (V)

The pressure that pushes the charge (electrons) in a wire is called voltage. Voltage is measured in volts. in our home's electrical circuit, we get a voltage level of 230 volts. In practice, we deal with a wide range of voltage levels; from very small to very large voltage level.

Electrical Earthling

The process of transferring the immediate discharge of electrical energy directly to the earth by the help of the low-resistance wire is known as an electrical earthling. The electrical earthling is done by connecting the non-current carrying part of the equipment or neutral of the supply system to the ground.

Resistance(R) Resistance is a measure of the oppose to current flow in an electrical circuit. Resistance is measured in ohms, symbolized by the Greek letter omega (Ω).

$$Voltage(Volt) = resistance\ (ohms) \times current(ampere)$$

$$V = R \times I$$

Electric Power (P)

The capability to do work in a particular way is called power. Electric power is the rate, per unit time at which electrical energy is transferred by an electric circuit. The SI unit of power is joule/second or watt.

$$\textbf{Electric Power}(\textbf{watt}) = \textbf{voltage}(\textbf{volt}) \times \textbf{current}(\textbf{ampere})$$

$$\mathbf{1\ watt} = \frac{\mathbf{1\ joule}}{\mathbf{1\ second}}$$

For example: for a 100-watt bulb, a voltage of 230 volts is applied. What is the value of current?

Solution: $Electric\ Power(watt) = voltage(volt) \times current(ampere)$

$$Current = electric\ power/\ voltage$$

$$Current = 100\ watt/\ 230\ volt$$

$$Current\ (I) =$$

$0.4347\ ampere$ ***Ans.***

Energy

The ability to do work for an object is called energy. The unit of energy is the joule. Where

$1\ joule = 1kg - m^2/\text{sec}^2$

For example: Two bulbs one of 50 watts and the other is of 100 watts, and both of them are used for 5 hours which one consumes more energy?

Solution: In this case, both bulbs consume energy time is the same the bulb with high power will consume more energy because it (100w bulb) provides more light, which means that it more power consumes.

We can see that the amount of electrical energy consumed by an electrical appliance depends upon two factors

I. Power of appliance:

The power of electrical appliances is given in terms of a watt.

II. Duration of usage:

The duration of usage can be given in terms of the hour.

So,

Electrical Energy= Power × Duration Of Usage

$$Energy\ (E) = \ Power(Watt) \times Time\ (hour)$$

$$Energy\ (Wh) = \ P(Watt) \times T\ (hour)$$

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

So, electricity is the product of power and time. The unit of electrical energy is watt-hour.

Example: An Energy of 150 Watt-hour is consumed in 1 hour what is the consumed power?

Solution: given in question energy E= 150 Wh

$$we\ know\ that\ Energy\ (E) = \ Power(W) \times Time\ (hour)\backslash$$

There for $P = 150\ watt$ ***Ans.***

Example: an electrical bulb consumes energy at the rate of 100 W and is used for 10 hours. What is the consumed energy?

Solution:

$$Energy\ (E) = \ Power(W) \times Time\ (hour)$$

$$Energy\ (E) = \ 100(W) \times 10(hour)$$

$$Energy\ (E) = \ 1000\ Wh$$ ***Ans***

Example: To find the cost of heating water using a 1500-watt water heater for 4 hours, and the cost of an electric unit is ₹ 3/KWh.

Solution:

$Electrical\ Energy\ Consume = Power(W) \times Time\ (hour)$

$$\text{E} = 1500\ W \times\ 4\ hour$$

$$\text{E} = 6000\ Wh$$

$$\text{E} = 6\ KWh$$

$$1\ KWh\ Energy\ =\ 1\ Unit\ of\ electricity$$

There for 6 units of consumed

And $cost$ = 6 KWh × ₹ 3/KWh

$cost$ ₹ 18 ***Ans***

AC AND DC CURRENT

DC CURRENT: the direction of the current does not change with time. The DC is a constant current. Therefore, the symbol of the DC is a straight line. Direct current may be converted from an alternating current supply by use of a rectifier, which contains electronic elements or electromechanical elements that allow current to flow only in one direction. Direct current may be converted into an alternating current with the help of an inverter. The symbol of the DC current is as shown in the figure below.

Fig.3.35: DC current symbols

A PV module produces DC power or DC current, or DC voltage the DC current flows in DC load or a DC circuits.

AC CURRENT: Electric charge in alternating current (AC), on the other hand, changes direction periodically. The voltage in AC circuits also periodically reverses because of the current change direction. AC current is generally used to power homes and businesses and is also present when audio and radio signals are carried on electrical wires. A rectifier is an electrical device that converts alternating current (AC).

The symbol of AC current is as shown in the figure below.

Fig.3.36 AC current symbol

SESSION 3

Practical Exercise

1. Identify the electrical and marking tools.
2. Measure a current, and voltage resistance by the use of a multimeter.
3. Draw a table of safety tools for use in solar PV installation
4. Draw a line diagram of on grid system

Check your progress

A. Fill in the blank

1. .... The area is required to set up a 1 KWp grid connected rooftop solar system**. 10 Square Meter**
2. **..................** system used for batteries backup power. **Off-grid system**
3. **...................** converts variable DC output of Solar PV panels into AC power. **Invertor**
4. 1 Unit of Electricity equals to......................**1kwh**

B. Multiple Choice Questions

1. Energy production from PV systems depends on-

a) Location. b) Weather. c**)both a and b**

2. Full Form of ACDB-

a) AC Distribution Box
b) AC Disconnected Box
c) AC and DC Box
d) None of The Above

3. Which type of solar system a great solution for remote locations and underdeveloped Communities?

a) On-grid
b) Off-grid
c) Hybrid

d) Both a & b

4. Which type of solar system does not use of battery

a) **On grid**

b) Off-grid

c) Hybrid

d) Both a & b

C. Short Answer Question

Q.1. Write the following definitions of

i. Current

ii. Voltage

iii. Electricity

Q.2 writes the name of the major component of the off-grid solar system.

Q.3 what is the working principle system of the on-grid solar system?

Q.4 what are DC and AC Current

Module 4	Work and Health safety

Module Overview
This module focuses on the critical aspects of work and safety for solar panel installation technicians. It provides students with the necessary knowledge and practices to ensure safe, efficient, and compliant installation procedures. In this module understanding of the safety protocols and best practices required for solar panel installation. They will be equipped to perform their duties while minimizing risks, ensuring not only their own safety but also the safety of their co-workers and clients.
Learning Outcomes
• Explain the toolbox talk and different types of hazards in the installation • Discuss and perform the different safety drill practices • Describe the different types of safety kit
Module Structure
Session 1: Personal Protective Equipment

Introduction

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 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

Establish and Follow Safe Work Procedure

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. Food 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. 4.1: 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.

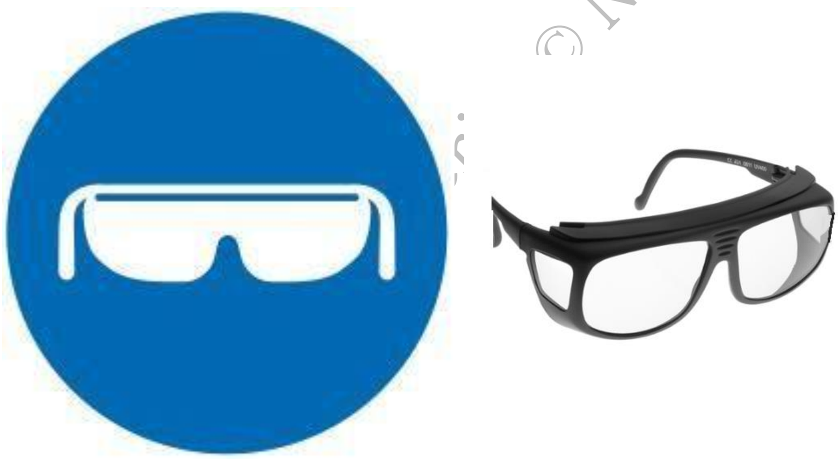


Fig 4.2: Protect Your Eyes

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 these on or take them off.

Ear Plugs - Ear plugs 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. 4.3: Hearing Protection

4. Maintain a Good Respiration

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:

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).

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.

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 dusk 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.4.4: 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. 4.5: 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. 4.6: 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.4.7: Protection for the feet

8. **Safety sign**

Fig.4.8 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**

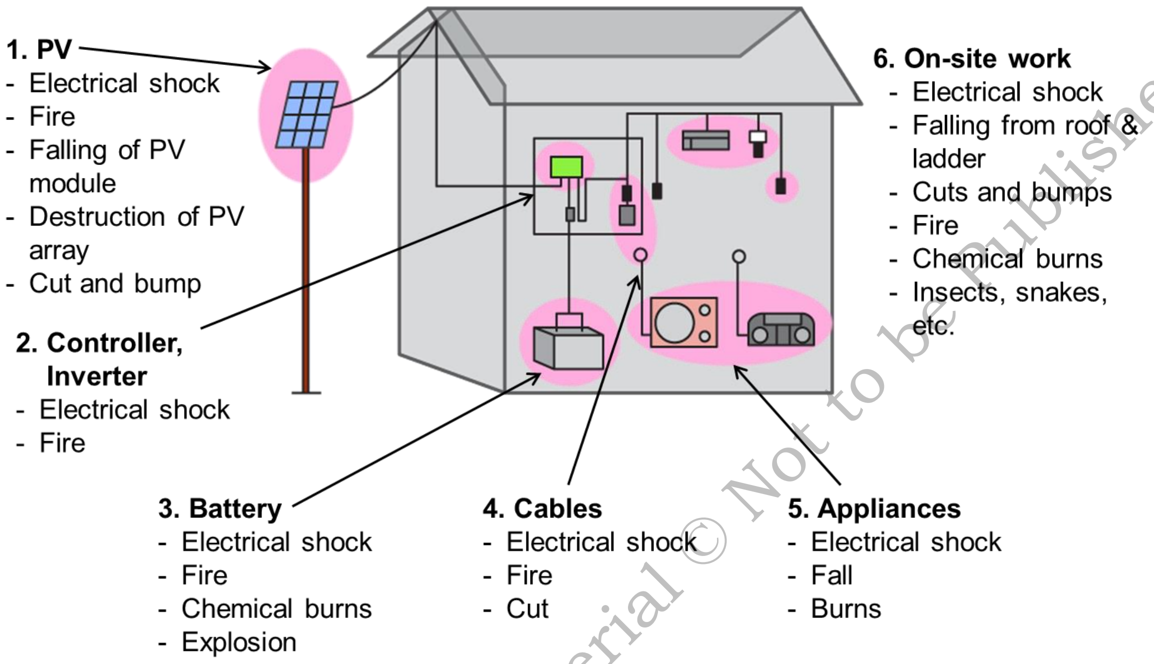


Fig.4.9 Solar Home Systems – Safety Risks

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 energized 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 are generally made of silicon (semiconductor).

During photovoltaic cell production, chemicals are used. The most dangerous ones are described below.

The doping operation of the cell issuer consists in bubbling a neutral gas in phosphoryl chloride ($POCl_3$), which is toxic and corrosive. Hydrofluoric acid (HF) baths are used for silicon engraving. To texturize the surface of silicon, we have to realize chemical attacks on the surface with soda (NaOH) and acids (hydrofluoric: HF, nitric: HNO_3, hydrochloric: HCl). The phosphoryl chloride ($POCl_3$), 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 gasses 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.

Session :1

Practical Exercise

1. Make a list of safety tools we used in solar installation.
2. Sketch a personal protective Equipment kit.

Check your progress

A. Fill in the blank

1. Workshop where tools and ....are used for making or repairing things. **Machines**

2. PPE refers to the equipment which .... the user from health hazards or ....at work. **Protects, safety risks**

3. Wearing a helmet offers protection and can prevent .... **Head injuries**

4. The ....are the most complex and fragile parts of our body. **Eyes**

B. Multiple Choice Question

1. 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. one 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.

Answer Key

Module 1: Introduction of Solar Energy

Session 1: Introduction to Energy

B. Fill in the blank

1. Energies
2. Geothermal, Ocean
3. Solar power
4. Photovoltaic (PV)

C. Multiple choices Question

1. (a)
2. (a)
3. (a)
4. (d)
5. (a)

D. Match the columns

1. Non-Renewable of Energy
2. Renewable
3. Solar cells
4. Solar energy

Session 2: Solar Energy

B. Fill in the blank

1. Renewable energy
2. Photovoltaic cells
3. Solar Collectors, Radiators
4. Tubing, Insulated Tank

C. Multiple choice question

1. (d)
2. (a)
3. (a)
4. (c)
5. (c)

SESSION 3: Solar PV Technology

A. Fill in the blank

1. Calculators
2. Light, electricity
3. Silicon
4. Photovoltaic effect

B. Multiple Choice question

1. (a)
2. (a)
3. (a)
4. (a)
5. (c)

SESSION 4: Solar Power Generation and Current Trend

1. PV array
2. DC power
3. Inverter
4. 278 KWh
5. Energy

B. Multiple Choice Question:

1. (a)
2. (a)
3. (a)
4. (a)
5. (a

Session 1: Solar Water Pump and Its Components

A. Multiple Choice Questions.

1. (a)
2. (c)
3. (c)
4. (b)

B. Fill in the Blanks.

1. (2-15) HP
2. (1-3) HP
3. (1.2-1.5) HP
4. MPPT

Session 2: The Solar Panel and Its Components

A. Multiple Choice Questions.

1. (a)
2. (a)
3. (c)
4. (a)

B. Fill in the Blanks.

1. Photovoltaic
2. Thin film
3. 25 years,
4. Solar radiations.

Session 3: Solar Panel Mounting Structure

A. Multiple Choice Questions.

1. (a)
2. (c)
3. (c)
4. (c)

B. Fill in the blanks

1. Blasted
2. Ground Mounting

3. M20
4. 12 to 15 feet

Session 4: Power Conditioning Unit

A. Multiple Choice Questions.

1. (d)
2. (a)
3. (d)

B. Fill in the blanks.

1. Maximum Power Point Tracker
2. Pulse width modulation
3. Ampere

Session 5: Inverter

A. Multiple Choice Questions.

1. (c)
2. (b)
3. (b)

B. Fill in the blanks.

1. Grid tie inverter
2. VFD
3. KVA or VA

Session 6: Battery Unit

A. Multiple Choice Questions.

1. (a)
2. (d)
3. (b)
4. (c)

B. Fill in the blanks

1. Chemical Energy
2. State of charge
3. Ampere hour
4. 5 years

Session 7: Cable Connections

A. Multiple Choice Question

1. (a)
2. (a)
3. (a)

B. Fill in the Blanks

1. Miniature circuit breaker
2. Ampere
3. Multi-Contact 4

Section 8 Earthling System and Its Types

A. Multiple Choice Question

1. (b)
2. (c)
3. (d)

C. Fill in the Blanks

1. 3 Meters,
2. Lightening Arrestor,
3. Roof.

Module 2: Tools for Solar Systems Installations

Session 1: Mechanical and General Tools

A. Fill in the blank

1. Tough steel
2. Screwdrivers
3. Hammer
4. fine-toothed saw
5. solar installation
6. Nipper
7. drilling small holes

B. Multiple Choice Question

1. (a)
2. (a)
3. (a)

Session 2: Electrical, Safety, Marking, And Civil Tools

A. Fill in the blank

1. Analog Multimeter
2. earth electrode
3. Very low
4. Insulation resistance (IR) test

B. Multiple Choice Questions

1. (a) Electrical resistance tester
2. (a) Pyranometer
3. (a) solar irradiance
4. (c) marking tool
5. (d) workpiece

C. Match the columns

1. Crowbar Pulls	Two Objects Apart
2. Solar Compass:	Navigational Instrument
3. Clamp Meter	Measure the Current
4. Center punch	Marking Tool

Session 3: Electrical Parameters and Solar PV System

B. Fill in the blank

1. 10 Square Meter
2. Off-grid system
3. Invertor
4. 1kwh

B. Multiple-Choice Questions

1. (c) both a and b
2. (a) AC Distribution Box
3. (b) Off-grid
4. (a) On-grid

Unit-4 Work and Safety

A. Fill in the blank

1. Machines
2. Protects, safety risks
3. Head injuries
4. Eyes

B. Multiple Choice Question

1. (a)
2. (d)
3. (a)
4. (a)

ABBREVIATION

AC: Alternating current

CPV: Concentrating solar photovoltaics

DC: Direct current

DH: Discharge Head

DESCO: Distributed energy service company

EPC: Engineering, procurement, and construction

EV: Electric vehicle

GW/GWh: Gigawatt/gigawatt-hour

HP: Horse Power

Kw/Kwh: Kilowatt/kilowatt-hour

MW/MWh: Megawatt/megawatt-hour

MPPT: Maximum power point tracker

PV: Photo Voltaic

SWH: Solar water heater/heating

SH: Suction Head

TH: Total Head

VFD: variable-frequency drive

W/Wh: Watt/watt-hour

Wp: Peak Watt, also known as Watt-peak\

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. under common usage, the term battery also applies to a single cell if it constitutes the entire electrochemical storage system.

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. When This Property of Light Is Combined with The Properties Of

Resistance (R) — the property of a conductor, which opposes the flow of an electric current

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