DRAFT STUDY MATERIAL

# Junior Technician-
# Solar EV Charging Station

(Job Role)

**Qualification pack: Ref. Id. SGJ/Q4001**

**Sector: Skill Council for Green Jobs (SCGJ)**

**Textbook for Class IX**

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## Textbook for Class IX

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

# FOREWORD

The National Education Policy (NEP) 2020 has redefined the direction of school education in India by emphasising vocational education, experiential learning, and the meaningful integration of technology in classrooms. It aims to prepare learners not only for academic excellence but also for skill-based pathways that align with the nation's growing technological and industrial landscape. In this context, the renewable energy sector, particularly solar energy and electric mobility, has emerged as a significant area for future employment and innovation.

The Junior Tech Solar EV Charging Station (Class IX) textbook is a timely initiative developed by the PSS Central Institute of Vocational Education (PSSCIVE), Bhopal, to introduce school learners to the fundamentals of solar energy, electric vehicle (EV) technology, and basic charging infrastructure. The content has been designed to build foundational knowledge and practical competencies that encourage scientific thinking, innovation, and sustainable practices among young learners.

This textbook provides an age-appropriate understanding of solar photovoltaic (PV) systems, EV charging concepts, safety procedures, hands-on activities, and real-life applications. It aligns with the National Skills Qualifications Framework (NSQF) and aims to promote skill-based learning at the school level, paving the way for advanced vocational courses in the renewable energy domain.

I appreciate the dedicated efforts of the Department of Engineering and Technology, PSSCIVE, and the team of subject experts, teachers, and resource persons who contributed to the development of this significant learning resource. Their commitment ensures that the material remains relevant, technically sound, and accessible to students and teachers alike.

It is my firm belief that this initiative will inspire students to engage with clean energy technologies and contribute meaningfully to India's vision of a sustainable, green, and self-reliant future.

**Dr. Deepak Paliwal**
Joint Director
PSSCIVE,

Bhopal
August 2025

# PREFACE

The paradigm shift in Indian education envisioned by the National Education Policy 2020 (NEP 2020) underscores the importance of integrating vocational education, competency-based learning, and practical exposure to prepare learners for future job markets. In line with this vision, the PSS Central Institute of Vocational Education (PSSCIVE), Bhopal, has developed the Jr Tech Solar EV Charging Station textbook for Class IX under the framework of vocational education envisioned by the National Education Policy (NEP) 2020.

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

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

We express our sincere thanks to the Ministry of Education, NCERT, and the National Skills Qualifications Framework (NSQF) team for their continuous guidance. We extend heartfelt gratitude to the experts, teachers, and institutions whose insights and support enriched the content. Their contributions helped shape a resource that is both academically sound and practically meaningful.

We hope this textbook will inspire students to explore the world of renewable energy and play a constructive role in promoting sustainable practices for a better future.

**Dr. Saurabh Prakash**
Head and Professor
Department of Engineering & Technology
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# ACKNOWLEDGEMENT

The PSS Central Institute of Vocational Education (PSSCIVE), Bhopal, expresses deep gratitude to all individuals and institutions who contributed to the development of the Junior Tech Solar EV Charging Station (Class IX) textbook.

We extend our sincere thanks to the Ministry of Education (MoE), Government of India, and the National Council of Educational Research and Training (NCERT) for their continuous support in strengthening school-level vocational education.

We gratefully acknowledge the valuable contributions of the Director, NCERT, and officials of the NSQF Cell for their guidance in aligning the curriculum with national standards. We also appreciate the support from the National Skill Development Corporation (NSDC), Skill Council for Green Jobs (SCGJ), Junior Technician- Solar EV Charging Station (SGJ/Q4001) and other industry partners for their insights into emerging green technologies.

We place on record our special thanks to Prof. Saurabh Prakash, Course Coordinator, for his leadership and commitment in the development of this course. We also acknowledge the contributions of Mr Ankit Singh Chauhan (Assistant Professor) for his technical insights, drafting inputs, and editorial support in shaping the textbook content.

Our thanks are due to all subject matter experts, reviewers, vocational teachers, and team members who shared their knowledge and experience. Their collective efforts have enriched the quality and relevance of this resource.

We also appreciate the assistance of the Publication Division, NCERT, for designing, formatting, and producing the textbook with high standards of accuracy and presentation.

This collaborative effort reflects our shared mission to empower young learners with skills, knowledge, and values for a sustainable and technologically advanced future.

**PSSCIVE**
August 2025

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# MODULE 1 INTRODUCTION OF SOLAR ENERGY

## MODULE OVERVIEW

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

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

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

## LEARNING OUTCOMES

After the completion of this module, you will be able to:

1. Define and categorize the various forms and sources of energy. Differentiate between renewable and non-renewable energy.
2. Describe how solar energy is harnessed from the Sun and India's potential for solar energy generation.
3. Explain the operational principle of a photovoltaic (PV) cell.
4. Identify the key components of a solar PV system.
5. Compare different types of solar panels in terms of efficiency and materials.
6. Describe the main components of a solar panel and their functions.

## MODULE STRUCTURE

Session 1: Introduction to Energy

Session 2: Potential of Solar Energy

Session 3: Fundamentals of Solar Photovoltaic (PV) Technology

Session 4: Solar Power Generation and Application

Session 5: Solar Panel and Its Components

# SESSION 1: INTRODUCTION TO ENERGY

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

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

The amount of work something can do depends on how much energy it gets. In fig. 1.1 shows the different forms of Energy.

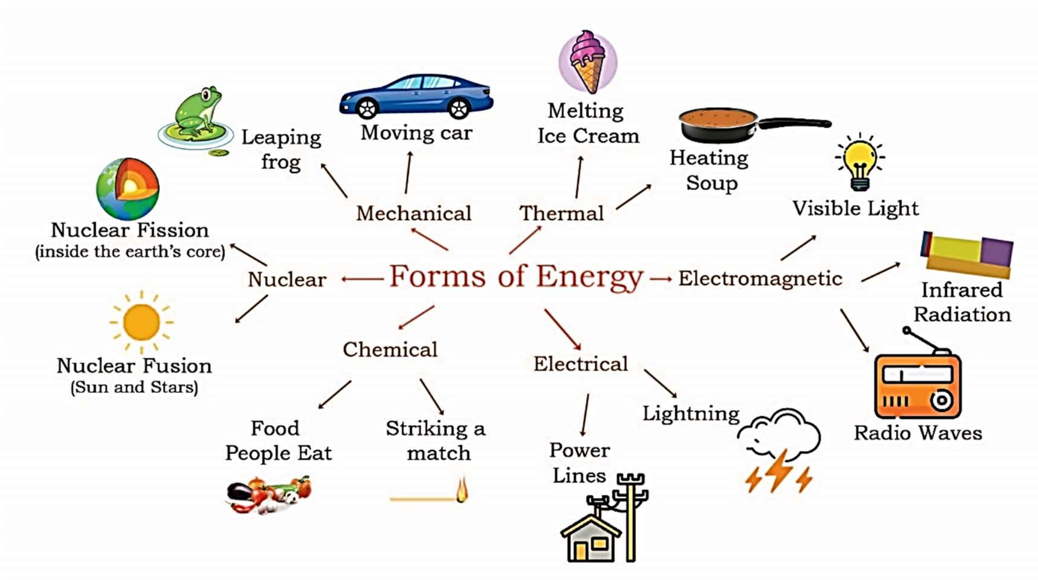



**Fig. 1.1: Form of Energy**

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

1. Primary and Secondary Energy
2. Commercial and Non-commercial Energy
3. Renewable and Non-Renewable Energy
4. Conventional and Non-Conventional Energy

## 1. Primary and Secondary Energy

### a) 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).

**b) 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**

**a) 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.

**b) 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**

**a) 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.

**b) Non-renewable Energy**

Non-renewable energy is the conventional fossil fuels such as coal, oil, and gas, which are likely to deplete over time. The non-renewable energy sources are very limited and are likely to be exhausted over 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**

**a) 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.

**b) Non-conventional energy**

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

**INTRODUCTION TO RENEWABLE ENERGY SOURCES**

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

**a) Solar Energy**

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


**Fig. 1.2: Photosynthesis process**

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

Modern solar power systems for homes and industries use photovoltaic (PV) technology to harness the sun's energy. "Photo" means "produced by light," and "voltaic" refers to "electricity produced by a chemical reaction." Photovoltaic cells convert solar energy into electricity through a chemical process. Each cell contains a semiconductor, which is a solid material that can conduct heat or electricity under certain conditions. The cells connect through a circuit and frame to form a module. The method of using solar energy is illustrated in Fig. 1.3.

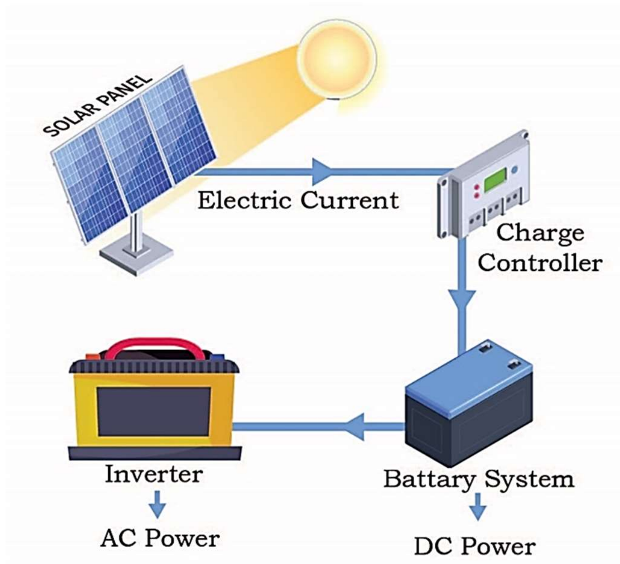



**Fig. 1.3: Solar energy generation system through the solar panel**

### b) 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.

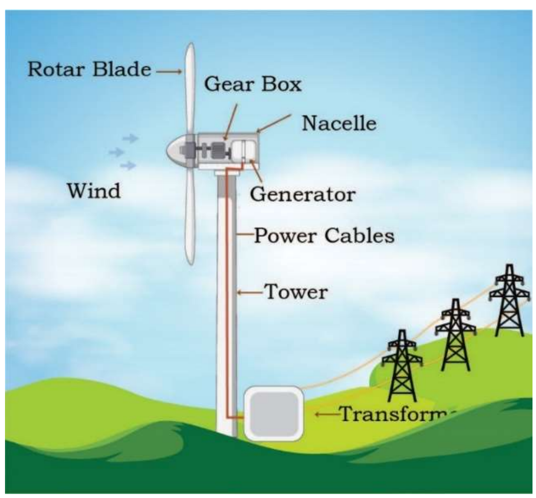



**Fig. 1.4: Wind energy generation system through wind turbine**

### c) 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. They are powered by the kinetic energy of flowing water as it moves downstream. Hydropower (hydel) utilises turbines and generators to convert that kinetic energy into electricity. The hydro-electric energy generation system is shown in Fig. 1.5.

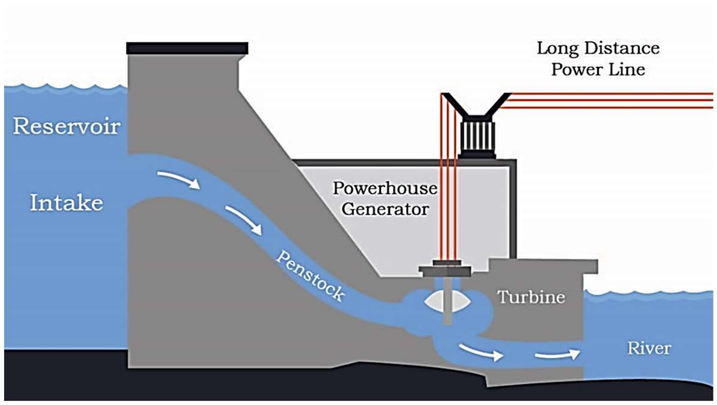



**Fig. 1.5: Hydroelectric energy generation system through the hydroelectric dam**

**d) 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.

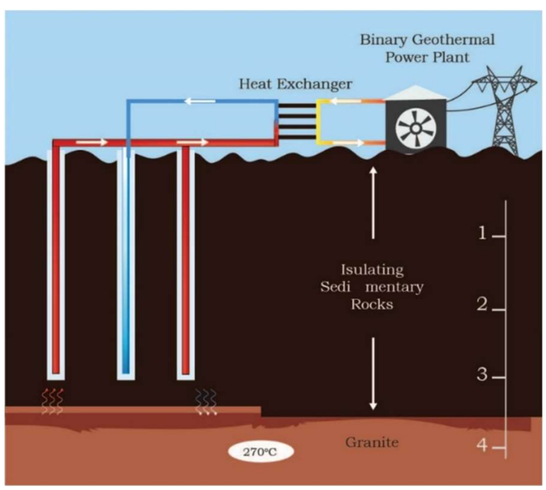



**Fig. 1.6: Geothermal energy generation system**

**e) 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.

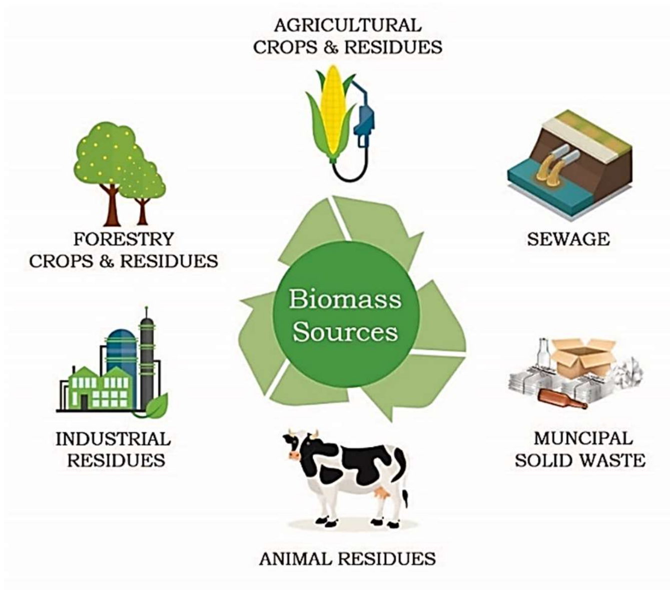



**Fig. 1.7: Biomass energy generation system**

**f) 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. The flow diagram of tide or wave energy is shown in Fig. 1.8 (a), and the generation of electricity with the help of tides or waves is shown in Fig. 1.8 (b).

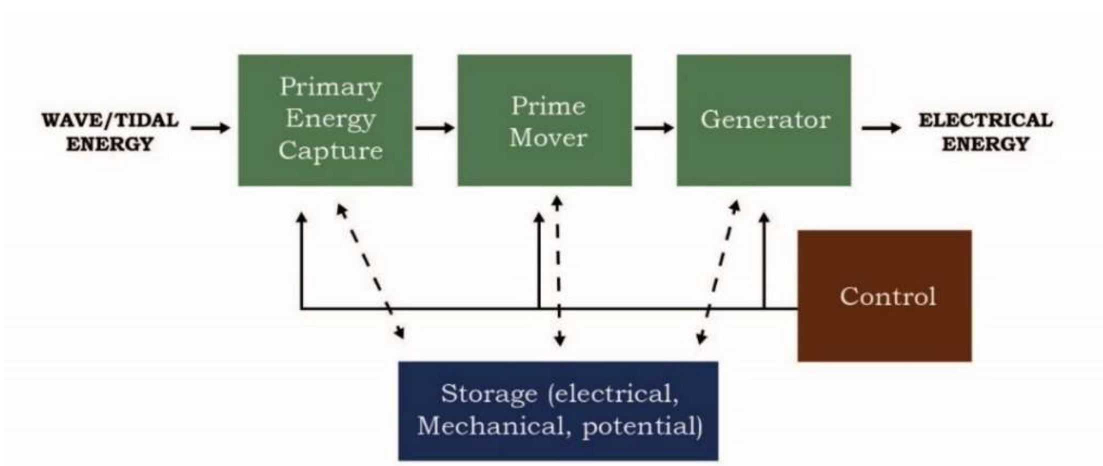



**Fig.1.8 (a): Flow diagram of tide/wave energy use**

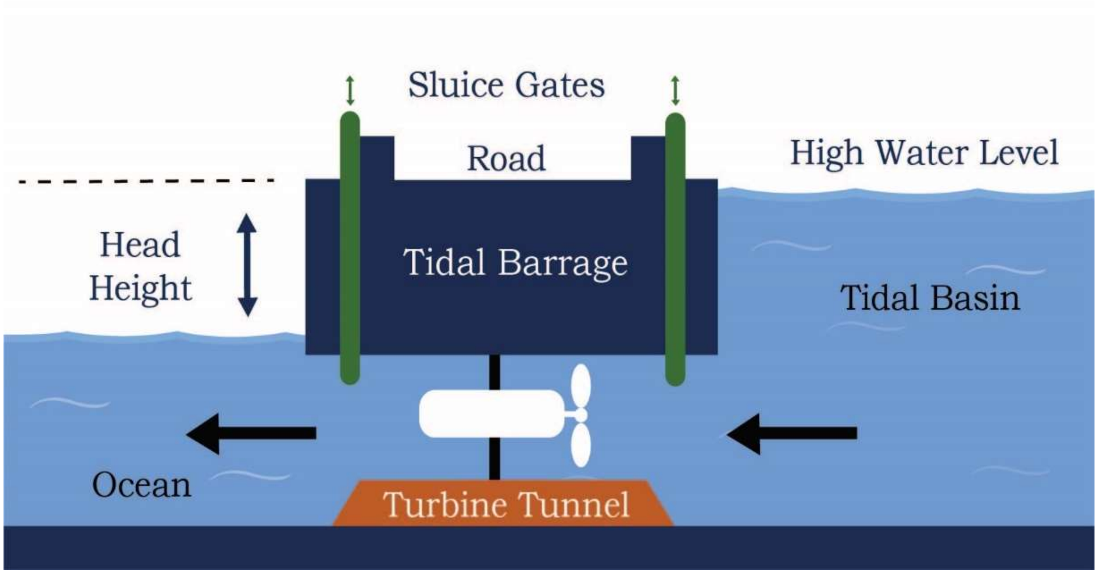



**Fig. 1.8 (b): Tide/Wave Energy Use**

**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 a 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<br>• Easy to get and easy to transport<br>• Can be used to generate electrical energy and make products, such as plastic | • Non-renewable<br>• Burning produces smog<br>• Burning coal releases substances that can cause acid precipitation<br>• Risk of oil spills |
| **Nuclear** | • A very concentrated form of energy<br>• Power plants do not produce smog | • Produces radioactive waste<br>• Radioactive elements are non-renewable |
| **Solar** | • An almost limitless source of energy<br>• Does not produce air pollution | • Expensive to use for largescale energy production<br>• Only practical in sunny areas |

| | | |
|---|---|---|
| **Water** | • Renewable<br>• Does not produce air pollution | • Dams disrupt a river's ecosystem, available only in areas that have rivers |
| **Wind** | • Renewable energy source<br>• Relatively inexpensive to generate<br>• 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<br>• Power plant requires little land | • Only practical areas near hot Spots<br>• Wastewater can damage soil |
| **Biomass** | • Renewable energy source | • Requires a large area of farmland<br>• Produces smoke |

## ACTIVITY

1) Make a table of the advantages of various renewable energies.
2) Draw the layout of the geothermal power plant.
3) Make a list of renewable energy sources.
4) Make a table of the advantages of various non-renewable energy sources.
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 sources of renewable energy.
3) Differentiate between renewable energy and non-renewable energy.
4) Explain solar energy and its advantages.

**B. Fill in the blank**

1) The sun is the prime source of all types of .......................
2) Renewable sources include ...............and ................energies.
3) The most promising alternative energy sources include..............and hydroelectric power.
4) Modern residential solar power systems use ................ to collect the sun's energy.

**C. Multiple Choice 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-commercial energy
   c) hydraulic energy
   d) None of these

## SESSION 2: 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.

India is richly endowed with solar energy resources: much of the country receives high solar irradiance (typically 4–7 kWh per $m^2$ per day) across large land areas. Harnessing this solar resource is key for India’s sustainable energy transition, for meeting its climate goals (including net-zero by 2070) and for reducing dependence on fossil fuels.

**Estimated Solar Potential**

India has significant solar power potential. The National Institute of Solar Energy (NISE) estimated it at about 748 GW (Giga-Watt-peak) by using around 3% of available wasteland for solar panels.

However, a recent assessment by The Energy and Resources Institute (TERI) found that India’s actual solar potential could be about 10,830 GW (10.83 TW). This includes capacity from land, rooftops, agricultural use (Agri-PV), floating solar, and urban areas.

An even newer report from the Ministry of New and Renewable Energy (MNRE) and the Indian Space Research Organisation (ISRO), published in September 2025, suggests that India could feasibly install around 3,343 GW of ground-mounted solar power.

**Current Installed Capacity & Growth (2025)**

As of the fiscal year 2024-25, India has a total renewable energy (RE) capacity of about 220 gigawatts (GW), not including large hydro projects. Solar energy makes up around 48% of this total capacity.

In the first nine months of 2025 (January to September), India added about 29.5 GW of new solar capacity. This includes about 22.5 GW from utility-scale sources, 5.8 GW from rooftop installations, and 1.17 GW from off-grid and distributed systems.

The proportion of solar energy in new installations keeps increasing. For example, in the second quarter of 2025, India produced around 43 billion units (BU) of solar power, which is a 19.2% increase compared to the same time last year.

This shows India is making strong progress, though this is still a long way from fully tapping its potential.

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 utilisation for water pumping.
(8) Solar furnaces.
(9) Solar electric power generation by: -
    (i) Solar PV
    (ii) Solar Thermal
(10) EV Charging Station

**APPLICATIONS OF SOLAR ENERGY**

**a) Heating and cooling of the residential buildings**

The solar Heating and cooling system generally maintain 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 specially 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 solar space heating system is illustrated in Fig. 1.9.

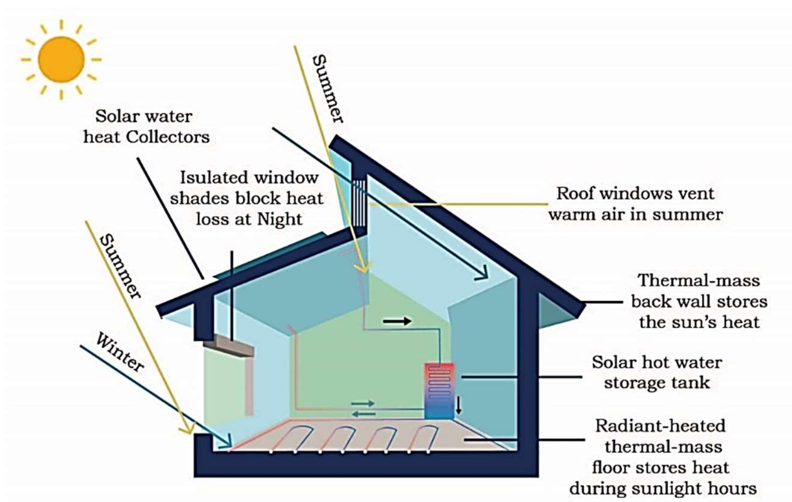



**Fig. 1.9: Solar Space Heating System**

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 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.

**b) Solar water heating system**

A solar water heater commonly comprises a collector (blackened flat plate type or evacuated tube) with associated metal tubing, facing the general direction of the sun. The flat plate type collector is provided with a transparent glass cover and a layer of thermal insulation below the plate.

The evacuated tube type collectors have glass tubes coupled together in which the water flows from top to bottom.

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 transfers and regulates 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.

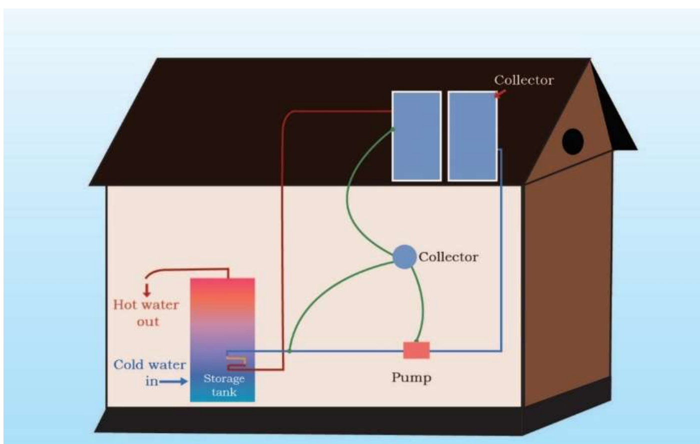



**Fig. 1.10: Solar water heating system**

**c) 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.

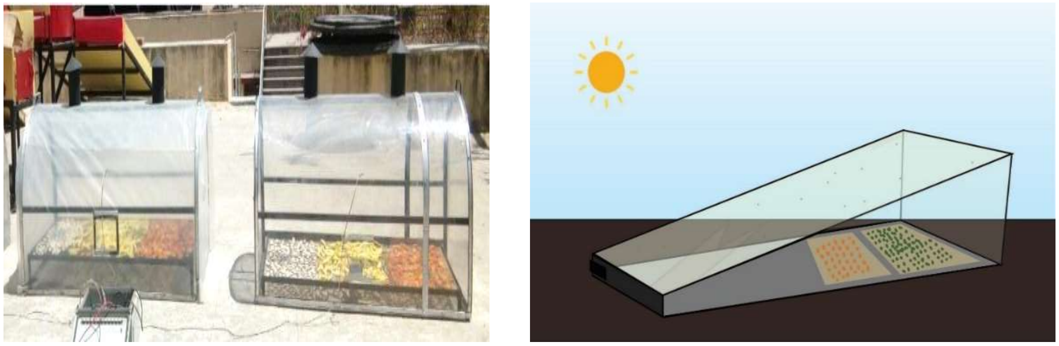
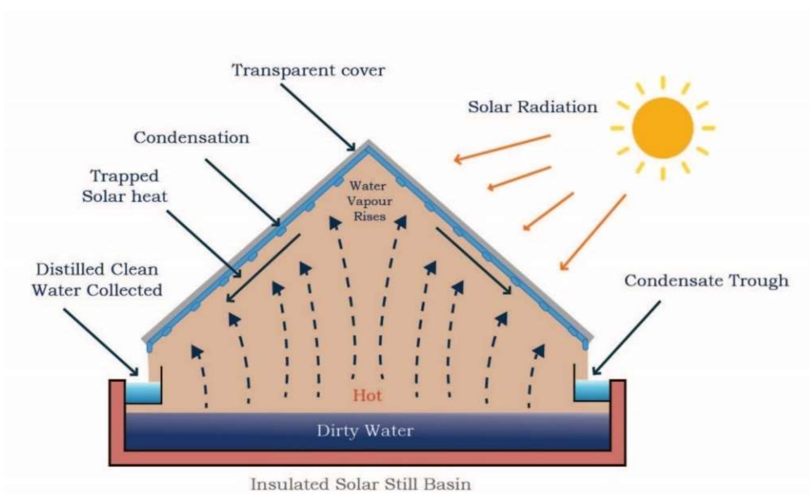


**Fig. 1.11: Solar Dryer System (levelling needed)**

**d) 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**

e) **Solar Cooker**

A solar cooker is an appliance that uses the energy of direct sunlight to heat, cook or pasteurise 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 cooks the food. Fig. 1.13 shows the typical image of a solar cooker.

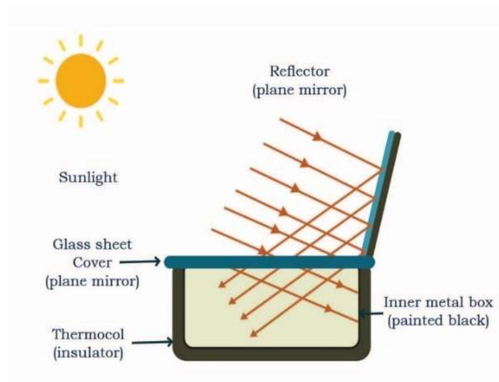



**Fig. 1.13: Solar cooker**

f) **Solar Water Pumping System**

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

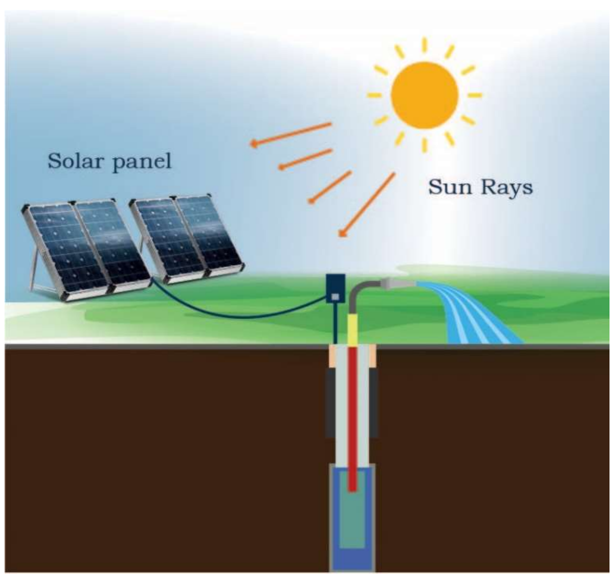



**Fig. 1.14: Solar Water Pumping**

## ACTIVITY

(1) Sketch the 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 and name 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 _____________.
2. Solar _____________ which can be used for the conversion of solar energy directly into electricity.
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.
4. The collector _____________ is connected by a pipe to an _____________ that stores hot water during non-sunny periods.

**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

# SESSION 3: SOLAR PHOTOVOLTAICS (PV) TECHNOLOGY

## Photovoltaic and Photovoltaic Cells

When sunlight strikes a photovoltaic cell (as shown in Fig. 1.16), 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, which is shown in the Figure 1.17.

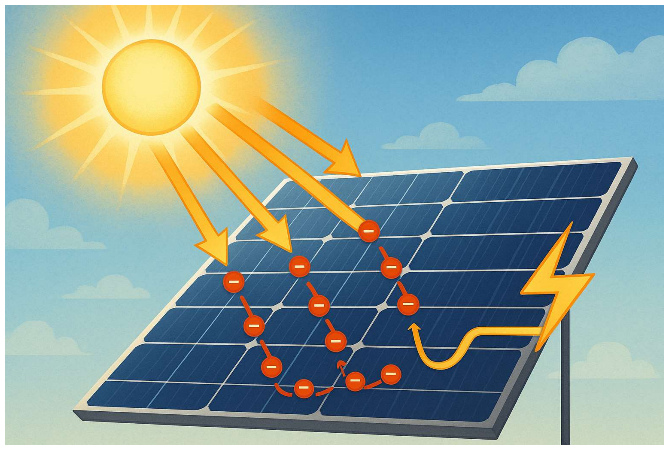


**Fig 1.16: Photovoltaic effect**

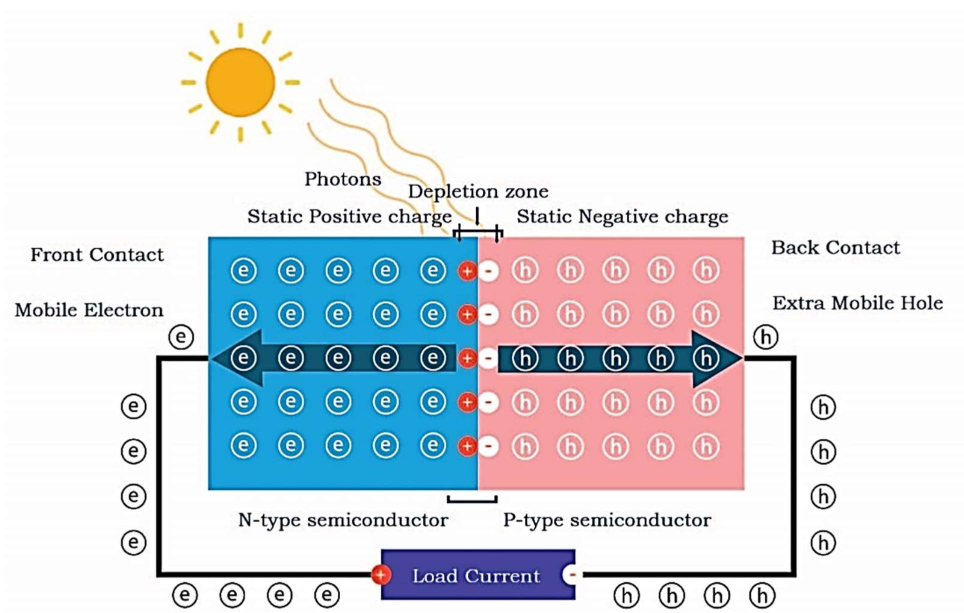



**Fig. 1.17: Movement of holes and electrons in cells**

## 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**

**Did You Know?**

Over 95% of solar cells around the world are made from silicon, a special semiconductor. When sunlight hits these cells, it knocks electrons loose, creating an electric current. This current, guided by electric fields and metal contacts, can power things like your calculator or even an entire home.

## ACTIVITY

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.

2. The term “photo” means ......and “voltaic” means..........

3. Which materials are used in a PV cell.................

4. A PV cell converts sunlight into electricity is known as the...............

**B. Multiple Choice question**

1. One single PV cell produces up to power

   a) 12 watts
   b) 10-watt
   c) 2-watt
   d) All of these

2. Full name of PV

   a) Photovoltaic
   b) photocopy
   c) photosynthetic

d) None of these

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

a) **Flat plate and concentrators**

b) Circular, rectangular plate

c) Thermal plate

d) None of these

4. Full name of NISE

a) **National Institute of Solar Energy**

b) National Institute of Science Energy

c) Neutral Intensity of Solar Energy

d) none of these

5. The efficiency of solar cells is about

a) 10%

b) 25%

**c) 15%**

d) 60%

**C. Short answer question**

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

## SESSION 4. SOLAR POWER GENERATION AND APPLICATION

### SOLAR POWER GENERATION

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

About 5,000 trillion kWh per year of energy comes 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 an energy security and reliability perspective, solar is the most secure of all sources, since it is abundantly available. Theoretically, a small fraction of the total incident solar radiation can meet the entire country's power requirements.

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

### SOLAR PV SYSTEM

Solar Photovoltaic power generation and a reliable supply of power 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 optimises 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 a 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.

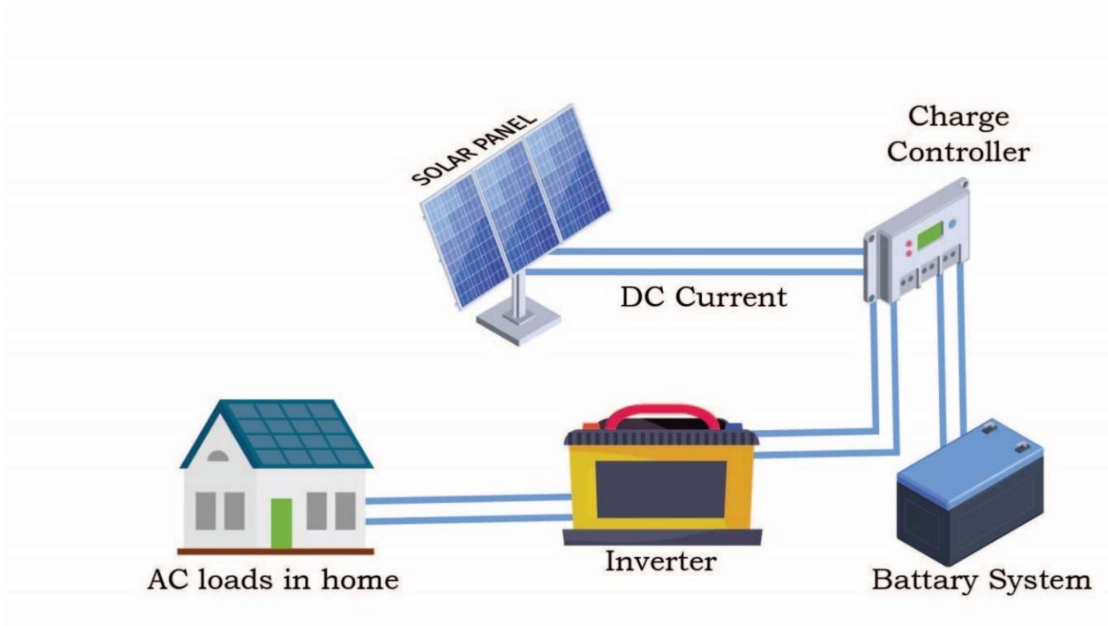



**Fig. 1.20: Off-Grid System**

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, a battery, a charge controller, a grid box, an inverter, a mounting structure, and a 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, a Generator is used.

### 2. Grid-Connected PV Systems

In a grid-connected system, power is fed into the grid during the daytime and taken 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 a DC supply into AC and feeds the solar power to the grid or supplies it 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.

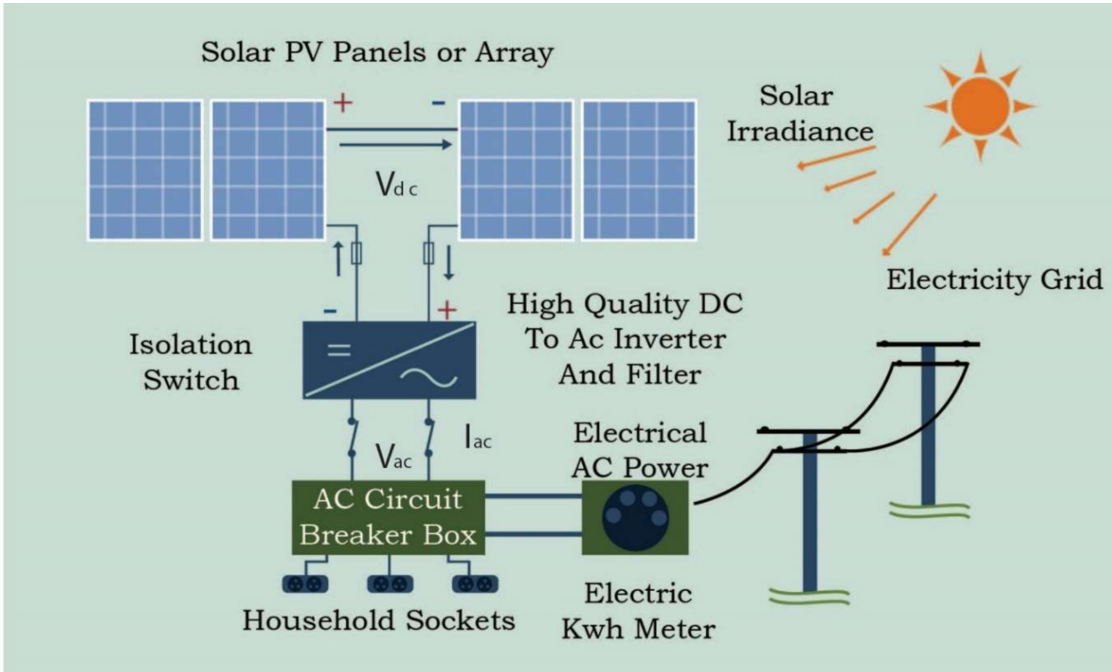



**Fig. 1.21: Grid-connected solar power plant**

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 requirements of feeding the power into the grid.

### 3. Hybrid Solar PV System

This system is the combination of a 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 home. In some cases, auxiliary sources of energy, like a diesel generator, are used in addition to solar PV modules and the grid.

### LIMITATIONS OF SOLAR PHOTOVOLTAIC ENERGY CONVERSION

- Generation of solar power during sunshine hours
- Require storage to supply power at night
- Low efficiency
- Require a large area
- Low power generation during the cloudy season.

## ACTIVITY

1. Draw the Block diagram of an off-grid / autonomous solar plant.

2. Make a pie chart of energy generation in India.

3. Make a table of state-wise lar generation.

4. Draw the line diagram of the grid-connected solar system.

## CHECK YOUR PROGRESS

**A. Fill in the blank**

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

**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) **daytime**
   - b) evening time
   - c) sunset
   - d) None of these
4. 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 the major components of the grid power generation system.
3. Name of Solar cell power plant components and their working.

## SESSION 5: THE SOLAR PANEL AND ITS COMPONENTS

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

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

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

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

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

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

The 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-sensitised solar cells, nanocrystal-based solar cells, and perovskite-based solar cells.

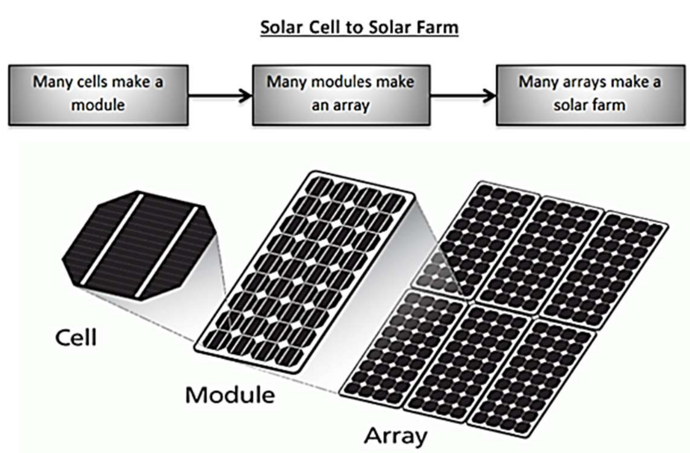



**Fig. 1.22: PV Cell, Module, Array**

**Photovoltaic Panel/module:** Photovoltaic Panel (shows in Fig. 1.22) 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 (as shown in fig. 1.23) 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**.**

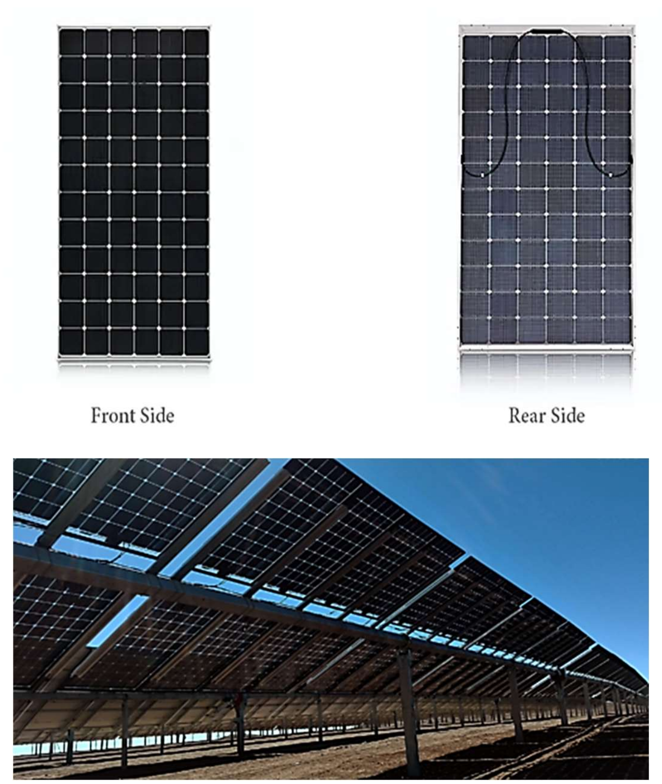



**Fig. 1.23: Bifacial Solar PV Panel**

**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 1.24.

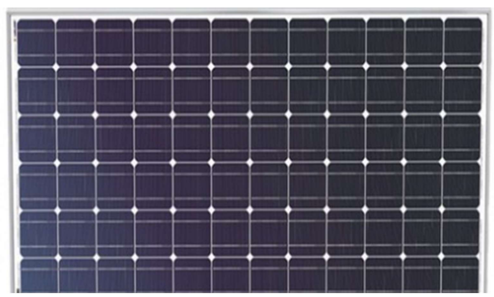


**Fig. 1.24: Mono Crystalline Solar PV Panel**

**Poly Crystalline Solar PV Panels**

As shown in the fig.1.25, 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. 1.25: 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 Figure 1.26, 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. 1.26: Thin Film PV (Amorphous) Panels**

**SOLAR PANEL LAYERS**

A Solar PV Panel consists of a multi-layered unit (as shown in Fig. 1.27) 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.

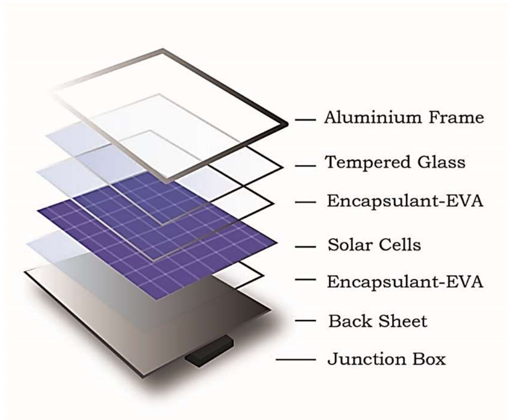



**Fig. 1.27: Solar Photovoltaic cell layer**

**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 may look more aesthetically pleasing, but it absorbs more heat. This raises the temperature of the solar cells, which increases resistance and slightly lowers overall 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. 1.2: Comparison of Different Types of PV Modules**

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

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

**Technical Parameters and Performance of Solar PV Panel**

Solar photovoltaic (PV) panels have different technical specifications that affect how well they perform. It's important to understand these details to choose the right panel for your needs. Key factors to consider include the panel's power output, efficiency rating, temperature response, and voltage. You should also look at performance metrics like energy production, degradation rate, and warranty details. These aspects help you evaluate the long-term reliability of solar PV systems. By reviewing these technical specs carefully, you can make better decisions when selecting solar panels for your renewable energy projects. The Front and back sides of the PV module are shown in the figure. 1.28.

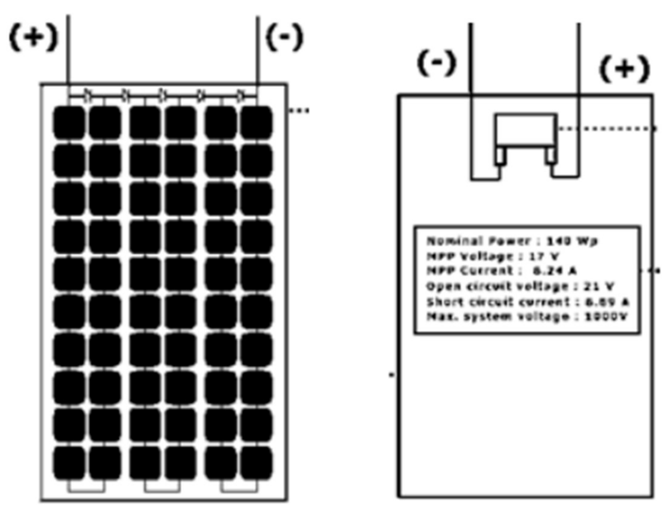



**Fig. 1.28: Front Side and Back Side of a PV Module: The Junction Box, consisting of Positive and Negative Terminals, is placed behind the module**

A Solar PV Module is characterised by the following parameters:

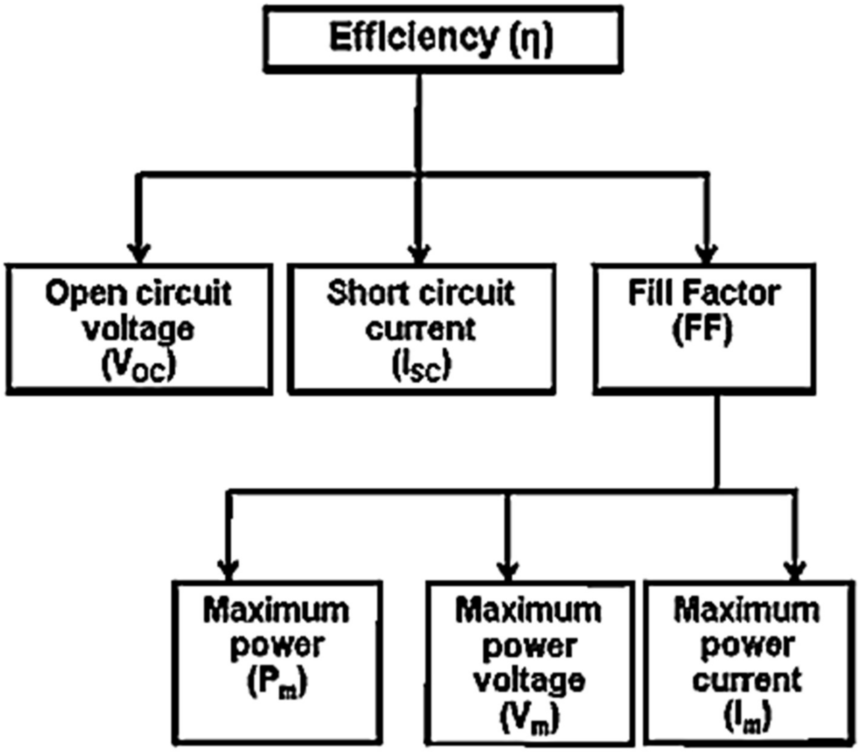



**Fig. 1.29: Solar PV Module Characterisation**

**Table 1.3: Sample values of major Technical Specifications of a solar PV panel**

| PARAMETER | VALUE |
|---|---|
| Max Power $P_{max}$ (W) | 100 W |
| Power Tolerance (+/-) | 0.05% |
| Max Power Voltage $V_{mp}$ (V) | 18 V |
| Max Power Current $I_{mp}$ (A) | 5.56 A |
| Open Circuit Voltage $V_{oc}$ (V) | 22.3 V |
| Short Circuit Current $I_{sc}$ (A) | 6.1 A |
| Max. System Voltage VDC | 1000/600 |

### A. Short Circuit Current ($I_{sc}$)

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

### B. Open Circuit Voltage ($V_{oc}$)

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

### C. Maximum Power ($P_{max}$)

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

### D. Fill Factor (FF)

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

### E. I-V Curve

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

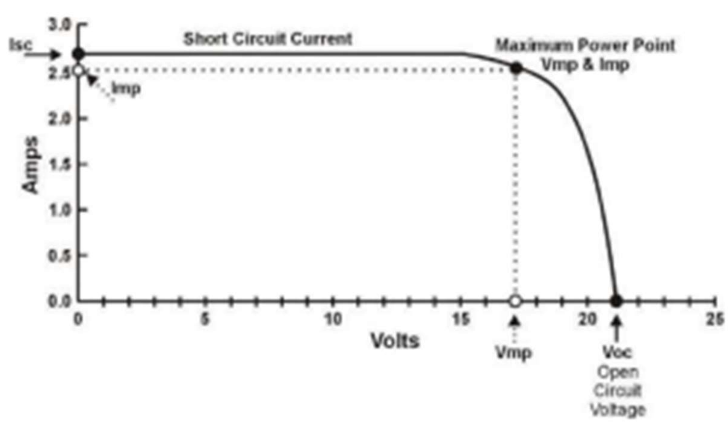



**Fig. 1.30: Characteristics of a PV Cell with Operating Point ($V_{mp}$/$I_{mp}$)**

### F. Efficiency

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

### G. Standard Testing Conditions (STC)

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

a) Irradiance on the cell surface: 1000 W/m²

b) Air temperature: 25°C

c) Air mass (AM): 1.5

**H. Nominal Operating Cell Temperature (NOCT)**

While PV modules are rated at STC (25°C, 1000 W/m², AM 1.5), they generally operate at higher temperatures and lower sunlight levels in real conditions. To estimate the power output, it is important to know the module's expected operating temperature. The Nominal Operating Cell Temperature (NOCT) is the temperature of open-circuited cells under these conditions:

a) Irradiance on cell surface: 800 W/m²

b) Air temperature: 20°C

c) Wind velocity: 1 m/s

d) Mounting: open back side

**ACTIVITY**

**Activity 1: Compare and Conclude – Types of Solar Panels**

**Objective:** To compare the characteristics of different types of solar panels.

**Materials Required:**

- Chart paper or digital slide template
- Images or printed photos of **Monocrystalline, Polycrystalline, Bifacial, and Thin Film Panels**
- Markers and glue

**Procedure:**

1. Divide students into four groups; assign each group one type of panel.
2. Each group researches the following parameters:
   - Efficiency
   - Cost
   - Appearance
   - Advantages and disadvantages
3. Prepare a comparative chart or presentation.
4. Present findings to the class.

**Learning Outcome:** Students will understand the differences between types of solar panels and their practical applications.

**Activity 2: Solar Efficiency Challenge**

**Objective:** To explore factors affecting solar panel efficiency.

**Materials Required:**

- Small solar cell
- Multimeter or voltmeter (optional)
- Transparent plastic sheet, coloured sheet, and glass plate

**Procedure:**

1. Place the solar cell under sunlight and measure the voltage (or brightness of LED if connected).
2. Cover it with a transparent sheet, then with a coloured sheet, and finally with glass.
3. Note changes in performance with each layer.
4. Discuss which material allows the lightest to pass and gives the maximum output.

**Learning Outcome:** Students will learn how materials, shading, and surface colour affect solar panel efficiency.

## CHECK YOUR PROGRESS

**A. Multiple Choice Questions**

1. **What is the main function of a photovoltaic (PV) cell?**
   a) To store solar energy
   b) To convert solar energy into electrical energy
   c) To reflect sunlight
   d) To cool solar panels

2. **Which semiconductor material is most commonly used in solar PV cells?**
   a) Copper
   b) Iron
   c) Silicon
   d) Aluminium

3. **Which type of solar panel can capture sunlight from both front and back sides?**
   a) Polycrystalline panel
   b) Monocrystalline panel
   c) Thin film panel
   d) Bifacial panel

4. **What is the typical efficiency range of monocrystalline silicon PV modules?**
   a) 5–10%
   b) 10–14%
   c) 15–20%

d) 25–30%

5. **Which of the following conditions are used as Standard Testing Conditions (STC) for PV modules?**
   a) 25°C, 1000 W/m², Air mass 1.5
   b) 35°C, 900 W/m², Air mass 2
   c) 20°C, 800 W/m², Air mass 1
   d) 25°C, 700 W/m², Air mass 1.5

**B. Fill in the Blanks**

1. A solar panel is a collection of ______________ connected mainly in series.
2. The semiconductor material most commonly used in PV cells is ____________.
3. The ____________ is the ratio of the maximum power from a solar cell to the product of $V_{oc}$ and $I_{sc}$.
4. ___________________________ can generate power from both sides of the panel.
5. The efficiency of commercial solar PV modules usually ranges between ____________________.

**C. Short and Long Answer Questions**

1. What is a solar panel and how does it work?
2. What are the main components of a solar PV panel?
3. Differentiate between monocrystalline and polycrystalline solar panels.
4. Explain the concept of Bifacial Solar PV Panels.
5. What are the Standard Test Conditions (STC) for measuring PV performance?
6. What is the difference between Open Circuit Voltage ($V_{oc}$) and Short Circuit Current ($I_{sc}$)?
7. What factors affect the efficiency of a solar panel?
8. Explain the concept of Nominal Operating Cell Temperature (NOCT).

# MODULE 2 BASICS OF SOLAR ENERGY AND ELECTRICAL CONCEPTS

## MODULE OVERVIEW

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

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

## LEARNING OUTCOMES

After completing this module, students will be able to:

1. Explain the basic concept, sources, and importance of solar energy.
2. Understand fundamental principles of electricity, including current, voltage, resistance, and power.
3. Apply Ohm's Law to simple electrical circuits.
4. Identify key components and technologies used in solar photovoltaic (PV) systems.
5. Recognise and use common terminology, symbols, and units related to solar and electrical systems.
6. Describe the generation and practical applications of solar power.

## MODULE STRUCTURE

Session 1: Fundamentals of Solar Energy

Session 2: Fundamentals of Electricity

Session 3: Terminology and Definitions

# SESSION 1: FUNDAMENTALS OF SOLAR ENERGY

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

There are two main types of solar technology:

a) Photovoltaic (PV) systems, which convert sunlight directly into electricity, and
b) Solar thermal systems, which utilise sunlight for power generation and heating purposes.

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

**SOLAR RADIATION**

The sun radiates about 3.8 x $10^{26}$ Watts of power in all directions. Out of this, about **1.7 $10^{17}$ Watts** is received by the Earth. The average solar radiation outside the Earth's atmosphere is 1.35 kW/$m^2$, 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 comprise ultraviolet, visible, and infrared radiation. The amount of solar radiation that reaches any given location on 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 the sun's 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 absorb nearly all the ultraviolet radiation, and water vapour, carbon dioxide absorbs some of the energy in the infrared range. In addition, part of the solar radiation is scattered (i.e., its direction has been changed) by droplets in clouds by atmospheric molecules, and by dust particles.

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

**i. Beam Solar Radiation**

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

**ii. Diffuse Solar Radiation**

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

**iii. Total Solar Radiation**

The total solar radiation received at any point on the Earth's surface is the sum of the beam and diffuse radiation. This is referred to in a general sense as insolation at that point. More specifically, insolation is defined as the total solar radiation energy received on a horizontal surface of a unit area (e.g., 1 $m^2$) on the ground in unit time (e.g. 1 day). The various types of solar radiation are represented in the sketch in Fig. 2.1.

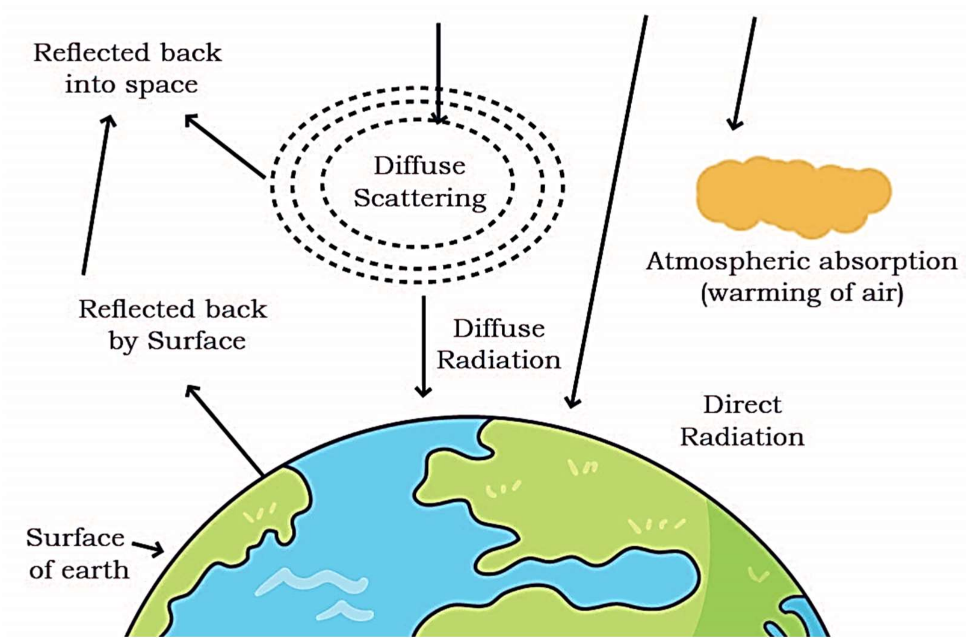



**Fig. 2.1: Direct, diffuse and total radiation**

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

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

1. **Pyrheliometer***:* - It is an instrument that measures beam radiation.

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

**SOLAR RADIATION AND PRINCIPLES**

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

**Direct Radiation**

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

**Diffuse Radiation**

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

**Reflected Radiation**

This is the radiation reflected by the ground and other physical surroundings. This distinction is very important, since some solar energy systems make use of all incoming light (e.g. PV panels), while others only use direct radiation (e.g. a solar heater with a parabolic dish). Apart from climate and the cloud cover, important factors determining global radiation are the latitude of the site, the time of the year and time of the day. 4 The time of the year and the time of the day influence the length of the sun path through the atmosphere and thus the intensity of the direct sunlight. The intensity is highest when the sun is perpendicular above the solar collector. Knowledge of the sun path from day to day and season to season is also required to optimise the orientation and tilting of the device.

**SOLAR ENERGY DATA**

***Solar Irradiance***

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

***Insolation***

Insolation (incident solar radiation) is a measure of the solar energy received on a specific area over a specific period, normally an hour or a day. It is measured in $kWh/m^2$ /day or $MJ/m^2$ /day. By knowing the insolation levels of a particular region, we can determine the size of the solar collector that is required. An area with poor insolation levels will need a larger collector than an area with high insolation levels.

**MEASUREMENT OF SOLAR RADIATION**

Solarimeter is a general term used to describe solar radiation measuring devices. Instruments, which measure global radiation, are called pyranometers and 5 pyrheliometer is used for measuring direct radiation. Sunshine recorders are used to record the sunshine hours.

**HOW SOLAR CELLS CREATE SOLAR POWER**

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

**ACTIVITY**

**Measure the Power of the Sun (Simple Solar Irradiance Test)**

**Objective:** To understand how sunlight intensity changes with time and angle.

**Materials Required:**

- Small solar panel (from a solar toy or calculator)
- Multimeter (to measure voltage)
- Notebook and pencil
- Protractor (optional)

**Procedure:**

1. Connect the solar panel to the multimeter.
2. Place the panel flat under direct sunlight and note the voltage reading.
3. Tilt the panel at different angles (0°, 30°, 60°) and note how the voltage changes.
4. Repeat the readings in the morning, noon, and evening.
5. Record observations in a table.

**Learning Outcome:** Students learn how the **angle of sunlight** and **time of day** affect solar power generation.

## CHECK YOUR PROGRESS

### A. Multiple Choice Questions

**1.** Solar energy is obtained from the:

a) Wind
b) Moon
c) Sun’s radiation
d) Water

**2.** The device used to measure **beam (direct) radiation** is called:

a) Pyranometer
b) Pyrheliometer
c) Solarimeter
d) Sunshine recorder

**3.** The process in which hydrogen fuses into helium in the Sun is called:

a) Combustion
b) Nuclear fusion
c) Evaporation
d) Radiation

**4.** Diffuse radiation is caused by:

a) Reflection and scattering in the atmosphere
b) Direct sunlight hitting the Earth
c) Light from stars
d) Sunlight passing through water

**5.** The total solar radiation received on Earth’s surface is called:

a) Global radiation
b) Beam radiation
c) Sky radiation
d) Heat radiation

### B. Fill in the Blanks

**1.** Solar energy is a ________ and abundant source of energy.

**2.** The average solar radiation outside the Earth’s atmosphere is about ________ $kW/m^2$.

**3.** A device used to measure **total or global radiation** is called a ________.

**4.** The process by which sunlight is converted into electricity is called the _________ effect.

**5.** Solar irradiance is measured in _________ per square metre.

**C. Short and Long Answer Questions**

1. Mention two main types of solar technologies.
2. What are the three types of solar radiation?
3. Define solar irradiance and insolation.
4. What are the environmental and economic benefits of using solar energy?
5. Explain how solar cells create solar power.
6. Describe the instruments used for measuring solar radiation.
7. What factors affect the amount of solar radiation received at a place?

## SESSION 2: FUNDAMENTALS OF ELECTRICITY

Electricity is a natural force that comes into existence whenever there is a flow of electric charge between two components. When working with circuits, users need to understand some basic electrical concepts. If connections in a circuit are made incorrectly, it can cause serious harm to both people and the circuit components.
The main terms associated with electricity are as follows:

- Current
- Voltage
- Power
- Energy

**Current**

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

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

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

The electric current flows in the circuit from the positive terminal of the cell to the negative terminal, passing through the bulb and the ammeter, as shown in Fig. 2.2.

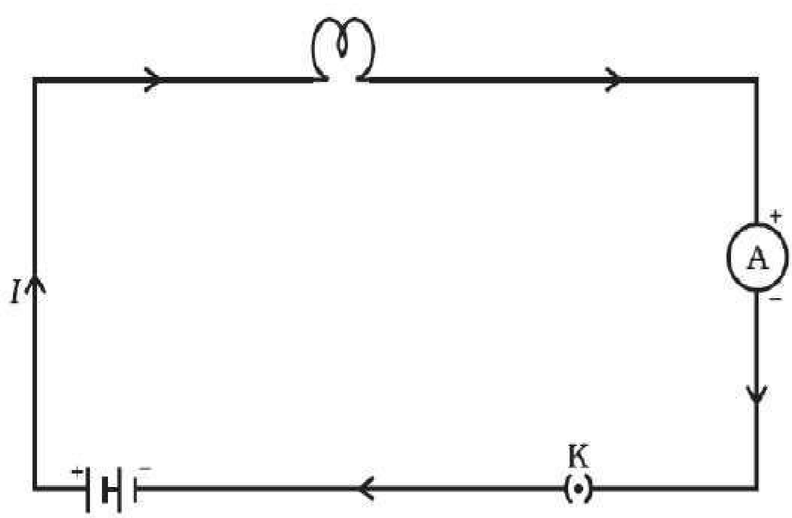



**Fig. 2.2: Shows a Simple Electric Circuit that includes a Cell, an LED Bulb, an Ammeter, and a Plug Key.**

**Direct Current (DC) and Alternating Current (AC)**

AC is defined by its frequency. In India, the frequency of Alternating Current (AC) is 50 Hertz, meaning it completes 50 cycles every second. In countries like the USA and Canada, the AC frequency is 60 Hertz, as shown in Fig. 2.3.

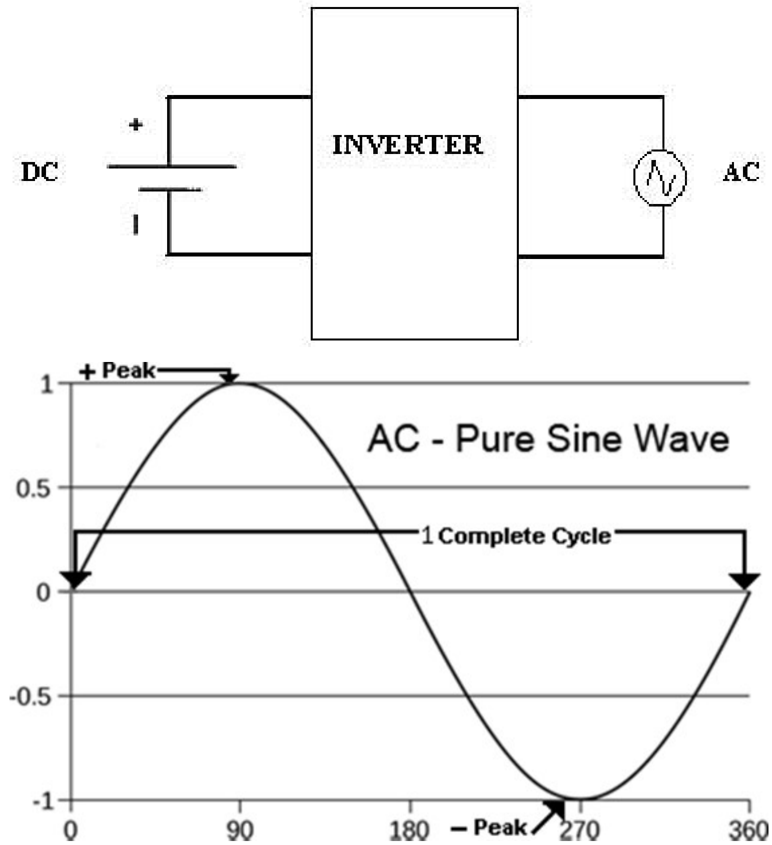



**Fig. 2.3: Shows the waveforms and circuits for Alternating Current and Direct Current.**

**Voltage**

What causes electric charge to flow?

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

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

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

**Single Phase and Three Phase Voltage**

As mentioned, current flows because of the voltage difference between two points. If the voltage source creates direct current (DC), it is called DC voltage. If the source creates alternating current (AC), it is called AC voltage. AC became more popular in the late 19th century because it was a more cost-effective option compared to DC. The connection of load to a three-phase supply, is shown fig. 2.4.

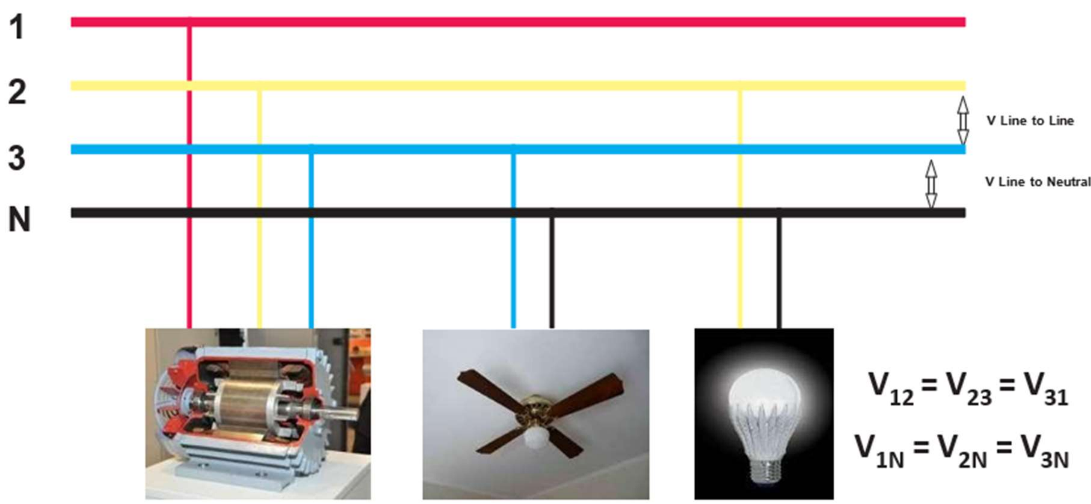



**Fig. 2.4: Connection of load to a three-phase supply (Three-phase, four-wire system)**

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

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

**Power**

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

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

**P= 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 locations. 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 a product of the power of the electrical appliance and the 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**

**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 a joule (J).

One joule of energy is equal to the work done by applying a force of 1 Newton 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, the energy consumed 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 |

**Ohm's Law**

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

**Activity:**

1. Set up a circuit as shown in Figure 2.5, consisting of a nichrome wire XY of length, say 0.5 m, an ammeter, a voltmeter and four cells of 1.5 V each. (Nichrome is an alloy of nickel, chromium, manganese, and iron metals.)

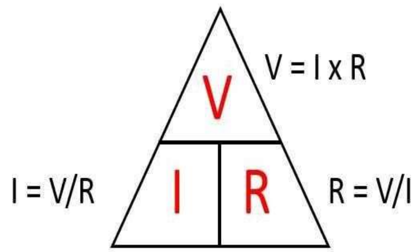



**Fig. 2.5: Ohm's triangle**

**Table 2.1: Observation Table to calculate V-I Ratio**

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

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

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

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

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

**Resistance**

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

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

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

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

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

- A component of a given size that offers low resistance is a good conductor, as shown in the figure. 2.6.
- A conductor having some appreciable resistance is called a resistor, as shown in the figure. 2.7.
- A component of identical size that offers a higher resistance is a poor conductor.
- An insulator of the same size offers even higher resistance, as shown in the figure 2.8.

| | | |
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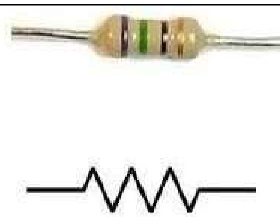
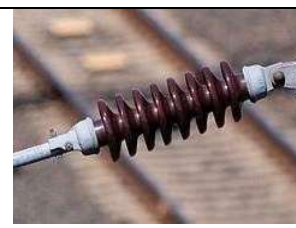
|  |  |  |
| **Fig. 2.6: Good conductor - copper wire** | **Fig. 2.7: Resistor (with symbol)** | **Fig. 2.8: Insulator – ceramic** |

**CONNECTION IN SERIES AND PARALLEL**

**A. COMBINATION OF RESISTORS**

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

**Table 2.2: Voltage across and current flowing through a system of resistors**

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

## B. SERIES

In a series combination of resistors, the current is the same in every part of the circuit or the same current through each resistor. The LED Lamps connected in series are shown in Fig. 2.9.

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

The individual voltages can be calculated as follows:

- Calculate Total/Effective resistance

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

- Calculate the Current flowing through the circuit

$$I_t = \frac{Vs}{Rt}$$

Also, $I_t=I_1=I_2=I_3= \dots =I_n$

- Calculate Voltage through each element/LED lamp:

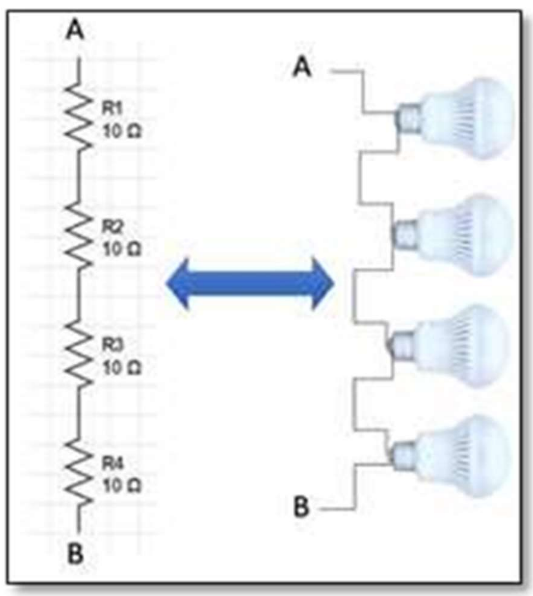



**Fig. 2.9: Series-connected LED lamps**

$$V_n=I_n \times R_n$$

**Table 2.3: Voltage and Current for elements connected in series**

| | |
|---|---|
| Voltage is added in a series branch | $V_t=V_1+V_2+V_3+\dots+V_n$ |
| Current remains the same across the series branch | $I_t=I_2=I_3=I_4=\dots+I_n$ |

**PARALLEL**

Now, let us consider the arrangement of three resistors joined in parallel with a combination of cells (or a battery). The LED Lamps connected in parallel are shown in Fig. 2.10.

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

The individual current through elements can be calculated as follows:

- Calculate Total/Effective resistance

  $1/R_t = 1/R_1 + 1/R_2 + 1/R_3 \ldots \ldots . + 1/R_n$

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

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

- Calculate current through individual element as follows:

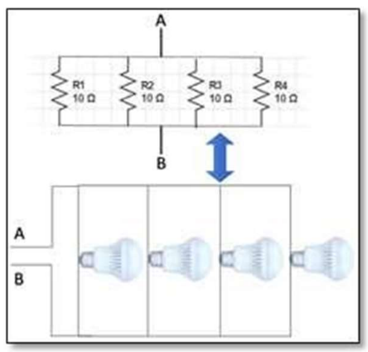



**Fig. 2.10: Parallel-connected LED lamps**

$I_n = V_s / R_n$

**Table 2.4: Voltage and Current for elements connected in Parallel**

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

1. We have seen that in a series circuit, the current is constant throughout the electric circuit. Thus, it is obviously impracticable to connect an electric bulb and an electric heater in series, because they need currents of widely different values to operate properly.
2. Another major disadvantage of a series circuit is that when one component fails the circuit is broken and none of the components works.
3. On the other hand, a parallel circuit divides the current through the electrical

gadgets. The total resistance in a parallel circuit is decreased. This is helpful, particularly when each gadget has different resistance and requires a different current to operate properly.

4. All household circuits and appliances are connected in Parallel. Hence, they all operate at the same voltage. The total current requirement of a house is the sum of the individual currents required for each appliance.

## ACTIVITY

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

## CHECK YOUR PROGRESS

**A. Multiple Choice Questions (MCQs)**

1. The unit of electric current is:
a) Volt (V)
b) Ohm (Ω)
c) Ampere (A)
d) Watt (W)

2. Which device is used to measure voltage in a circuit?
a) Ammeter
b) Rheostat
c) Voltmeter
d) Galvanometer

3. In India, the frequency of alternating current (AC) is:
a) 40 Hz
b) 50 Hz
c) 60 Hz
d) 100 Hz

4. The relationship between voltage, current, and resistance is given by:
a) $P = V/I$
b) $R = V/I$
c) $V = IR^2$
d) $I = P/V$

5. The electricity we receive at home is:
a) DC Supply

b) AC Supply
c) Mixed Supply
d) Constant Voltage Supply

**B. Fill in the Blanks**

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

**C. Answer the following Questions**

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

## SESSION 3: TERMINOLOGY AND DEFINITIONS

1. **Irradiance ($W/m^2$):** Irradiance is the solar energy that reaches the Earth's surface per unit area.
2. **Insolation or Irradiation ($Wh/m^2$):** Insolation or irradiation is the total solar energy received by the Earth's surface over a specific time period.
3. **Solar Constant:** The solar constant is the amount of energy that hits a 1 $m^2$ area of the Earth's atmosphere each second, when the Earth is at its average distance from the sun. This value is 1367 $W/m^2$.
4. **Direct Normal Irradiance ($W/m^2$):** This is the solar radiation that reaches the Earth's surface without being absorbed or scattered.
5. **Beam Radiation ($W/m^2$):** This is the cosine component of the Direct Normal Irradiance, is shown in Fig. 2.11.

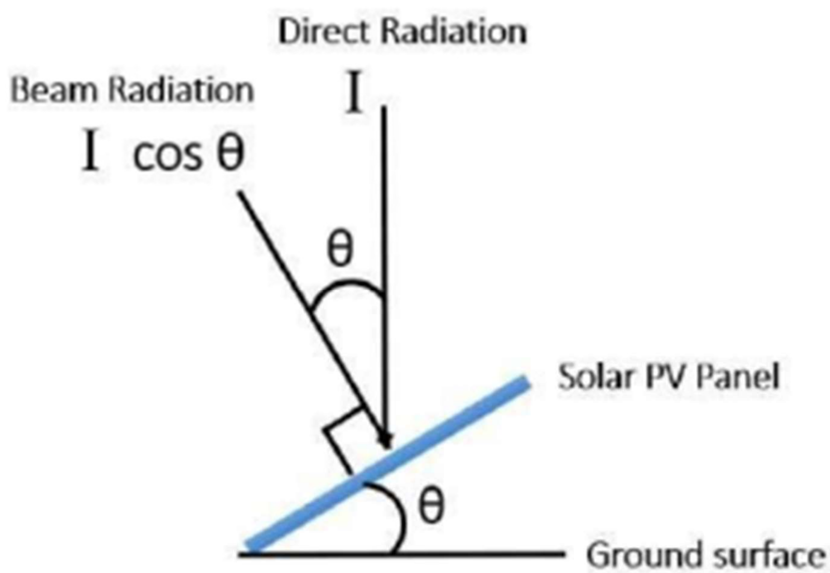



**Fig. 2.11: The cosine component of direct radiation is called 'Beam Radiation**

6. **Diffused horizontal irradiance ($w/m^2$):** This is the total amount of scattered radiation.
7. **Albedo radiation ($w/m^2$):** This is the part of diffused and direct radiation that gets reflected by the Earth and other objects.
8. **Global horizontal irradiance ($w/m^2$):** This is the total of diffused radiation, direct radiation, and albedo radiation, as shown in Fig. 2.12.

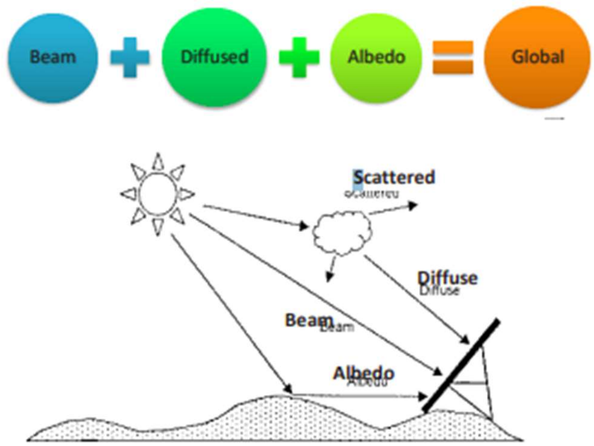



**Fig. 2.12: Global horizontal radiance is the total of all radiation (beam, diffuse and albedo) falling on the solar PV panel**

9. **Irradiance at tilted surface (w/m²):** It is defined as the radiation falling on any tilted surface.

10. **Air mass (AM):** The Air Mass is the path length that light takes through the atmosphere, normalised to the shortest possible path length (that is, when the sun is directly overhead) as shown in Fig. 2.13. The Air Mass measures the reduction in the power of light as it passes through the atmosphere and is absorbed by air and dust. In simple terms, it is defined as the distance travelled by solar radiation in Earth's atmosphere.

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

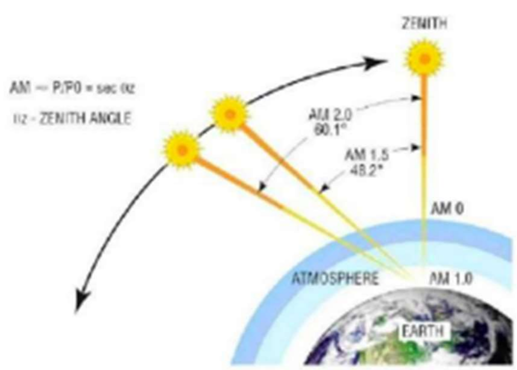



**Fig. 2.13: Air Mass**

11. **Latitude angle (or angle of latitude):** It is defined as the angle drawn between the lines joining the centre of Earth to the site with its projection on the equatorial plane. For India, it is considered to be positive. It is denoted by 'ϕ'.

12. **Solar hour angle:** It is defined as the angular measurement of time. Conventionally, it is taken as positive in the morning and negative in the afternoon. It is denoted by 'ω'.

13. **Declination angle:** It is defined as the angle drawn between the lines joining the centre of Earth to the centre of the Sun, having its projection on the equatorial plane of the Earth. It is denoted by ‘δ’. The figure of declination angle is shown in Fig. 2.14.

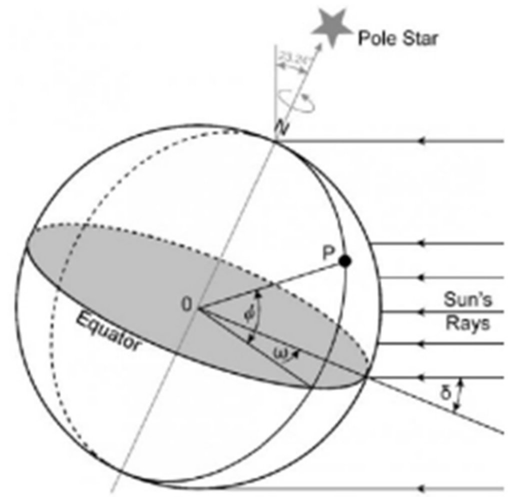



**Fig. 2.14: Declination angle**

14. **Equinox:** Literally "equal night", a day when the number of hours of daylight equals the number of hours of night. The vernal equinox, usually March 21, signals the onset of spring, while the autumnal equinox, usually September 21, signals the onset of autumn.

15. **Solstice:** A day when the sun is at the highest point in the sky (summer solstice, 21 June) or at the lowest point in the sky (winter solstice, 22 December).

16. **Azimuth angle**: It is defined as the angle between the sun’s rays and true South. A positive solar azimuth angle indicates a position East of South, and a negative azimuth angle indicates West of South, as shown in Fig. 2.15.

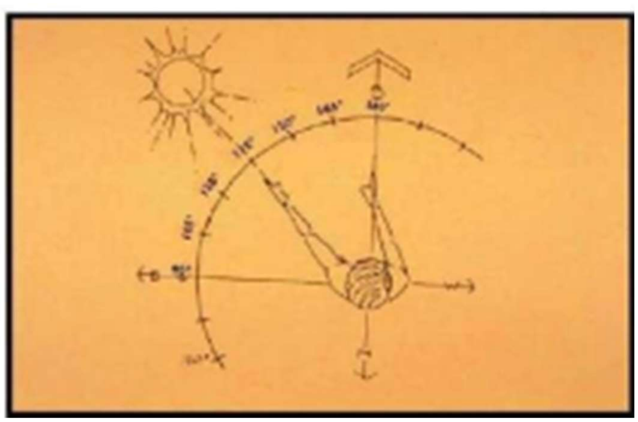


**Fig. 2.15: Sun Azimuth**

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

as shown in Fig. 2.16.

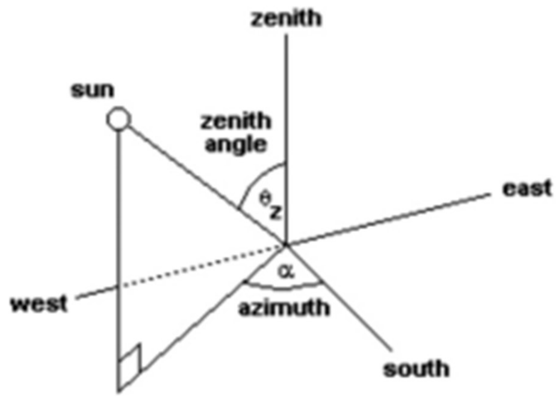



**Fig. 2.16: Zenith angle and azimuth angle**

**ACTIVITY**

**Understanding the Solar Radiation and Sun Path Diagram**

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

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

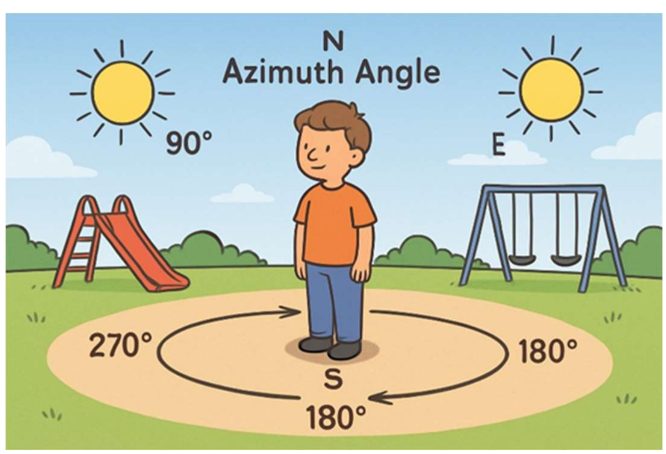
Imagine the sun is playing a game of hide and seek in the sky every day. It rises from one side, climbs up, travels across the sky, and then goes down on the other side. But here's the twist — it never takes the same path every day. The path changes with the seasons.

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

Let's break it down:

**1. Azimuth Angle – The Sun's Direction**

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



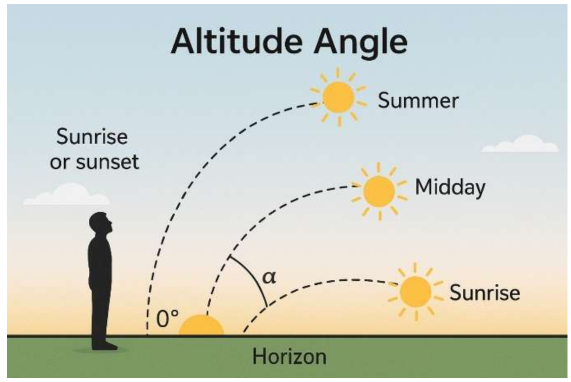

- If the Azimuth angle is 90°, the sun is in the east.

- If it’s 180°, it's directly south.
- If it's 270°, the sun is in the west.

It’s like asking: “Which way should I turn to see the sun?”

**2. Sun Height – How High is the Sun?**

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



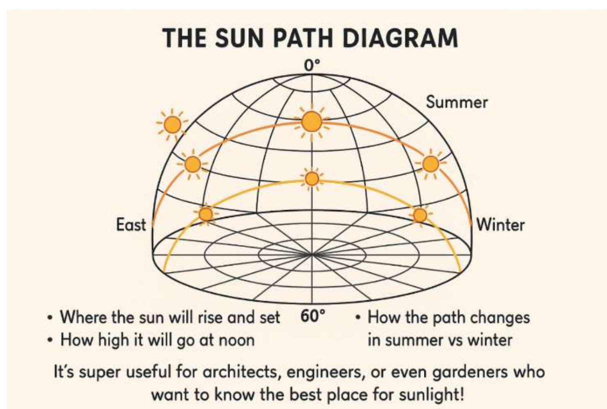

That’s where Sun Height (also called Altitude Angle) comes in. It tells you how far above the horizon the sun is.

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

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

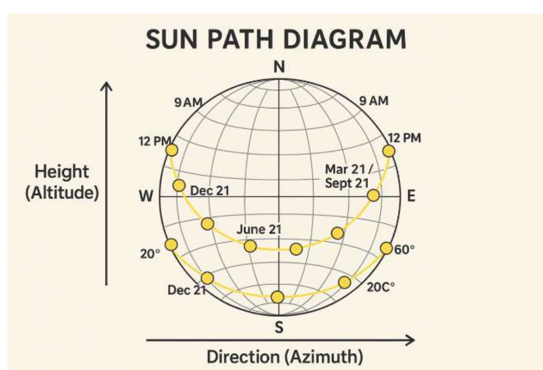
**The Sun Path Diagram**

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




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

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




**Think of it like this:**

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

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

**Tilt Angle and the Cosine Effect**

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

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

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

**The Role of Tilt Angle**

To get the best energy output, we don't keep solar panels flat all the time. Instead, we tilt them so that they can face the sun more directly during the year, as shown in Fig. 2.17.

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

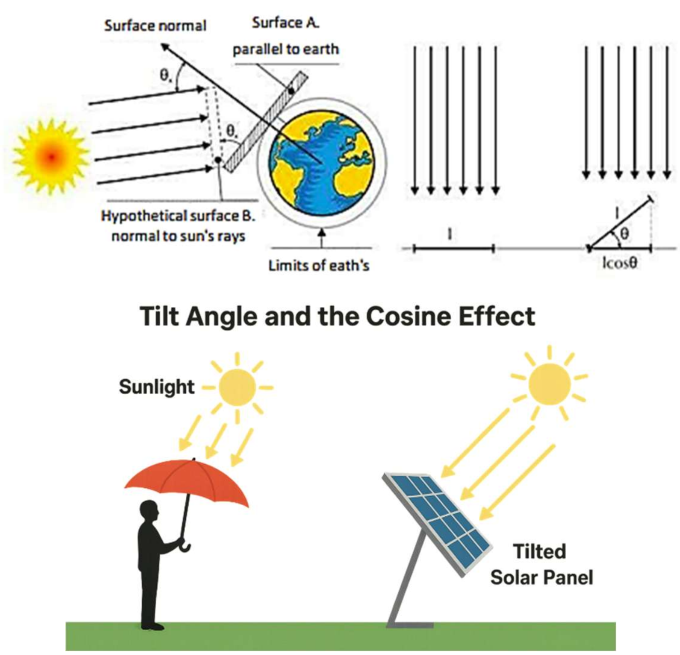



**Fig. 2.17: Optimal Tilt Angle**

To illustrate, India lies between the latitudes: 80’0” N to 360’0” N. For example, as Delhi’s latitude is 28.60 N, the tilt angle of the solar panel will be shown in Fig. 2.18.

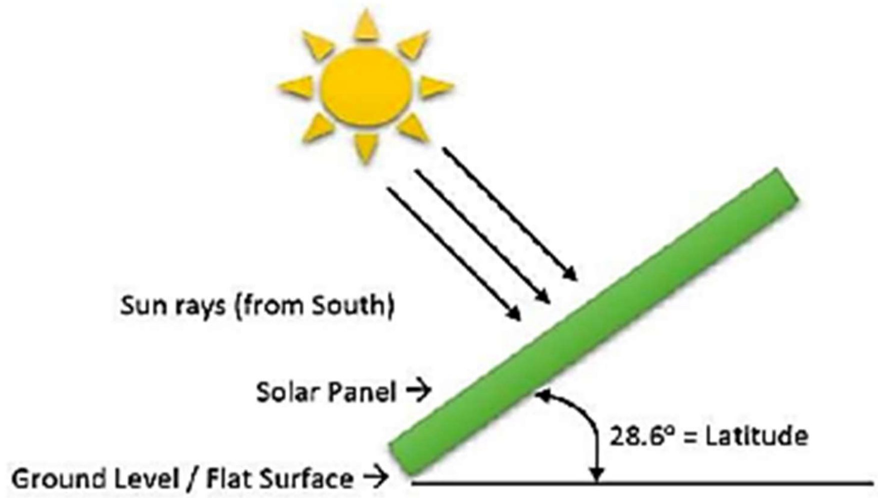



**Fig. 2.18: Latitude angle**

## KNOW YOUR PROGRESS

### A. Multiple Choice Questions

1. The total solar energy received by the Earth’s surface over a period of time is called:

a) Irradiance
b) Insolation
c) Albedo radiation
d) Air mass

2. The Air Mass (AM) of sunlight when the sun is directly overhead is:

a) AM 0
b) AM 1
c) AM 2
d) AM ∞

3. The angle between the sun’s rays and the vertical is called:

a) Latitude angle
b) Declination angle
c) Zenith angle
d) Azimuth angle

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

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

**B. Fill in the Blanks**

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

**C. Short Answer Type Questions**

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

| MODULE 3 | INTRODUCTION OF SOLAR EV CHARGING STATION |
|---|---|

## Module Overview

Solar EV charging stations use solar panels to create clean energy for charging electric vehicles (EVs). This helps reduce our dependence on traditional power sources and lowers carbon emissions. These stations meet the growing demand for electric vehicles and promote clean energy in transportation, making them attractive to environmentally conscious consumers and businesses. They can be set up in many places, like parking lots and residential areas, providing easy charging options while using spaces that aren't often used. As technology advances and costs go down, the increase in solar EV charging stations will be important for encouraging more people to adopt electric vehicles.

## Learning Outcomes

After completing this module, students will be able to:

- Describe the roles and responsibilities of a Junior Technician – Solar EV Charging Station.
- Identify and explain the main components of a Solar EV Charging Station, such as solar panels, inverters, batteries, and charge controllers.
- Understand the working principles and interconnection of different components in the system.

## Module Structure

Session 1: Role and Responsibility of Junior Technician – Solar EV Charging Station

Session 2: Components of Solar EV Charging Station

## SESSION 1: ROLE AND RESPONSIBILITY OF JUNIOR TECHNICIAN – SOLAR EV CHARGING STATION

A Junior Technician at a Solar EV Charging Station plays a vital role in ensuring the smooth and safe operation of the system. Their work combines knowledge of solar energy, electrical systems, and EV charging technologies.

**Key Roles and Responsibilities**

a) System Installation Support: Assist in the installation of solar panels, inverters, batteries, and EV chargers as per technical guidelines.
b) Routine Inspection: Regularly check the condition of panels, wiring, connectors, and chargers to ensure efficient functioning.
c) Operation Monitoring: Observe energy generation and consumption data, and report any irregularities to the supervisor.
d) Maintenance and Cleaning: Clean solar panels, tighten connections, and replace minor faulty components to maintain performance.
e) Safety Compliance: Follow all safety rules while handling electrical components and charging systems to prevent hazards.
f) Customer Assistance: Help users understand charging procedures and basic troubleshooting steps.
g) Record Keeping: Maintain logs of daily operations, maintenance activities, and energy performance reports.
h) Sustainability Promotion: Encourage the use of renewable energy and spread awareness about eco-friendly transport solutions.


**Fig. 3.1: Key Roles and Responsibilities**

## JOB OPPORTUNITY

With the rapid growth of Electric Vehicles (EVs) and renewable energy, the demand for skilled technicians in solar-powered EV charging systems is rising quickly. A Junior Technician in this field has a wide range of exciting career paths and opportunities ahead.

- Solar EV Charging Station Technician – Work at public or private EV charging stations to maintain and operate solar-integrated systems.
- Solar PV Technician – Install and service solar panels used in charging infrastructure and other solar energy systems.
- EV Charging Equipment Installer – Specialises in setting up and testing various types of EV chargers.
- Maintenance Technician (Renewable Energy) – Ensure smooth operation of solar and battery systems at energy sites.
- Technical Assistant (EV Projects) – Support engineers in planning and implementing EV charging projects.
- Service Technician (Automotive EV Sector) – Work in EV workshops handling charging, battery maintenance, and energy systems.
- Solar EV Charging Entrepreneur: Establishment and operation of EV charging Stations.

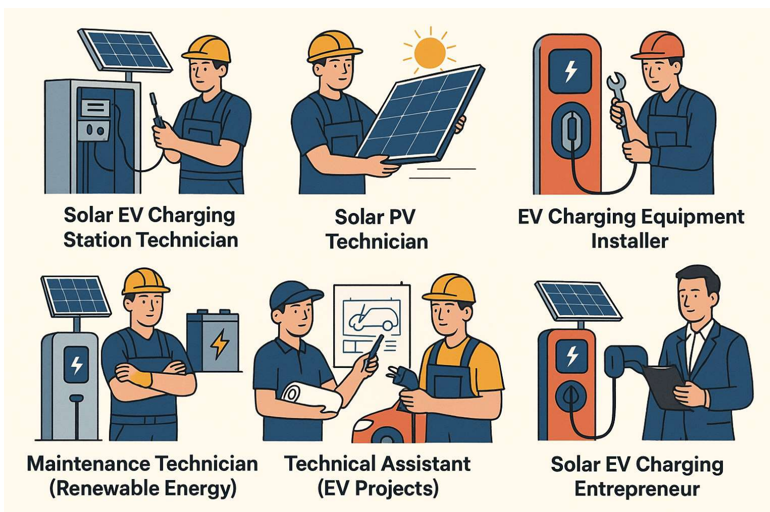



**Fig. 3.2: Job Opportunity**

### Basic Skills and Knowledge of a Solar-Powered EV Charging Junior Technician

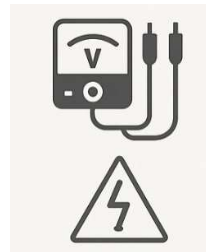
A Solar-Powered EV Charging Junior Technician plays a vital role in installing, maintaining, and operating solar-based electric vehicle (EV) charging systems. This position requires a combination of technical skills, electrical knowledge, and practical field experience to ensure safe and efficient performance of the system.

Below is a detailed discussion of the basic skills, knowledge, and responsibilities required for this role:

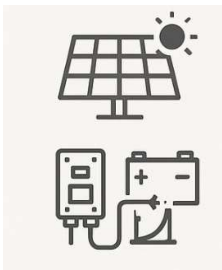
### 1. Basic Knowledge Requirements

A Junior Technician will have a fundamental understanding of the following areas:

#### a. Electrical Systems




- Basic concepts of voltage, current, resistance, and power.
- Safe handling of AC and DC electrical circuits.
- Knowledge of wiring, earthing, fuses, circuit breakers, and protection systems.



#### b. Solar Power Systems

- Working principle of solar photovoltaic (PV) systems.
- Components of a solar plant — solar panels, inverters, charge controllers, and batteries.
- Understanding of solar energy conversion and maximum power point tracking (MPPT).

### 2. Basic Technical and Practical Skills

A Junior Technician must possess both hands-on skills and the ability to work safely in technical environments.

#### a. Installation Skills

- Mounting and alignment of solar panels on rooftops or ground structures.
- Connecting PV modules, inverters, and batteries as per circuit design.
- Installing EV chargers and ensuring proper grounding and protection.


#### b. Testing and Maintenance Skills

- Using measuring tools such as a multimeter, clamp meter, insulation tester, and solar power meter.
- Inspecting cables, connectors, fuses, and breakers for wear or damage.
- Performing periodic maintenance of PV modules, cleaning panels, and checking inverter performance.

- Diagnosing common faults in electrical and charging systems.

**c. Safety and Compliance Skills**

- Following electrical safety standards (e.g., IS/IEC 60364, IS 17017 for EV charging).
- Applying Lockout-Tagout (LOTO) and other safety procedures during maintenance.
- Understanding of fire and electrical shock prevention.

**d. Documentation and Reporting**

- Recording installation and maintenance activities.
- Preparing inspection checklists, test reports, and fault logs.
- Communicating findings to senior technicians or engineers.


**3. Core Responsibilities**

The Junior Technician's duties typically include both technical operations and support tasks in the field.

**a. Installation Responsibilities**

- Assist in setting up solar panels, inverters, and mounting structures.
- Help in wiring and connection of the solar plant and EV chargers.
- Support in integrating solar systems with the power grid and battery storage.
- Ensure proper alignment, orientation, and connectivity of all components.

**b. Maintenance Responsibilities**

- Regular inspection and cleaning of solar panels to maintain efficiency.
- Checking battery health, charging cycles, and BMS data.
- Inspecting charger connectors, cables, and cooling systems.
- Reporting any faults, inefficiencies, or safety hazards immediately.

**c. Operational Responsibilities**

- Monitor system performance using monitoring software or meters.
- Ensure optimal charging performance during different sunlight conditions.
- Maintain records of energy generation, storage, and charging output.
- Assist in troubleshooting under supervision of a senior engineer.

**d. Safety and Quality Responsibilities**

- Follow all electrical and site safety protocols.
- Use personal protective equipment (PPE) during work.
- Ensure compliance with national and local electrical standards.
- Maintain cleanliness and order at the work site.

**4. Interpersonal and Professional Skills**

Apart from technical abilities, a Junior Technician should demonstrate:

- Teamwork: Ability to work under supervision and coordinate with engineers and co-workers.
- Communication: Clear reporting of technical issues and updates.
- Problem-Solving Attitude: Basic analytical thinking for diagnosing faults.
- Time Management: Efficiently completing tasks within given schedules.
- Adaptability: Willingness to learn new technologies like smart charging and IoT-based systems.

**CHECK YOUR PROGRESS**

**A. Multiple Choice Questions**

**1.** Which of the following is **not** a responsibility of a Junior Technician at a Solar EV Charging Station?

a) Assisting in the installation of solar panels and EV chargers
b) Performing regular inspection and cleaning of solar panels
c) Designing the complete solar plant layout
d) Helping customers understand charging procedures

**2.** A Junior Technician must follow safety procedures such as _________ during maintenance work.

a) Earthing and grounding
b) Lockout-Tagout (LOTO)
c) High-voltage testing only
d) Using bare hands to test wires

**3.** Which of the following tools is used to measure electrical current and voltage?

a) Screwdriver
b) Clamp meter
c) Hammer
d) Spanner

**4.** The Junior Technician helps promote sustainability by:

a) Encouraging the use of renewable energy and eco-friendly transport
b) Increasing use of fossil fuels
c) Reducing the number of charging stations
d) Disconnecting solar panels during the daytime

**B. Fill in the Blanks**

1. The main role of a Junior Technician at a Solar EV Charging Station is to ensure ______________ and ____________ operation of the system.
2. Basic electrical concepts such as voltage, current, resistance and ________________ are essential for a Junior Technician to understand.
3. A Junior Technician must maintain logs of daily ____________________, maintenance activities, and energy performance reports.
4. During installation, the Junior Technician ensures proper alignment, orientation, and ___________ of solar panels and chargers.

**C. Short Answer Questions**

1. Explain any **three safety responsibilities** of a Junior Technician working at a Solar EV Charging Station.
2. List **four career opportunities** available for a Junior Technician in the Solar EV Charging field.

## SESSION 2: COMPONENTS OF SOLAR EV CHARGING STATION

As the world is shifting to sustainable transportation, Electric Vehicles (EVs) are a key solution to reduce fossil fuel dependence and greenhouse gas emissions. The environmental benefits of EVs depend on the electricity used for charging, highlighting the importance of solar-based EV charging stations.

These stations generate clean, renewable electricity from sunlight, significantly lowering carbon emissions compared to traditional grid sources. Once installed, solar panels operate at low costs, helping EV owners save on fuel and electricity expenses.

A Solar EV Charging Station is a system that uses solar energy to charge electric vehicles. Solar charging stations can serve remote or off-grid areas, making them ideal for rural regions and locations with unreliable power. By promoting sustainability and energy security, these stations support national renewable energy goals while meeting the increasing demand for EV charging infrastructure.

**Concept of EV Charging System**

An Electric Vehicle (EV) Charging System is a setup that provides electrical energy to recharge the batteries of electric vehicles. Just as conventional vehicles require fuel from petrol or diesel stations, electric vehicles require electricity to run, which is supplied through a charging system.

The EV charging system serves as a bridge between the power source (grid or renewable energy) and the battery of the electric vehicle. Its main function is to ensure that electricity is delivered safely, efficiently, and in the right form (voltage and current) for charging the EV's battery.

An Electric Vehicle (EV) charging station is a system designed to deliver electrical energy safely and efficiently from a power source to an electric vehicle's battery, as shown in Fig. 3.3. It includes several interconnected components that work together to control, convert, and monitor the charging process.

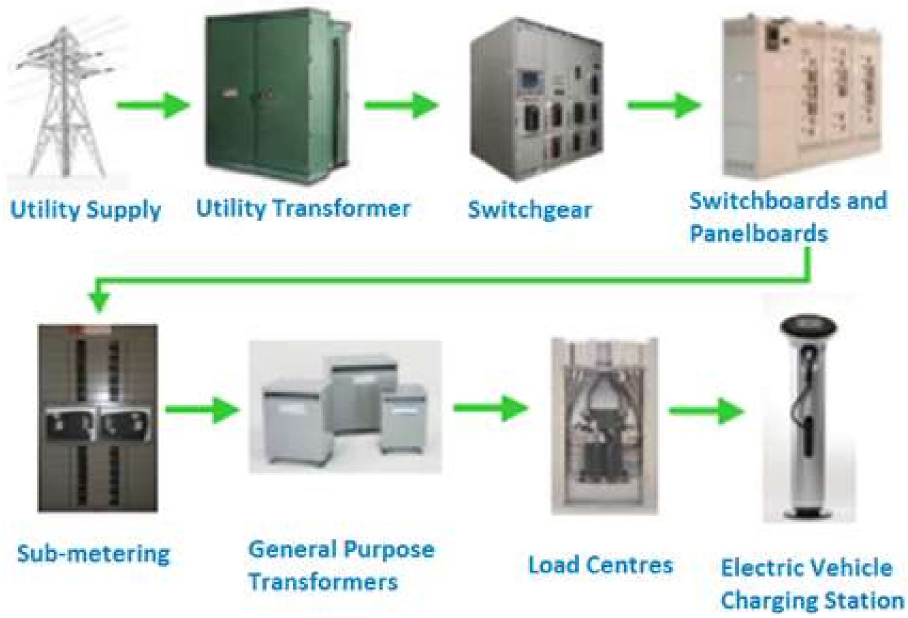



**Fig. 3.3: Process of Solar EV Charging Station**

Let's discuss the key components of an EV charging station and their basic functions:

1) Power Supply System
2) Distribution panel
3) Electric Vehicle Supply Equipment
4) Power Converter/ rectifier
5) Charging connectors and cables
6) Control and Communication System
7) User Interface (Display and Input System)
8) Metering and Billing System
9) Cooling and Thermal Management System
10) Enclosure and Mounting Structure
11) Network and Cloud Connectivity (Smart Charging System)

1. **Power Supply System:** The power supply system is the main source of electrical energy for the electric vehicle (EV) charging station shown in Figure. 3.4. This energy can come from several sources, including the utility power grid, which delivers electricity from large power plants, renewable energy systems like solar panels that harness sunlight, or battery storage systems that store energy for later use.

   The system supplies the necessary energy to recharge electric vehicles efficiently and reliably. It maintains a consistent voltage and frequency to ensure that the charging unit operates safely and effectively without damaging the vehicle's battery. The system is designed to handle variations in power supply, ensuring that the charging process continues smoothly even if there are brief disruptions in the electrical supply.

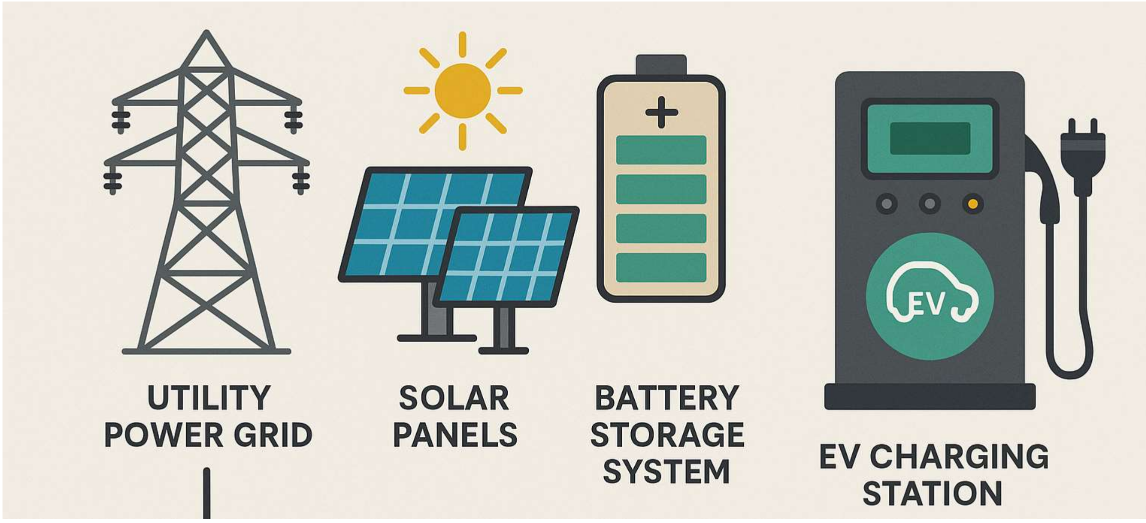



**Fig. 3.4: The Power Supply System for the Electric Vehicle (EV) Charging Station**

## 2. Distribution Panel (Switchgear and Protection Devices)

A collection of electrical panels, circuit breakers, fuses, and switches are essential for controlling and protecting the power flow in a charging station, as shown in Fig. 3.5.

This system controls and distributes electricity effectively to each charging point, ensuring that power is delivered where needed. It safeguards equipment against potential hazards such as overloads, short circuits, or electrical faults, thereby preventing damage and ensuring longevity. The system is designed to ensure safe and reliable operation, which is essential for maintaining the overall functionality of the charging station.

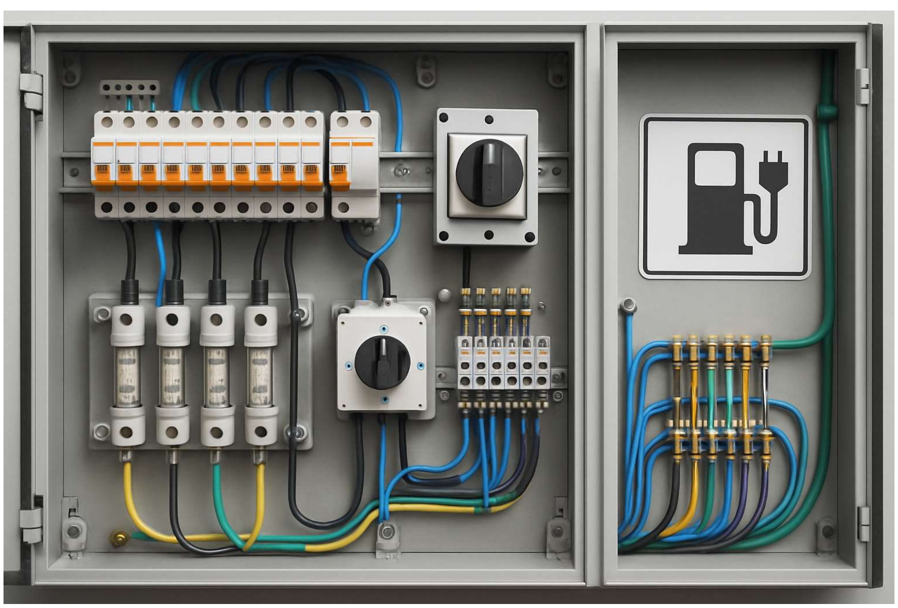


**Fig. 3.5: Distribution Panel**

### 3. EVSE (Electric Vehicle Supply Equipment)

EVSE is the main charging unit or charger body that connects the vehicle to the power source, as shown in Fig. 3.6. It includes both hardware and software components for charging control. Its functions are to: -

- Regulate the flow of electricity to the vehicle.
- Monitor charging parameters like voltage, current, and temperature.
- Communicate with the EV to ensure compatibility and safety.
- Provide user interface and safety features such as automatic shut-off.


**Fig. 3.6: The main components of an EV high-power charging infrastructure.**

| | | |
|---|---|---|
| 1. Charger | 2. Charging cable | 3. Cooling unit |
| 4. DC charging controllers | 5. DC power electronics and distribution | 6. DC energy meter |

### 4. Power Converter / Rectifier

The power converter converts the type of electrical power depending on the charging system. In AC chargers, the conversion (AC to DC) happens inside the vehicle. In DC chargers, conversion occurs externally in the charging station, as shown in Fig. 3.7. Its functions are to:

- Convert AC (Alternating Current) into DC (Direct Current) for the EV battery.

- Control voltage and current levels for optimal charging.
- Ensure efficiency and protection from power losses.

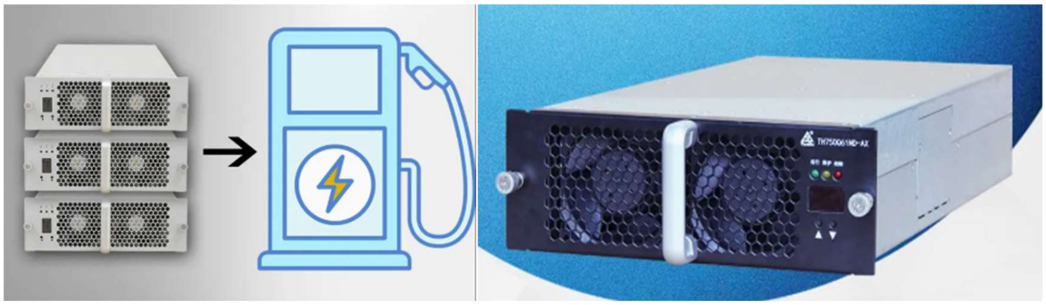


**Fig. 3.7: Rectifier of EV Charging Station**

### 5. Charging Connector and Cable Assembly

The physical link between the charging station and the electric vehicle. It consists of a charging cable and a connector plug that fits into the vehicle's charging port, as shown in Fig. 3.8. Some of its functions are:

- Transfers power safely from the station to the EV.
- Provides data communication signals between the charger and vehicle.
- Includes locking mechanisms for safety during charging.
- Uses different connector types depending on standards.


**Fig. 3.8: charging cable and a connector plug**

### 6. Control and Communication System

An electronic system that manages charging operations and ensures communication between the charger, the vehicle, and sometimes the grid, as shown in Fig. 3.9. Some of its functions are:

- Facilitation of real-time data exchange (e.g., charging status, energy flow, temperature).
- Supporting smart charging features such as load management and remote monitoring.
- Enabling communication protocols like OCPP (Open Charge Point Protocol) or CAN bus.
- Ensuring interoperability with different EV models.


**Fig. 3.9: Control and Communication System**

## 7. User Interface (Display and Input System)

The front-end system through which users interact with the charging station, as shown in Fig. 3.10. Some of its functions are:

- Displaying charging information (power level, duration, cost, etc.).
- Allowing users to start, stop, or schedule charging sessions.
- Providing access control through RFID cards, mobile apps, or QR codes.

- Enhancing user experience through easy navigation and visual indicators (LED lights).


**Fig. 3.10: User Interface (Display and Input System)**

## 8. Metering and Billing System

Integrated energy meter and billing software are used for monitoring energy consumption and cost calculation, as shown in Fig. 3.11. Some of its functions are given below:

- Measuring the total electrical energy consumed during charging.
- Generating usage records for billing and reporting.
- Helping operators manage payments through online or prepaid systems.

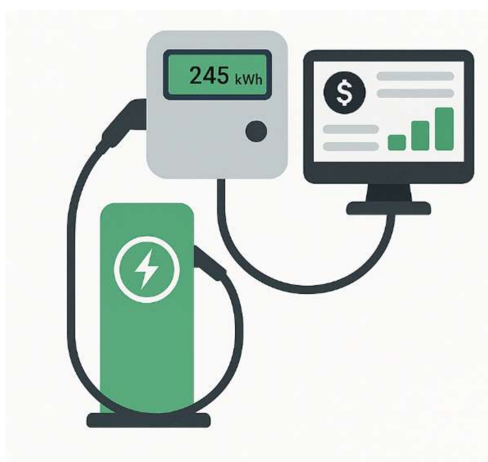



**Fig. 3.11: Energy Meter and Billing Software**

## 9. Cooling and Thermal Management System

High-power DC chargers generate heat during operation, so a cooling system is used to maintain optimal temperature. Some of its functions are given below:

- Preventing overheating of electrical components and cables, like plastic tubes, as shown in Fig. 3.12 (a).
- Enhancing system efficiency and longevity.
- Using air or liquid cooling, depending on charger capacity, as shown in Fig. 3.12 (b).

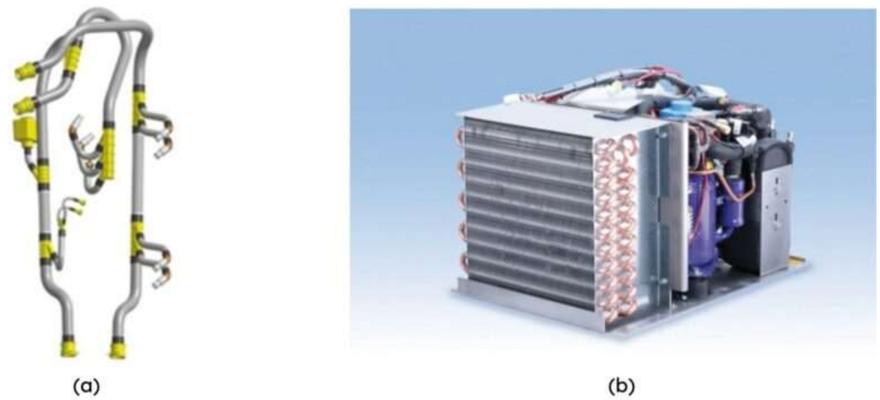



**Fig. 3.12: The power cooling units in EV charging stations, using: (a) plastic tubes; and (b) a cooling system.**

**10. Enclosure and Mounting Structure**

The physical casing or cabinet that houses all the electrical components. It can be wall-mounted, floor-standing, or pole-mounted, as shown in Fig. 3.13. Some of its functions are:

- Protecting components from dust, moisture, and weather conditions.
- Ensuring user safety by preventing accidental contact with live parts.
- Providing durability and aesthetic design for public or private use.

**Fig. 3.13: Mounting Structure**

**11. Network and Cloud Connectivity (Smart Charging System)**

Modern charging stations are connected to cloud-based platforms for monitoring and management, as shown in Fig. 3.14. Some of its functions are:

- Enables remote monitoring of charger performance and maintenance.
- Allows data analytics for usage patterns, fault detection, and load balancing.
- Supports integration with renewable energy sources and grid management systems.

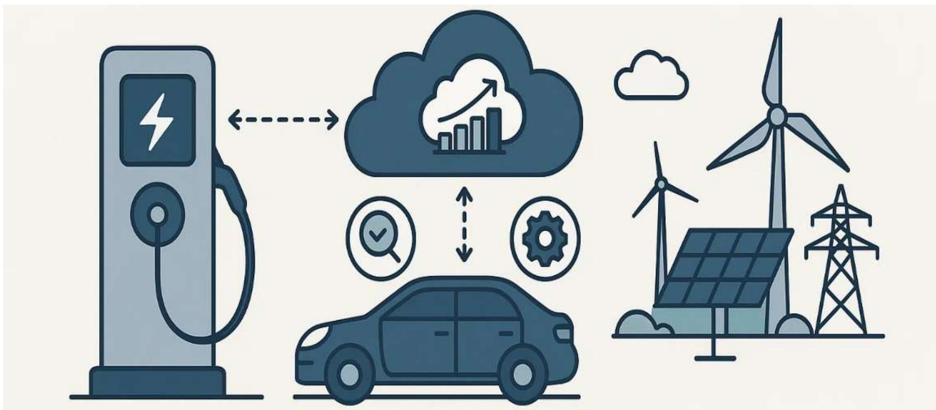


**Fig. 3.14: Network and Cloud Connectivity (Smart Charging System)**

**12. Onboard Charger:** Located inside the EV, it converts AC (Alternating Current) from the charger into DC (Direct Current) that the battery can store. In fast chargers, this conversion is done externally (off-board), as shown in Fig. 3.15.

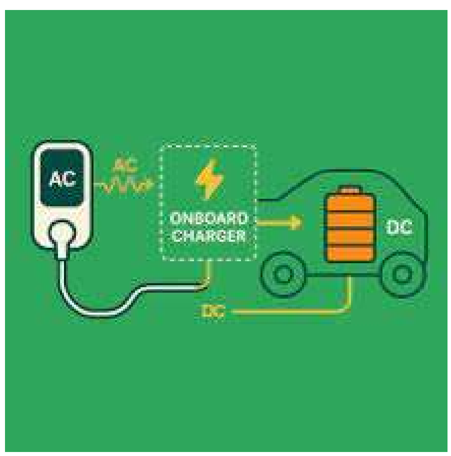



**Fig. 3.15: Onboard Charger**

**13. Battery Management System (BMS)**: The BMS monitors and controls battery charging and discharging to ensure safety, efficiency, and battery longevity. It prevents overcharging, overheating, or damage to the battery, as shown in Fig. 3.16.

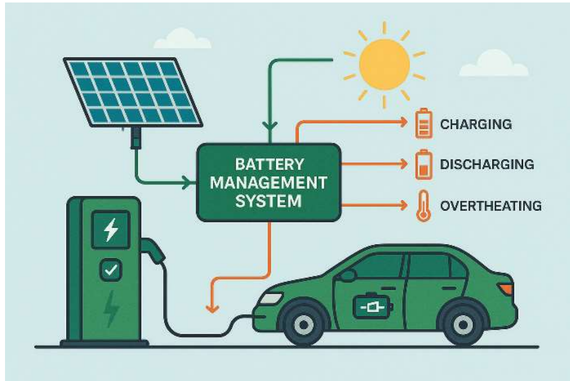



**Fig. 3.16: Battery Management System (BMS)**

**Working Principle of an EV Charging System**

Electric Vehicles (EVs) connect to charging stations using appropriate connectors, which facilitate the flow of electricity. To ensure compatibility and safety, the charging station communicates with the vehicle before initiating the charging process. Once compatibility is confirmed, the station begins supplying power, which can be either alternating current (AC) or direct current (DC), as shown in Fig. 3.17.

The power supplied is then converted into a suitable form for the vehicle's battery by an onboard or offboard charger. Throughout the charging process, the Battery Management System (BMS) plays a crucial role by continuously monitoring essential parameters such as voltage, current, and temperature.

Charging will automatically halt once the battery reaches its full capacity or if any faults or irregularities are detected, ensuring safe and efficient operation.

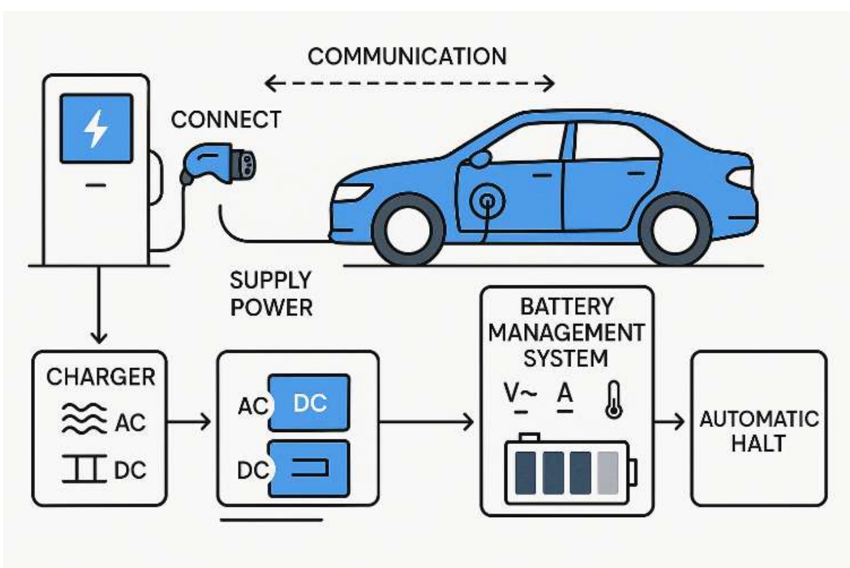



**Fig. 3.17: Working process of EV charging system**

## Types of EV Charging Systems and Their Functionality

Electric Vehicle (EV) charging systems can be categorised based on charging speed, type of current (AC or DC), and location of installation. Each type of system has its own features, applications, and levels of power delivery, as shown in Fig. 3.18.

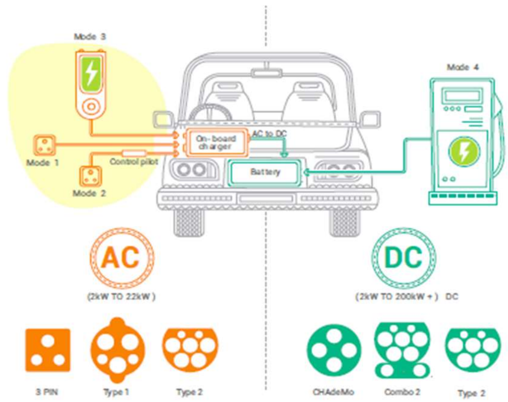



**Fig. 3.18: Types of Charging Systems**

Let's understand the various types of EV charging systems and how they function:

### 1. Level 1 Charging (Slow or Basic Charging)

Level 1 charging represents the most basic form of electric vehicle (EV) charging, utilising a standard household AC socket, specifically designed for a 230V single-phase power supply as commonly found in India. This method does not necessitate any specialised installation, making it extremely accessible for most users.

To initiate Level 1 charging, the EV is connected to a conventional power outlet using the charger cable that comes with the vehicle. Inside the vehicle, the onboard charger plays a crucial role by converting the AC power sourced from the outlet into DC power to charge the battery effectively. Given the relatively low power output—typically ranging from 2 to 3 kW—this method may result in longer charging durations compared to higher-level charging alternatives.

The time required for a full charge can vary significantly based on the battery size of the EV, but it generally takes between 8 to 12 hours to reach a complete charge from a Level 1 source. This extended time frame makes Level 1 charging less suitable for quick refills but perfectly adequate for users with the luxury of overnight charging.

Level 1 charging is ideally suited for home settings where charging can occur during the night or when the vehicle is not in use for extended periods. It is an excellent option for individuals who have predictable daily driving patterns and can charge the vehicle slowly without the urgency of rapid refuelling. This method provides a convenient solution for those who prioritise ease of use over charging speed, allowing EV owners to integrate charging seamlessly into their daily routines.

**2. Level 2 Charging (Moderate or Fast AC Charging)**

Level 2 chargers are designed to supply alternating current (AC) power, typically operating at either 230V single-phase or 400V three-phase. These chargers provide a higher current output compared to Level 1 chargers, which makes them more efficient for electric vehicle (EV) charging. They require dedicated Electric Vehicle Supply Equipment (EVSE) to ensure safe and effective charging.

The charging station delivers AC power through a specific connector, commonly the Type 2 plug, which is widely adopted in Europe for electric vehicles. Once the power is supplied, the vehicle's onboard charger takes on the essential task of converting this AC power into direct current (DC) to effectively charge the vehicle's battery. Depending on the setup and the specific vehicle model, Level 2 chargers can deliver power ranging from 7 kW to 22 kW, significantly reducing charging times compared to Level 1 chargers.

Under optimal conditions, a Level 2 charger can fully charge an electric vehicle in approximately 3 to 6 hours. This charging speed makes it suitable for a variety of situations where users can park their vehicles for extended periods, such as at home overnight or during a workday.

Level 2 chargers are commonly found in various settings, including residential complexes, where they are often installed in garages or designated parking spaces, workplaces, where employees can charge their vehicles while at work, shopping malls that offer charging stations to attract environmentally conscious consumers, and public charging stations strategically located in urban areas for convenient access. This versatility makes Level 2 chargers a key component in the expansion of electric vehicle infrastructure, supporting a growing number of EV users and promoting sustainable transportation options.

**3. Level 3 Charging (DC Fast Charging or Rapid Charging)**

This charging system delivers Direct Current (DC) directly to the vehicle battery, effectively bypassing the onboard charger. It is recognised as one of the fastest and most advanced charging options available.

The charger is equipped with a built-in converter that transforms alternating current (AC) from the electrical grid into DC. Through specialised connectors—such as CCS, CHAdeMO, or GB/T—DC power is supplied directly to the vehicle's battery. The power output can vary significantly, ranging from 50 kW to 350 kW, depending on the specific type of charger being used.

The charging time generally varies between 30 minutes to 1 hour to achieve up to an 80% charge. This charging solution is particularly well-suited for commercial stations, highways, and fleet operations where quick turnaround times are essential.

**4. Ultra-Fast or Supercharging Systems**

This advanced charging solution represents the next generation of DC fast charging technology, specifically designed for high-end electric vehicles (EVs), similar to Tesla Superchargers.

The charging system operates at a voltage range of 400 to 800 volts or higher, enabling it to deliver power levels of up to 350 kW or more. With this capability, it can charge a compatible EV battery to 80% capacity in under 20 minutes. Additionally, it incorporates sophisticated thermal management and communication systems to ensure the safety and longevity of the battery during the charging process.

This technology is ideally suited for premium EV networks, facilitating long-distance travel along major corridors and express highways, making it an invaluable asset for EV owners seeking quick and efficient charging solutions during their journeys.

**5. Wireless (Inductive) Charging System**

Wireless charging employs magnetic induction to facilitate energy transfer from a charging pad on the ground to a receiver located in the vehicle, eliminating the need for conventional cables, as shown in Fig. 3.19.

The charging pad generates an electromagnetic field, which is then captured by a receiver coil in the vehicle. This coil converts the field into electrical energy, effectively charging the vehicle's battery. The system operates when the vehicle is parked directly over the pad and is properly aligned.

The charging duration is comparable to that of Level 2 AC charging.

This technology is particularly well-suited for implementation in smart cities, residential garages, or in future autonomous electric vehicles, providing a convenient and efficient charging solution.

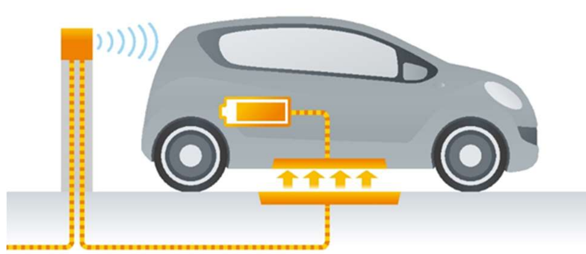


**Fig. 3.19: Wireless Ching**

### 6. Battery Swapping System (Alternative Concept)

This innovative system allows for the rapid replacement of a discharged battery with a fully charged one, eliminating the need for traditional charging methods and ensuring minimal downtime for electric vehicles (EVs).

The process begins when an EV drives into a battery swapping station. Here, an automated or manual system efficiently removes the depleted battery and replaces it with a fully charged one. Meanwhile, the removed battery is charged separately at the station, ensuring a quick turnaround for the next vehicle in need.

This battery swapping solution is particularly beneficial for two-wheelers, three-wheelers, and commercial fleets where time is of the essence and quick replacements are necessary to maintain operational efficiency, as shown in Fig. 3.20.

**Fig. 3.20: Battery Swapping System**

## CATEGORIES OF ELECTRIC VEHICLES

The electric vehicle (EV) ecosystem consists of several interconnected elements: vehicle categories, chargers, charging technologies, and battery types. Understanding these components helps in grasping how electric mobility functions as a complete system.

Electric vehicles are classified based on how they use and store electrical energy. The main categories are:

| | Battery Electric Vehicle (BEV) | Plug-in Hybrid Electric Vehicle (PHEV) | Hybrid Electric Vehicle (HEV) | Fuel Cell Electric Vehicle (FCEV) |
|---|---|---|---|---|
| Description: | Fully electric vehicles are powered entirely by rechargeable batteries. | Combines an electric motor and an internal combustion engine (ICE). | Uses both an electric motor and a fuel engine, but cannot be plugged in. | Uses hydrogen fuel cells to generate electricity onboard. |
| Power Source: | Electricity is stored in onboard batteries. | It can be charged from an external power source and also run on fuel. | Battery charges through regenerative braking and the engine. | Hydrogen gas is stored in tanks. |

| | | | | |
|---|---|---|---|---|
| Functioning | An electric motor drives the vehicle; no internal combustion engine is used. | Runs on electricity for short distances; Automatically switches to fuel when the battery is low | The electric motor assists the engine during acceleration. | The fuel cell converts hydrogen and oxygen into electricity, producing only water as a by-product. |
| Examples: | Tesla Model 3, Tata Nexon EV, MG ZS EV. | Toyota Prius Plug-in, Volvo XC90 Recharge. | Honda City e: HEV, Toyota Camry Hybrid. | Toyota Mirai, Hyundai Nexo. |

**Details of EVCS installed/energised by PSU OMCs in States / UTs**

| S. N. | State/ UTs | EV Charging Stations under FAME-II Subsidy Scheme | | Total No. of EV charging stations installed by OMCs from their own funds as on 01.01.2025 |
|---|---|---|---|---|
| | | **No. of EV Chargers installed as on 01.01.2025** | **No. of EV Charging Stations energised as on 01.01.2025** | |
| 1 | **Andaman & Nicobar** | 0 | 0 | 6 |
| 2 | **Andhra Pradesh** | 354 | 20 | 912 |
| 3 | **Arunachal Pradesh** | 2 | 0 | 52 |
| 4 | **Assam** | 83 | 2 | 448 |
| 5 | **Bihar** | 58 | 2 | 517 |
| 6 | **Chandigarh** | 0 | 0 | 23 |
| 7 | **Chhattisgarh** | 30 | 1 | 498 |
| 8 | **Delhi** | 41 | 5 | 316 |
| 9 | **Goa** | 9 | 0 | 70 |
| 10 | **Gujarat** | 312 | 50 | 1104 |
| 11 | **Haryana** | 366 | 3 | 1068 |
| 12 | **Himachal Pradesh** | 21 | 0 | 136 |
| 13 | **Jammu & Kashmir** | 23 | 0 | 170 |
| 14 | **Jharkhand** | 116 | 0 | 349 |
| 15 | **Karnataka** | 370 | 3 | 1516 |
| 16 | **Kerala** | 208 | 0 | 679 |
| 17 | **Ladakh** | 0 | 0 | 11 |
| 18 | **Lakshadweep** | 0 | 0 | 1 |
| 19 | **Madhya Pradesh** | 154 | 6 | 1114 |

| | | | | |
|---|---|---|---|---|
| 20 | **Maharashtra** | 431 | 121 | 1595 |
| 21 | **Manipur** | 8 | 0 | 57 |
| 22 | **Meghalaya** | 25 | 0 | 54 |
| 23 | **Mizoram** | 2 | 0 | 16 |
| 24 | **Nagaland** | 10 | 0 | 41 |
| 25 | **Odisha** | 114 | 0 | 661 |
| 26 | **Puducherry** | 7 | 1 | 27 |
| 27 | **Punjab** | 151 | 2 | 828 |
| 28 | **Rajasthan** | 351 | 7 | 1482 |
| 29 | **Sikkim** | 1 | 0 | 12 |
| 30 | **Tamil Nadu** | 444 | 6 | 1448 |
| 31 | **Telangana** | 238 | 1 | 1051 |
| 32 | **Tripura** | 1 | 0 | 55 |
| 33 | **Uttar Pradesh** | 269 | 10 | 2561 |
| 34 | **UT of Dadar and Nagar Haveli and Daman & Diu** | 3 | 0 | 12 |
| 35 | **Uttarakhand** | 41 | 4 | 212 |
| 36 | **West Bengal** | 280 | 7 | 933 |
| TOTAL | | **4523** | **251** | **20035** |

**Types of EV Charging Stations**

Electric Vehicle (EV) charging stations are crucial to the EV system, just like gas stations are for traditional cars. They provide the electricity needed to recharge an EV's battery, allowing for smooth and sustainable travel. However, charging stations vary in location, use, and speed to meet the different needs of EV users.

Some stations are set up at homes for easy overnight charging, while others are found in public areas or along highways to help with travel and daily commuting. Based on their location and usage, EV charging stations fall into four main types: Residential Charging Stations, Public Charging Stations, Workplace Charging Stations, and Highway/Fast-Charging Hubs.

Each type serves a specific purpose and has its own benefits. Some focus on comfort and cost, while others prioritise speed and accessibility. EV users and technicians understand how the charging network supports the growing movement towards electric vehicles across the country.

**a. Residential Charging Stations**

Residential charging stations are designed for personal use and are typically installed at home, in garages, or dedicated parking spots. They enable electric vehicle (EV) owners to charge their cars overnight, similar to charging a phone. These chargers usually come in Level 1, which connects to a standard 230V socket, and Level 2, which charges faster. The main advantages of home charging are convenience and cost savings, allowing daily commuters to start each day with a fully charged vehicle without relying on public stations.

**b. Public Charging Stations**

Public charging stations serve as "fuel pumps" for electric vehicles in public areas like shopping malls, parking lots, and metro stations. They can be Level 2 or DC fast chargers, providing quick charging for those running errands or traveling. Many offers convenient payment and monitoring systems, helping to reduce "range anxiety" and supporting urban EV infrastructure for users without home charging options.

**c. Workplace Charging Stations**

Workplace charging stations at offices, factories, and schools integrate charging into employees' routines, allowing them to charge their vehicles during the day. Most use Level 2 chargers for a balance of speed and safety. Providing EV charging demonstrates a company's commitment to green mobility and supports eco-friendly commuting while reducing reliance on public charging. For EV owners, it means the convenience of charging while they work, promoting a cleaner corporate culture and aligning with India's sustainable transport goals.

**d. Highway / Fast-Charging Hubs**

Highway or fast-charging hubs are crucial for long-distance EV travel. Located along highways, these stations use DC fast chargers to charge EVs up to 80% in 30–45 minutes. Similar to traditional fuel stations but powered by green technology, they enable long trips without range anxiety. Many hubs also include rest areas and cafés, promoting energy efficiency and tourism. Highway charging hubs represent the future of fast, clean, and efficient mobility.

## CHECK YOUR PROGRESS

**A. Multiple Choice Questions**

1. What is the main environmental advantage of solar-based EV charging stations?
    a) They increase vehicle speed
    b) They reduce fuel consumption and emissions
    c) They work only at night

d) They require no maintenance

2. Which component in the EV charging system converts AC power into DC power for battery charging?
   a) Distribution Panel
   b) Power Converter/Rectifier
   c) Battery Management System
   d) User Interface

3. The Battery Management System (BMS) in an EV primarily:
   a) Controls vehicle speed
   b) Monitors and manages battery safety and performance
   c) Changes tire pressure
   d) Displays navigation routes

4. Level 1 charging typically takes how long to fully charge an electric vehicle?
   a) 1–2 hours
   b) 3–4 hours
   c) 8–12 hours
   d) 20–30 minutes

5. Which type of charging station is mostly installed at homes for overnight charging?
   a) Public charging station
   b) Workplace charging station
   c) Residential charging station
   d) Highway hub

6. The network and cloud connectivity system in a smart charger helps in:
   a) Increasing vehicle range
   b) Remote monitoring and data analysis
   c) Reducing battery weight
   d) Cooling the charger

**B. Fill in the Blanks**

1. Electric Vehicles (EVs) help reduce ___________ and dependence on fossil fuels.
2. The physical link between the EV and charging station is called the ___________ and cable assembly.
3. Level 3 charging is also known as ___________ or rapid charging.
4. In a solar EV charging system, electricity is generated from ___________.
5. The system that monitors battery temperature, voltage, and current is known as the ___________.
6. The main component that controls and distributes power safely in a charging station is the ___________.

**C. Short Answer Questions**

1. What is the purpose of a Solar EV Charging Station?
2. Explain the function of the Power Supply System in an EV charging station.
3. What does the EVSE (Electric Vehicle Supply Equipment) do?
4. How does the Power Converter/Rectifier help in charging?
5. What role does the Cooling and Thermal Management System play?
6. Mention two main types of EV Charging Stations based on location.
7. What is Level 2 charging, and where is it commonly used?
8. Define Battery Swapping System

| MODULE 4 | TOOLS AND SAFETY FOR SOLAR EV CHARGING STATION INSTALLATION |
|---|---|

## MODULE OVERVIEW

In the Installation of a Solar EV Charging Station, most of the tools are commonly used and easily found. This module provides information on the uses of that tool for Solar EV Charging Station, 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.

## LEARNING OUTCOMES

After completing this Module, students will be able to:

1. Identify and name various tools and equipment used in the installation and maintenance of Solar EV charging stations, such as Multimeters, wire strippers, torque wrenches, solar panel cleaning kits, and insulation testers.
2. Describe the functions and uses of each tool and equipment in different tasks like wiring, testing, fixing panels, mounting structures, and connecting charging units.
3. Demonstrate safe handling and proper operating procedures for tools used in electrical and solar installation work.
4. Maintain and store tools correctly by cleaning, inspecting, and organising them for efficient and long-term use.
5. Use tools effectively in practical activities like connecting solar modules, assembling support structures, and testing electrical circuits.
6. Follow safety norms and personal protective measures while working with electrical tools and solar equipment to ensure safe operation.

## MODULE STRUCTURE

Session 1: Mechanical and General Tools

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

## SESSION 1: MECHANICAL AND GENERAL TOOLS

Mechanical and general tools are important for various jobs in industries and daily tasks like maintenance, construction, and repairs. These tools include hand tools, such as wrenches, screwdrivers, and pliers, as well as power tools like drills and saws. Knowing how to use these tools effectively is essential for both professionals and DIY projects. Choosing the right tools and taking care of them helps ensure safety and efficiency in completing tasks.

### a) Screwdriver

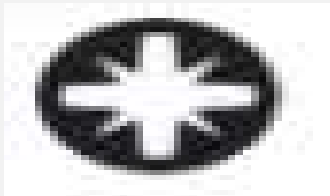
A screwdriver (as shown in Fig. 4.1) is a tool, manual or powered, for turning (driving or removing) screws. A typical simple screwdriver has a handle and a shaft and a tip that the user inserts into the screw head to turn it.

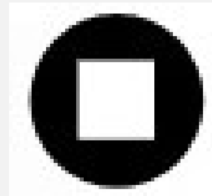
**Fig 4.1: Screwdriver**

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

**Table no. 4.1 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 (as shown in Fig. 4.2) 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 4.2: Hand Drill**

### c) Spanner (Wrench)

A spanner (as shown in Fig. 4.3) is a tool that helps you grip and apply torque to turn objects, usually rotary fasteners like nuts and bolts. In solar panel installations, spanners are mainly used to fasten panels to purlins using nuts and bolts.

**Fig 4.3: 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 (as shown in Fig. 4.4).

**Fig 4.4: 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 (as shown in Fig. 4.5).

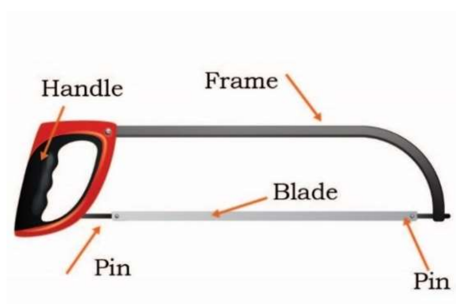



**Fig 4.5: Hacksaw**

### 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 (as shown in Fig. 4.6).

**Fig 4.6: 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 (as shown in Fig. 4.7).

**Fig 4.7: 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 (as shown in Fig. 4.8).

**Fig 4.8: 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 (as shown in Fig. 4.9).

**Fig 4.9: 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 (as shown in Fig. 4.10).


**Fig. 4.10: 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 (as shown in Fig. 4.11).

**Fig. 4.11 Pliers**

**l) Crimping tool**

A crimping tool is used to join two pieces of metal or other ductile materials (usually a wire and a metal plate) by deforming one or both of them to hold the other in place (as shown in Fig. 4.12).

**Fig 4.12: 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 (as shown in Fig. 4.13).

**Fig 4.13: 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 be arranged at a tilt angle equivalent to the latitude of the location. Angle finder helps set solar panels at the appropriate tilt angles for the right performance (as shown in Fig. 4.14).

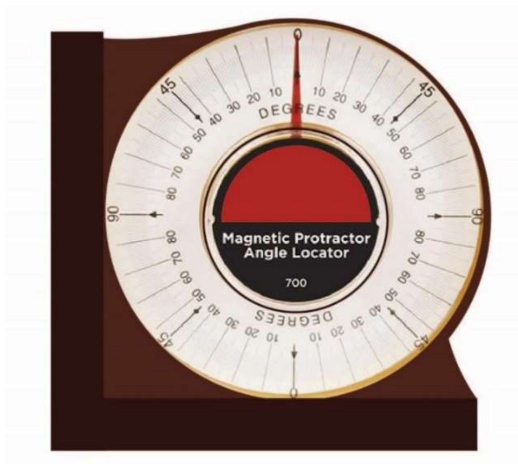



**Fig 4.14: Angle Finder**

## 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 (as shown in Fig. 4.15).

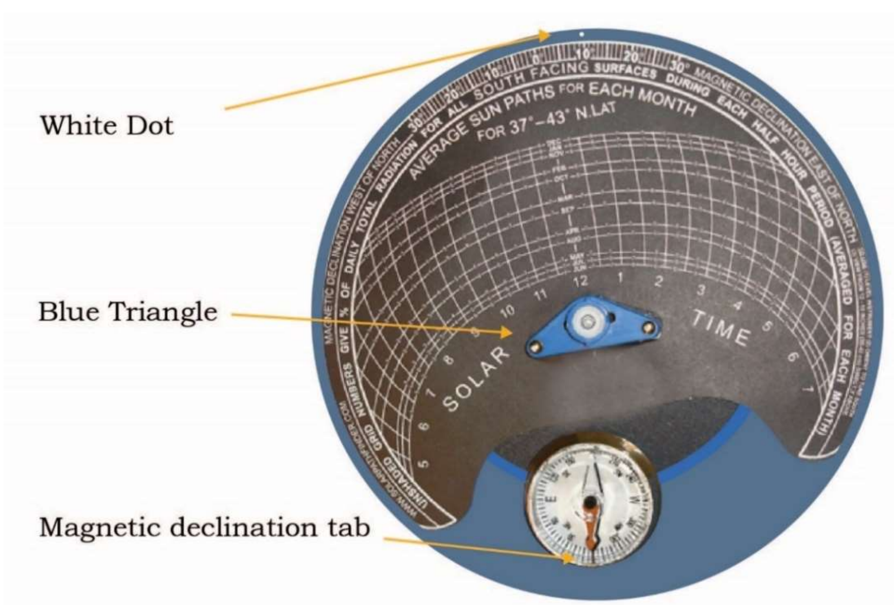



**Fig 4.15: Sun path Finder**

## ACTIVITY

1. Identify the different types of mechanical tools.
2. Make a list of general tools that are used in a Solar EV Charging Station.
3. Draw the different types of screwdrivers

## CHECK YOUR PROGRESS

**A. Fill in the blank**

1. The shaft is usually made of ............ to resist bending or twisting
2. Electrical .............offer faster operation and comfort to operators.
3. A ............. is a tool that delivers a blow to an object.
4. A hacksaw is a............, originally and principally for cutting metal.
5. Try-square implement used to check and mark right angles in .......... work
6. A........... is a tool used to "nip" or pull-out small amounts of a hard material?
7. A gimlet is a hand tool for .............., mainly in wood, without splitting.

**B. Multiple Choice Question**

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

   A. Pipe cutter

   B. Spanner

   C. Chisel

   D. Reamer

2. Grinder tools are used for the

   A. Measuring

   B. Ramming

   C. Cutting

   D. Grinding

3. Crimping 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. Analogue 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 (as shown in Fig. 4.16).


**Fig. 4.16: 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 (as shown in Fig. 4.17).

**Fig. 4.17: 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 (as shown in Fig. 4.18).


**Fig. 4.18: Electrical resistance tester**

**d) Pyranometer**

It is an instrument used for measuring solar irradiance or insolation on a horizontal surface. It is designed to measure the solar radiation flux density ($W/m^2$) from the hemispherical (1800) view. The instrument measures global (direct diffuse) solar radiation within a wavelength range of 0.3 µm to 3 µm (as shown in Fig. 4.19).

**Fig. 4.19: 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 features a sensor that detects falling solar energy. The display unit provides digital data of solar irradiance (as shown in Fig. 4.20).


**Fig. 4.20: Solar Power Meter**

### f) Pyrheliometer

A pyrheliometer measures the direct component of solar irradiance, which is important when installing concentrating collectors (as shown in Fig. 4.21).

**Fig. 4.21: Pyrheliometer**

**g) Clamp Meter**

A clamp meter is an Electrical Test Tool That Combines a Basic Digital Multimeter with A Current sensor (as shown in Fig. 4.22).


**Fig. 4.22: Clamp Meter**

**SAFETY TOOLS FOR SOLAR INSTALLATION**

**Safety & Protective Equipment:**

A solar EV Charging Station 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. 4.2: List of safety tools for use in Solar EV Charging Station.***

| 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. 4.23: Personal Protective Equipment (PPE) kit for workers**

## MARKING TOOLS

Marking and measuring are crucial for installing and manufacturing solar EV charging stations. Accurate measurements and markings ensure that parts fit correctly and work properly. That's why it's important to use various marking and measuring tools. These tools help achieve precise measurements and the right placement during the manufacturing process. Below is a 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, fibreglass, or a metal strip with linear measurement markings. It is a common measuring tool (as shown in Fig. 4.24).

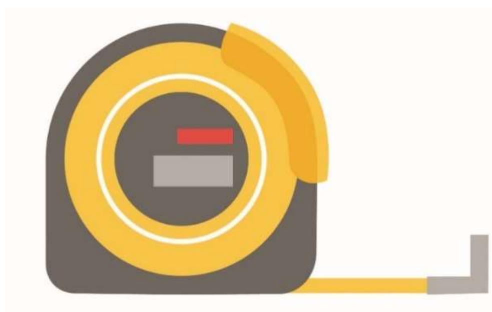


**Fig. 4.24: Measuring Tape**

### 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 (as shown in Fig. 4.25).

**Fig. 4.25: 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 (as shown in Fig. 4.26).

**Fig. 4.26: Plumb bob**

**d. Try Square**

An implement used to check and mark right angles in solar installation work (as shown in Fig. 4.27).

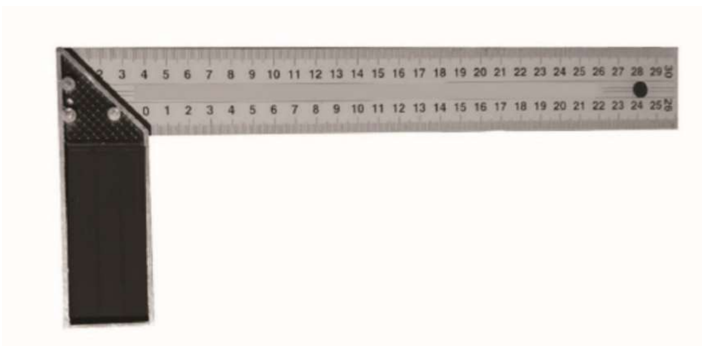


**Fig. 4.27: Try Square**

**e. Solar Compass**

A 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 (as shown in Fig. 4.28).


**Fig. 4.28: 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 (as shown in Fig. 4.29).

**Fig. 4.29: 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 manual labour. 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 fibreglass. It is used for making a deep trench in a solar installation (as shown in Fig. 4.30).

**Fig. 4.30: Pickaxe**

**b) Spud**

It is made of iron, pointed at one side for making holes in the soil (as shown in Fig. 4.31).


**Fig. 4.31: 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 carrying. Lift the Mortar Pan with a straight posture to avoid injury to your back (as shown in Fig. 4.32).

**Fig. 4.32: Mortar pan**

**d) Spade**

A spade is a tool used for digging straight-edged trenches, slicing and lifting sod, and edging flower beds or lawns. It is made of a metal sheet and a wooden handle. It is a common tool used in small solar installations (as shown in Fig. 4.33).

**Fig 3.33: Spade**

### e) Tractor post hole digger

It is a tractor-operated hole digger ideal for digging pits in any type of soil with less time and effort. It is a useful tool for ground-mounted solar power plants. A Pile foundation is created in the holes for the erection of mounting structures for solar modules (as shown in Fig. 4.34).

**Fig. 4.34: Tractor post hole digger**

### f) Crowbar

It is a hand tool used to pull two objects apart (as shown in Fig. 4.35).

**Fig. 4.35: Crowbar**

## ACTIVITY

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 EV Charging Station
4. Find the direction using a solar compass.

## CHECK YOUR PROGRESS

**A. Fill in the blank**

1. 1.................. uses a micro-ammeter with a moving pointer to display readings.
2. All the equipment of the power system is connected to the earth through the .....................
3. The resistance of the earth is..............
4. The electrical resistance tester instrument is used for an...........

**B. Multiple-Choice Questions**

1. Which measuring instrument is used for the total resistance between any two points separated by electrical insulation?
   a. Electrical resistance tester
   b. Multimeter
   c. Voltmeter
   d. Analog
2. Handheld portable Solar power meters are also used as.
   a. Pyranometer
   b. Multimeter
   c. Rotameter
   d. Electrometer
3. A pyrheliometer measures the direct component of
   a. solar irradiance
   b. resistance
   c. current
   d. none of these
4. Centre punch is a-
   a. holding tool
   b. cutting tool
   c. marking tool
   d. striking tool

5. Try square is used for marking at 90° to the edge of ________________.
   a. blade
   b. stock

c. burn slot
d. workpiece

**C. Short Answer Question**

Q1. Write two applications of the Clamp Meter

Q2. Write the four marking tool names

Q3 Write the four civil tools and their usage.

# MODULE 5 DESIGN CONSIDERATIONS FOR SOLAR EV CHARGING STATIONS

## MODULE OVERVIEW

This module teaches the essential steps for planning and building a Solar EV Charging Station. It covers how to analyse solar radiation data, determine energy needs, choose the right system parts, and create effective solar power setups. Students will also learn to estimate costs, size inverters, prepare circuit diagrams, assemble components, and carry out testing procedures. The material combines both theory and practical skills for developing solar charging systems in real-world settings.

## LEARNING OUTCOMES

After completing this Module, students will be able to:

- Interpret solar radiation data and understand its role in solar system design.
- Perform basic design calculations for sizing solar panels, inverters, and batteries.
- Identify and select key components of a Solar PV system for EV charging applications.
- Prepare line and circuit diagrams for solar system layouts.
- Conduct testing and performance analysis of Solar PV systems.
- Estimate system costs and evaluate feasibility based on technical and financial parameters.
- Ensure safety and quality assurance during installation and operation.

## MODULE STRUCTURE

Session 1: Solar Design Considerations and Calculations

## SESSION 1: SOLAR DESIGN CONSIDERATIONS AND CALCULATIONS

A Solar EVs Charging System is an integrated solution that uses solar energy to charge electric vehicles (EVs), reducing reliance on grid electricity and fossil fuels. Solar energy technology that converts sunlight into electricity. It consists of several key components working together to harness solar energy and generate power. Solar PV systems are fundamental for electricity generation, transmission and storage purposes, whether it has been used in irrigation, residential applications. The use of photovoltaic panels to support the electrical requirements of these systems has been executed globally for a long time.

However, introducing the best sizing techniques to such systems can benefit the end-user by saving money, energy, and time. The design and evaluation have been carried out through intuitive and mathematical methods.

The following steps will be used in the design process for a solar PV system. These steps will help you ensure that the system functions properly and generates electricity (as shown in Fig. 5.1).

**The important parameters for solar panel installation and commissioning**

1. Site survey and selection of site
2. Calculation of the solar irradiation for the site
3. Mounting Orientation and Tilt Angle
4. Roof Condition and Integrity
5. Electrical Wiring and Connections
6. Mounting Structure Installation
7. Inverter Installation and Connection
8. Commissioning and Testing
9. Safety Measures
10. Documentation and Handover

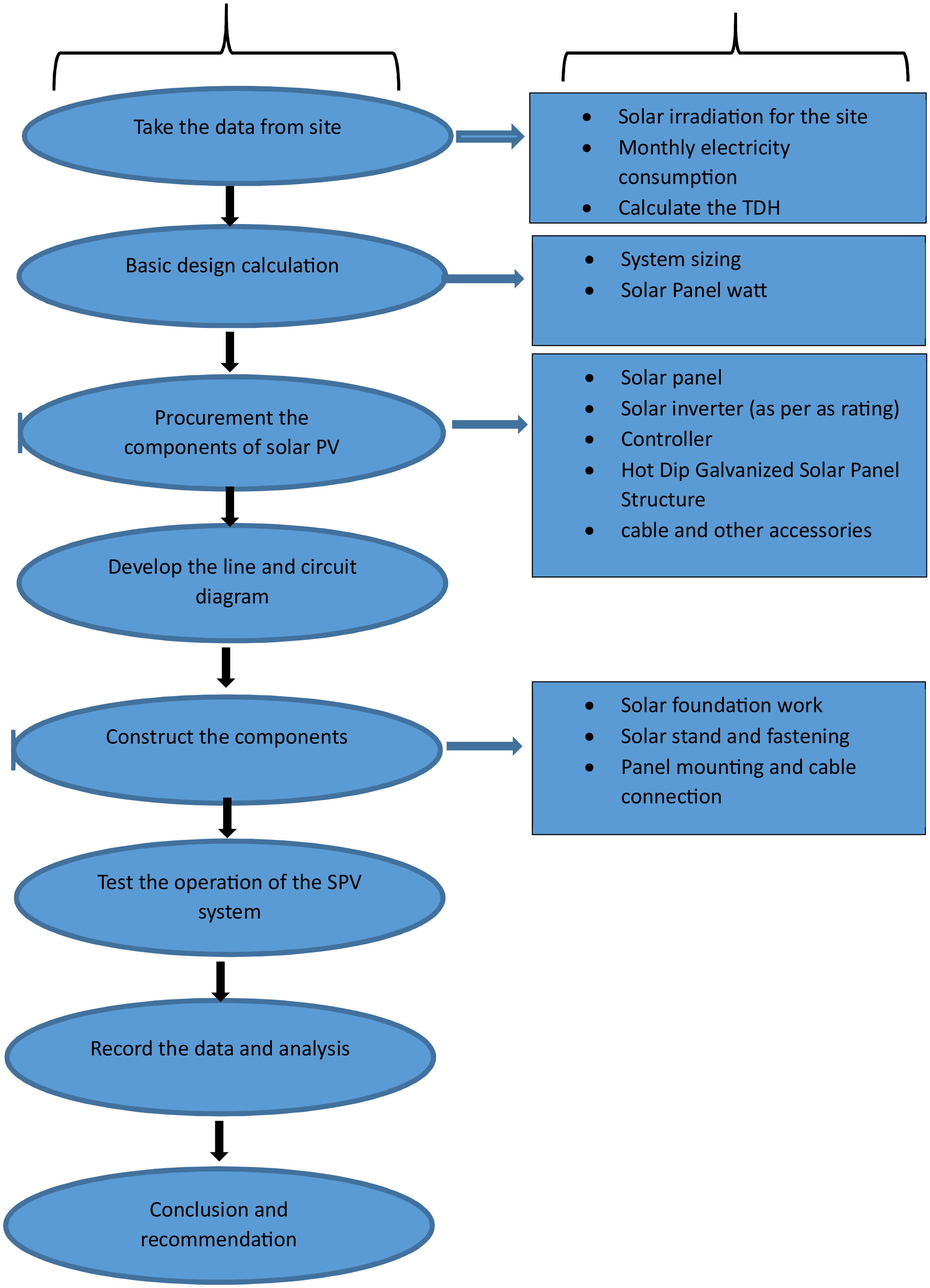



**Fig. 5.1: Flow chart of the Design and installation process of the solar PV system**

**DESIGN CONSIDERATION:**

**Step 1: Determination of the solar irradiation for the site**

The primary requirement for the design of any solar power project is accurate solar radiation data. It is essential to know the method used for measuring data for accurate design. Data may be instantaneously measured (irradiance) or integrated over some time (irradiation), usually one hour or a day. Data may be for beam, diffuse or total radiation, and for a horizontal or inclined surface. It is also important to know the types of measuring instruments used for these measurements. Radiation data for solar electric (photovoltaic) systems are often represented as kilowatt-hours per square meter (kWh/m$^2$) (as shown in Fig. 5.2). Direct estimates of solar energy may also be expressed as watts per square meter (W/m$^2$). Pyranometers are sensors that measure global shortwave radiation.

Typical applications of silicon-cell Pyranometer, as shown in Fig. 5.3, include incoming shortwave radiation measurement in Agricultural, ecological and hydrological weather networks and solar panel arrays.

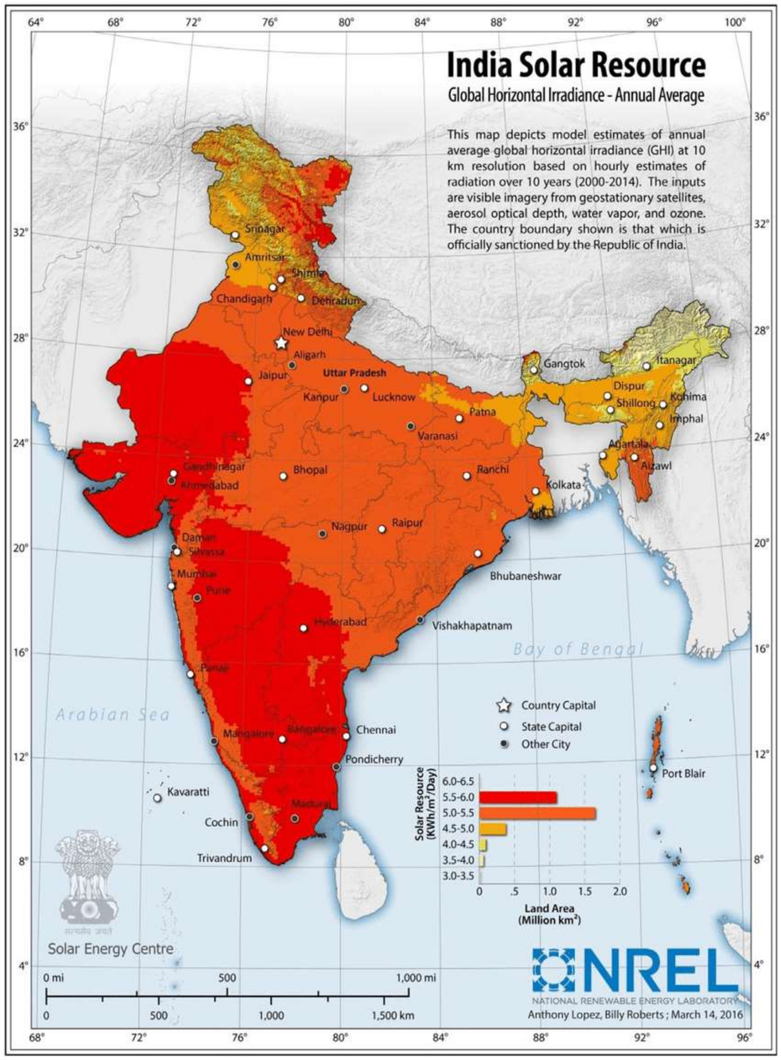



**Fig. 5.2: Solar Radiation Map of India**

*Source: National Renewable Energy Laboratory (NREL)*

The average solar Radiation in India is **5 kWh/m$^2$/Day**
**And we count the Average Hours of Radiation as 5 Hours per Day**


**Fig. 5.3: Pyranometer**

The professional solar radiation meter panel is designed with a "HOLD" button that supports maximum hold and data hold. Convenient for recording, user-friendly data comparison, and experimental investigation. Widely used for solar radiation measurement, solar energy research, meteorology, agriculture and physical and optical experiments. It can also be used to measure the light transmission intensity of glass to verify the performance of the glass, for example, a car window performance test.

India has a high potential for solar power generation of about 300 direct sunshine days per year. The regular solar incident in India varies with annual sunlight of 4 to 7 kWh/m². The Solar Radiation Map of India is shown in fig.4.38.

## Step 2: Basic design calculation:

Designing a solar rooftop system involves several basic calculations to ensure the system is appropriately sized and configured to meet your energy needs.

**Energy Consumption Analysis**: Determine your average daily energy consumption in kilowatt-hours (kWh).

**Roof Assessment:** Evaluate your rooftop's suitability for solar installation, considering factors like orientation, tilt angle, shading, and available space.

**The energy/ Power required**: For a Solar EV charging Station, how much power is required daily and every month? The first data needed is to estimate the energy requirement per day (kWh).

The following information details the solar energy requirements for charging a four-wheeler on a daily basis, considering the vehicle's battery capacity. The data is presented in Table 5.1, which outlines the battery size per car in kilowatt-hours (kWh), the number of vehicles charged per day, the total energy consumption per day in kWh, the necessary solar capacity in kilowatts (kW), the number of solar panels required (each rated at 450 watts), and the corresponding roof area in square meters ($m^2$).

**Table 5.1: Solar Requirement for Charging Four-Wheelers (Cars) per Day**

| Case | Battery Size per Car (kWh) | Vehicles per Day | Total Energy per Day (kWh) | Required Solar Capacity (kW) | No. of Panels (450 W each) | Roof Area (m²) |
|---|---|---|---|---|---|---|
| **1.** | **20 kWh** | 4 | 80 | 20 kW | 45 panels | 76.5 m² |
| **2.** | **30 kWh** | 4 | 120 | 30 kW | 67 panels | 113.9 m² |
| **3.** | **40 kWh** | 4 | 160 | 40 kW | 89 panels | 151.3 m² |

This information describes the solar energy needed to charge 6–8 three-wheelers each day based on their battery size. Table 5.2 shows the battery capacity in kilowatt-hours (kWh) for each vehicle, how many vehicles are charged daily, and the total energy used each day in kWh. It also includes the required solar capacity in kilowatts (kW), the number of solar panels needed (each rated at 450 watts), and the roof area required in square meters ($m^2$).

**Table 5.2: Solar Requirement for Charging 6–8 Three-Wheelers per Day**

| Case | Battery Size per Vehicle (kWh) | Vehicles per Day | Total Energy per Day (kWh) | Required Solar Capacity (kW) | No. of Panels (450 W each) | Roof Area (m²) |
|---|---|---|---|---|---|---|
| **1.** | **7 kWh** | 6 | 42 | 10.5 kW | 24 panels | 40.8 m² |
| **2.** | **7 kWh** | 8 | 56 | 14 kW | 32 panels | 54.4 m² |
| **3.** | **5 kWh** | 8 | 40 | 10 kW | 23 panels | 39.1 m² |
| **4.** | **10 kWh** | 6 | 60 | 15 kW | 34 panels | 57.8 m² |

Before performing the energy generation and sizing calculations, certain baseline assumptions were established. These include factors such as average peak sun hours, system efficiency, and panel specifications. Table 5.3 are summarised below:

**Table 5.3: Assumptions Used**

| Parameter | Value | Notes |
|---|---|---|
| Peak Sun Hours (PSH) | 5 hours/day | Typical for many Indian locations |
| System Efficiency (η) | 0.80 | Includes inverter & wiring losses |
| Panel Capacity | 450 W | Modern high-efficiency module |
| Panel Area | 1.7 $m^2$ each | Average surface area per panel |
| Energy per kW PV/day | 4.0 kWh | Derived from 5 × 0.8 |

The energy requirements and corresponding photovoltaic (PV) system sizing for charging 50 four-wheelers per day were evaluated under different battery capacity scenarios. The summary of these calculations is presented in Table 5.4.

**Table 5.4: Summary for 50 four-wheelers per day**

| *Case* | *Battery per car (kWh)* | *Vehicles/day* | *Total energy/day (kWh)* | *Required PV (kW)* | *Battery for 1-day backup (kWh)* |
|---|---|---|---|---|---|
| ***C1*** | 20 kWh | 50 | 1,000 kWh | 250.0 kW | **1,176.47 kWh** |
| ***C2*** | 30 kWh | 50 | 1,500 kWh | 375.0 kW | **1,764.71 kWh** |
| ***C3*** | 40 kWh | 50 | 2,000 kWh | 500.0 kW | **2,352.94 kWh** |

Based on the required PV capacities calculated for each case, the corresponding number of solar panels and the total roof area required were determined. Table 5.4 summarises these values for the three scenarios considered.

**Table 5.4: Panels & Roof area**

| **CASE** | **PV (KW)** | **PANELS (450 W EACH)** | **ROOF AREA ($M^2$)** |
|---|---|---|---|
| **C1 (20 KWH)** | 250.0 kW | 556 panels | **945.2 $m^2$** |
| **C2 (30 KWH)** | 375.0 kW | 834 panels | **1,417.8 $m^2$** |
| **C3 (40 KWH)** | 500.0 kW | 1,112 panels | **1,890.4 $m^2$** |

To estimate the overall investment required for setting up the solar charging station, cost evaluations were conducted for the PV system, inverter, and battery bank under three pricing scenarios—low, mid, and high. The inverter cost is assumed as 15% of the mid-range PV system cost, while battery costs are estimated based on system capacity. The summarised cost estimates for each case are presented in Table 5.5.

**Table 5.5: Cost Estimates (PV, inverter, battery) — low/mid/high**

| *Case kW* | PV cost (₹) **low/mid**/high | Inverter (15% of mid) | Battery cost (₹) **low/mid**/high |
|---|---|---|---|
| ***250*** | 1,50,00,000 | | 1,41,17,647 |
| | **1,87,50,000** | **₹28,12,500** | **1,88,23,529** |

| | | | |
|---|---|---|---|
| | 2,12,50,000 | | 2,35,29,412 |
| *(375 kW)* | 2,25,00,000 | | 2,11,76,471 |
| | **2,81,25,000** | **₹4,218,750** | **2,82,35,294** |
| | 3,18,75,000 | | 3,52,94,118 |
| *500 (kW)* | 3,00,00,000 | | 2,82,35,294 |
| | **3,75,00,000** | **₹5,625,000** | **3,76,47,059** |
| | 4,25,00,000 | | 4,70,58,824 |

**Cost Calculation Methodology**

The cost estimates for the PV system, inverter, and battery storage were calculated using standard unit rates for three pricing scenarios—**low**, **mid**, and **high**. The detailed methodology is summarised below:

- **PV System Cost:**

  PV Cost=PV Capacity (kW) × (₹60,000 / ₹75,000 / ₹85,000 per kW)

  *Example (C1, Mid):*

  250×75,000=₹18,750,000
- **Inverter Cost:**

  Inverter Cost=0.15×(PV Mid Cost)

  *Example (C1):*

  0.15×18,750,000=₹2,812,500
- **Battery Cost:**

Battery Cost=Battery Capacity (kWh)× (₹12,000 / ₹16,000 / ₹20,000 per kWh)

*Example (C1, Mid):* 1,176.47×16,000=₹18,823,529

**PRACTICAL NOTES & RECOMMENDATIONS**

1. **Scale is large**: A commercial-scale installation typically consists of a photovoltaic (PV) plant with a capacity ranging from 250 to 500 kW, supplemented by a battery storage system with a capacity of 1.2 to 2.35 MWh. Such setups require a significant amount of roof space and entail a considerable capital expenditure (CAPEX). Therefore, we focus exclusively on implementing ***On-Grid Systems*** instead of these types of installations.
2. **Simultaneous charging power matters:** PV above gives daily energy. If you plan many vehicles charging at the same time (e.g., multiple 7.2 kW chargers concurrently), ensure instant-power design: either increase PV, add a high-power battery buffer, or keep a grid connection for peak shaving.
3. **Space check:** Compare the roof areas above (945–1,890 $m^2$) to your available roof. Allow extra margin (10–20%) for maintenance aisles, tilt, shading, and future expansion.

4. **Phased approach recommendation:** Consider phasing: start with a smaller PV (e.g., 100–200 kW) + moderate battery + grid, monitor usage patterns, then expand. This reduces upfront cost and risk.
5. **Costs are estimates: T**hey vary by vendor, location, taxes, and BOS details. Use these as planning figures; get 3 installer quotes for firm numbers.

**Step 3: Selection of the inverter:**

After energy calculation, the inverter rating (KVA) kilovolt ampere will be calculated on the basis of system sizing.

Now, let's calculate the inverter's required capacity, i.e., the Volt-Ampere rating. In an ideal condition, an inverter would operate with 100% efficiency. Most inverters have an efficiency of between 60% and 80%. This efficiency can also be referred to as the power factor of an inverter. For our calculations, we would use a power factor of 0.8. Hence,

Power supplied (or VA rating of the inverter)

= Power consumed by equipment in watts / Power factor

**Step 4: Procurement of the components of the solar PV System:**

Before procurement, confirm the final design and specifications of your solar PV system, including the required capacity, type of solar panels, inverters, mounting system, wiring, and other components.

**Step 5: Develop the line and circuit diagram:**

Developing a line and circuit diagram for a solar PV system involves illustrating how the components are interconnected to form a complete electrical system.

A line diagram provides a visual representation of the electrical connections between the main components of the solar PV system. It shows the flow of electricity from the solar panels to the grid or load.

**Step 6: Construct the components:**

construct the main components of a solar PV system, like Solar Panels (Photovoltaic Modules), Mounting Structure, Inverter, Charge Controller (for Off-Grid Systems), Battery Bank (for Off-Grid Systems), DC Disconnect Switch, AC Disconnect Switch, Wiring and Cables, monitoring and control system, etc.

1. **Solar Panels:**
   We'll represent solar panels as rectangular shapes with a grid pattern to symbolise solar cells.
2. **Mounting Structure:**
   The mounting structure will be depicted as a frame or support system around the solar panels.
3. **Inverter:**

The inverter can be represented by a box with input and output terminals, symbolising the conversion of DC to AC electricity.

4. **Charge Controller (for Off-Grid Systems):**
   If the system is off-grid and includes a charge controller, we can represent it as a device between the solar panels and battery bank.
5. **Battery Bank (for Off-Grid Systems):**
   The battery bank can be shown as a collection of rectangular shapes connected in series or parallel to store energy.
6. **DC Disconnect Switch:**
   The DC disconnect switch will be represented as a switch symbol along the DC wiring between the solar panels and the inverter.
7. **AC Disconnect Switch:**
   Similarly, the AC disconnect switch will be depicted as a switch symbol along the AC wiring between the inverter and the main electrical panel.
8. **Wiring and Cables:**
   Wiring and cables will be shown as lines connecting the various components, with labels indicating DC or AC, and possibly cable types or sizes.
9. **Meter Installation:**
   The vendor will arrive to install the net meter at the agreed-upon location. They will disconnect the existing meter (if applicable) and install the new bidirectional net meter capable of measuring electricity flow in both directions. The installation may involve wiring connections to the electrical panel or meter socket, depending on the meter type and configuration.
10. **Monitoring and Control System:**
    The monitoring and control system can be represented as a separate box or panel with displays and indicators for system monitoring and data logging.

**Step 7: Test the operation of the Solar PV system:**

Testing the operation of a solar PV (photovoltaic) system involves verifying that all components are functioning correctly and efficiently generating electricity.

Here's a basic procedure for testing the operation of an SPV system:

**(a) Visual Inspection:**

Conduct a visual inspection of the entire system, including solar panels, mounting structures, inverters, wiring, and electrical connections.

Look for any signs of physical damage, loose connections, or debris that may affect performance.

**(b) Meter Readings:**

Check the readings on the bidirectional meter or net meter to confirm that it is accurately measuring electricity flow in both directions. Note the import and export readings to determine the net energy balance.

**(c) Inverter Status:**

Verify that the inverter is operational and converting DC electricity from the solar panels into AC electricity. Check the display panel or monitoring system of the inverter for any error codes or warnings.

**(d) Solar Panel Performance:**

Monitor the performance of individual solar panels using a monitoring system, if available. Compare the output of each panel to ensure uniformity and identify any panels that may be underperforming due to shading or defects.

**(e) System Output:**

Measure the total output of the solar PV system by recording the AC power output at the inverter or main electrical panel. Compare the actual output to the expected output based on factors such as solar irradiance, temperature, and system capacity.

**(f) Voltage and Current Measurements:**

Use a multimeter or clamp meter to measure the voltage and current at various points in the system, including at the solar panels, inverter input, and output. Ensure that voltage and current levels are within the specified range and consistent with the system design.

**(g) Load Testing:** Test the performance of the solar PV system under different load conditions by connecting various electrical loads, such as lights or appliances. Verify that the system can meet the demand for electricity from both the loads and any excess generation exported to the grid.

**Data Logging and Analysis:**

Collect data on system performance over time using a monitoring and data logging system. Analyse the data to identify trends, patterns, and any anomalies that may indicate issues with system operation or component failure.

**Safety Checks:**

Ensure that all safety precautions are observed during testing, including proper grounding, isolation of electrical circuits, and adherence to relevant safety standards and regulations.

**Documentation:** Document the results of the testing, including meter readings, measurements, observations, and any corrective actions taken. Keep records of system performance for future reference and maintenance purposes.

## ACTIVITY

1. What are the parameters of the selection and design of the solar PV system?
2. Draw the Flow chart of the Design and installation process of the solar PV system

## CHECK YOUR PROGRESS

**A. Multiple Choice Questions**

1. The main source of energy for a solar EV charging system is:
a) Wind energy
b) Biomass energy
c) Solar energy
d) Thermal energy

2. The component that converts DC from solar panels into AC is called:
a) Inverter
b) Rectifier
c) Transformer
d) Controller

3. Which device is used to store energy in a solar EV charging system?
a) Transformer
b) Battery bank
c) Controller
d) Motor

4. The device used to control the flow of power between the solar panels, battery, and EV is:
a) Charge controller
b) Alternator
c) Regulator
d) Rectifier

5. Which type of current is used to charge most electric vehicle batteries?
a) AC
b) DC

c) Both AC and DC
d) None of these

**B. Fill in the Blanks**

1. Solar panels convert __________ energy into electrical energy.
2. The process of maintaining the correct voltage and current during charging is called __________.
3. The inverter converts __________ current into __________ current
4. __________ helps protect the EV charging system from overcurrent and short circuits.
5. The capacity of a solar EV charging system is usually measured in __________.

**C. Short Answer Questions**

1. Define a solar EV charging system.
2. What are the main components of a solar EV charging setup?
3. Why is an inverter important in a solar charging system?
4. Mention one advantage of using solar energy for EV charging.
5. Explain the working principle of a solar EV charging system.
6. Describe the design and installation steps of a solar EV charging system.
7. What safety measures should be followed while testing a solar EV charging system?

# ANSWER KEY

| MODULE 1 INTRODUCTION OF SOLAR ENERGY | |
|---|---|
| **SESSION 1: INTRODUCTION TO ENERGY** | |
| **Fill in the blank** | **Multiple Choice Question** |
| 1. Energies. | 1. A |
| 2. Geothermal, Ocean | 2. A |
| 3. Solar power | 3. A |
| 4. Photovoltaic (PV) | 4. D |
| | 5. A |
| **SESSION 2: POTENTIAL OF SOLAR ENERGY** | |
| **Fill in the blank** | **Multiple Choice Question** |
| 1. renewable energy | 1. D |
| 2. Photovoltaic cells | 2. A |
| 3. solar collectors, radiators | 3. A |
| 4. Tubing, insulated tank | |
| **SESSION 3: SOLAR PHOTOVOLTAICS (PV) TECHNOLOGY** | |
| **Fill in the blank** | **Multiple Choice Question** |
| 1. Calculators | 1. C |
| 2. Light, electricity | 2. A |
| 3. Silicon | 3. A |
| 4. Photovoltaic effect | 4. A |
| | 5. C |
| **SESSION 4. SOLAR POWER GENERATION AND APPLICATION** | |
| **Fill in the blank** | **Multiple Choice Question** |
| 1. PV array | 1. A |
| 2. DC power | 2. A |
| 3. Inverter | 3. A |
| 4. 278 kWh | 4. A |
| 5. Energy | |
| **SESSION 5: THE SOLAR PANEL AND ITS COMPONENTS** | |
| **Fill in the blank** | **Multiple Choice Question** |
| 1. solar cells | 1. B |
| 2. silicon | 2. C |
| 3. fill factor (FF) | 3. D |

| | |
|---|---|
| 4. Bifacial solar panels | 4. C |
| 5. 15% and 18%. | 5. A |

| MODULE 2: BASICS OF SOLAR ENERGY AND ELECTRICAL CONCEPTS | |
|---|---|
| **SESSION 1: FUNDAMENTALS OF SOLAR ENERGY** | |
| **Fill in the blank** | **Multiple Choice Question** |
| 1. renewable | 1. C |
| 2. 1.35 | 2. B |
| 3. pyranometer | 3. B |
| 4. photovoltaic | 4. A |
| 5. watts or kilowatts | 5. A |
| **SESSION 2: FUNDAMENTALS OF ELECTRICITY** | |
| **Fill in the blank** | **Multiple Choice Question** |
| 1. electric current | 1. C |
| 2. voltage | 2. C |
| 3. ohm (Ω) | 3. B |
| 4. $3.6 \times 10^6$ joules | 4. B |
| 5. inverter | 5. B |
| **SESSION 3: TERMINOLOGY AND DEFINITIONS** | |
| **Fill in the blank** | **Multiple Choice Question** |
| 1. solar irradiance | 1. B |
| 2. 1367 W/m$^2$ | 2. B |
| 3. north (or true north) | 3. C |
| 4. latitude | 4. C |

| MODULE 3 INTRODUCTION OF SOLAR EV CHARGING STATION | |
|---|---|
| **SESSION 1: ROLE AND RESPONSIBILITY OF JUNIOR TECHNICIAN – SOLAR EV CHARGING STATION** | |
| **Fill in the blank** | **Multiple Choice Question** |
| 1. Smooth, safe | 1. C |
| 2. power | 2. B |
| 3. operations | 3. B |
| 4. connectivity | 4. A |
| **SESSION 2: COMPONENTS OF SOLAR EV CHARGING STATION** | |
| **Fill in the blank** | **Multiple Choice Question** |

| | |
|---|---|
| 1. greenhouse gas emissions | 1. B |
| 2. connector | 2. B |
| 3. DC fast charging | 3. B |
| 4. sunlight | 4. C |
| 5. Battery Management System (BMS) | 5. C |
| 6. distribution panel | 6. B |

**MODULE 4: TOOLS AND SAFETY FOR SOLAR EV CHARGING STATION INSTALLATION**

**SESSION 1: MECHANICAL AND GENERAL TOOLS**

| Fill in the blank | Multiple Choice Question |
|---|---|
| 1. Steel | 1. A |
| 2. Tools | 2. D |
| 3. Hammer | 3. A |
| 4. Fine toothed saw | |
| 5. wood | |
| 6. plier | |
| 7. Boring small holes | |

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

| Fill in the blank | Multiple Choice Question |
|---|---|
| 1. Analog meter | 1. A |
| 2. earthing system | 2. A |
| 3. very low | 3. A |
| 4. insulation test. | 4. C |
| | 5. D |

**MODULE 5: DESIGN CONSIDERATIONS FOR SOLAR EV CHARGING STATIONS**

**SESSION 1: SOLAR DESIGN CONSIDERATIONS AND CALCULATIONS**

| Fill in the blank | Multiple Choice Question |
|---|---|
| 1. solar | 1. C |
| 2. regulation | 2. A |
| 3. direct (DC); alternating (AC) | 3. B |
| 4. Circuit breaker or fuse | 4. A |
| 5. kilowatts (kW) | 5. B |

# GLOSSARY

| *Term* | *Definition* |
|---|---|
| ***AC (Alternating Current)*** | An electric current that changes direction periodically. |
| ***AC Charger*** | A charger that supplies alternating current to an EV. |
| ***AC Distribution Box*** | Panel distributing AC electricity in the system. |
| ***AC Energy Meter*** | A meter that measures AC power consumption. |
| ***AC Isolator*** | A switch is used to disconnect AC circuits. |
| ***Active Power*** | Real power consumed by electrical loads. |
| ***Adapter Plate*** | Component used to mount equipment securely. |
| ***Air Cooling System*** | A system used to cool EV batteries or chargers using air. |
| ***Air Mass*** | Atmospheric pressure factor affecting solar radiation. |
| ***Alarm Indicator*** | Visual or audio signal for faults. |
| ***Ampere (A)*** | Unit of electric current. |
| ***Ampere-Hour (Ah)*** | Battery capacity measurement. |
| ***Android App Interface*** | Mobile application to control charging. |
| ***Angle of Incidence*** | Angle between sunlight and PV panel. |
| ***Anti-Islanding Protection*** | Prevents PV systems from energising the grid during an outage. |
| ***API Integration*** | Communication between software systems. |
| ***App-Based Charging*** | Charging controlled via mobile app. |
| ***Arc Flash*** | Dangerous electrical explosion due to an arc. |
| ***Array Junction Box*** | Combines multiple PV strings. |
| ***Authentication*** | Verification of user identity. |
| ***Auto-Cutoff*** | Automatic disconnection at full charge. |

| | |
|---|---|
| ***Availability Factor*** | Percentage of time equipment is operational. |
| ***Backup Battery*** | A battery is used to store extra energy. |
| ***Battery Balancing*** | Equalising the voltage of battery cells. |
| ***Battery Capacity*** | The maximum charge a battery can store. |
| ***Battery Chemistry*** | Type of materials used in battery manufacturing. |
| ***Battery Charging Cycle*** | One complete charge and discharge. |
| ***Battery Cooling Plate*** | Plate used for thermal regulation in batteries. |
| ***Battery Degradation*** | Reduction in battery performance over time. |
| ***Battery Management System (BMS)*** | A system that monitors and protects battery health. |
| ***Battery Pack*** | A group of battery cells is combined together. |
| ***Battery Protection*** | Safety features to prevent battery damage. |
| ***Battery Swapping*** | Replace a discharged battery with a charged one. |
| ***Battery Voltage*** | Electrical potential of a battery. |
| ***Beam Radiation*** | Direct sunlight is hitting the panel. |
| ***Bidirectional Charger*** | Charger capable of feeding power back to the grid. |
| ***Bi-facial Module*** | Solar module producing power from both sides. |
| ***Bluetooth Interface*** | Short-range wireless communication. |
| ***Breaker Panel*** | Panel containing circuit breakers. |
| ***Bridge Rectifier*** | Converts AC to DC. |
| ***Bus Bar*** | Metallic strip for power distribution. |
| ***Cable Crimping*** | Process of joining cables with connectors. |
| ***Cable Management*** | Arranging and securing cables properly. |
| ***Cable Termination*** | Proper ending of cables with connectors. |
| ***Calibration*** | Adjustment of measurement devices. |

| | |
|---|---|
| ***Carbon Footprint*** | Amount of $CO_2$ emissions produced. |
| ***Charge Controller*** | Regulates battery charging from solar. |
| ***Charge Cycle*** | Complete charging and discharging of the battery. |
| ***Charge Port*** | The socket where the EV is connected for charging. |
| ***Charge Rate (C-Rate)*** | The speed at which the battery is charged. |
| ***Charger Efficiency*** | Percentage of useful power delivered. |
| ***Charging Algorithm*** | Method used for battery charging. |
| ***Charging Cable*** | Cable connecting EV to charger. |
| ***Charging Duration*** | Time taken to charge EV. |
| ***Charging Gun*** | Connector at the EV charging cable end. |
| ***Charging Infrastructure*** | System required for EV charging. |
| ***Charging Management System*** | Software to monitor charging. |
| ***Charging Point*** | Location where EV charging happens. |
| ***Charging Protocol*** | Set of rules for power transfer. |
| ***Charging Socket*** | Electrical outlet for EV charging. |
| ***Charging Station*** | Facility where EVs are charged. |
| ***Charging Tariff*** | Cost per unit of EV charging. |
| ***Circuit Breaker*** | Device to protect against overload. |
| ***Cloud Monitoring*** | Remote observation via cloud. |
| ***Communication Protocol*** | Language for device communication. |
| ***Conduit Pipe*** | Pipe used to protect cables. |
| ***Connector Pin*** | Metal pin used in charging connectors. |
| ***Contact Resistance*** | Resistance at contact points in connectors. |

| | |
|---|---|
| ***Contactor*** | Electrically controlled switch. |
| ***Current Limiter*** | A device that restricts current flow. |
| ***DC (Direct Current)*** | Current is flowing in one direction. |
| ***DC Charger*** | A fast charger supplying DC to an EV. |
| ***DC Distribution Box*** | Panel distributing DC power. |
| ***DC Fast Charging*** | High-speed charging using direct current. |
| ***DC Isolator*** | A switch is used to disconnect DC circuits. |
| ***Demand Response*** | Adjusting charging based on energy demand. |
| ***Dielectric Strength*** | Insulation strength of the material. |
| ***Digital Multimeter*** | A tool to measure voltage, current, and resistance. |
| ***Discharge Rate*** | The rate at which the battery drains. |
| ***Distributed Generation*** | Power is produced near consumption points. |
| ***Earth Electrode*** | Metal rod used for grounding. |
| ***Earthing Pit*** | Pit is designed for the grounding system. |
| ***Earthing Strip*** | Metal strip used for grounding connection. |
| ***Efficiency Ratio*** | Output-to-input power ratio. |
| ***Electrical Load*** | The device is consuming electricity. |
| ***Electrical Panel*** | Cabinet containing electrical components. |
| ***Electrolyser*** | Device producing hydrogen from water (optional for hybrid stations). |
| ***Energy Meter*** | Measures electrical consumption. |
| ***EVSE (Electric Vehicle Supply Equipment)*** | Technical term for EV charging equipment. |
| ***Fault Detection*** | Identifying system errors. |
| ***Global Radiation*** | Total sunlight including direct and diffused. |

| | |
|---|---|
| ***Grid Connectivity*** | Connection of system to power grid. |
| ***Ground Clearance*** | Space between equipment and ground. |
| ***Ground Fault*** | Leakage of electricity to ground. |
| ***Ground Lug*** | Connector for grounding cables. |
| ***GUI (Graphical User Interface)*** | Visual interface for system control. |
| ***High Voltage Cable*** | Cable used for DC fast charging. |
| ***Idle Mode*** | Standby mode of charging station. |
| ***IEC Standards*** | International electrical standards. |
| ***IoT Module*** | Device enabling internet connectivity. |
| ***Junction Box*** | Box housing wiring connections. |
| ***Kilowatt (kW)*** | Unit of power. |
| ***Kilowatt-Hour (kWh)*** | Unit of energy consumption. |
| ***LED Indicator*** | Light indicator showing status. |
| ***Li-ion Battery*** | Lithium-ion battery used in EVs. |
| ***Load Balancing*** | Adjusting load on power system. |
| ***MCCB*** | Molded case circuit breaker. |
| ***MCB*** | Miniature circuit breaker. |
| ***Megawatt (MW)*** | Large unit of power. |
| ***Mobile Charger*** | Portable charger for EVs. |
| ***Monitoring System*** | System that observes performance. |
| ***MPPT (Maximum Power Point Tracking)*** | Increases solar energy extraction. |
| ***No-Load Voltage*** | Voltage without load connected. |
| ***Open Circuit Voltage (Voc)*** | Voltage when circuit is open. |

| | |
|---|---|
| ***Output Power*** | Power delivered by charger. |
| ***Overcharge Protection*** | Prevents battery overcharging. |
| ***Panel Tilt Angle*** | Tilt of solar panel. |
| ***Peak Sun Hours*** | Number of sunny hours equivalent. |
| ***Photovoltaic (PV)*** | Technology converting sunlight to electricity. |
| ***PID (Potential Induced Degradation)*** | PV performance reduction due to voltage stress. |
| ***Plug-and-Charge*** | Charging without manual input. |
| ***Power Factor*** | Efficiency of electrical system. |
| ***Power Quality*** | Stability of electrical supply. |
| ***QR Code Charging*** | Charging activated by QR scan. |
| ***Relay*** | Electrically operated switch. |
| ***Remote Monitoring*** | System tracking from remote location. |
| ***Smart Charging*** | Optimized EV charging system. |
| ***Solar Array*** | Collection of solar panels. |
| ***Solar Charger*** | Charger powered by solar energy. |
| ***Solar Radiation Sensor*** | Measures sunlight intensity. |
| ***Voltage Drop*** | Loss of voltage along cables. |