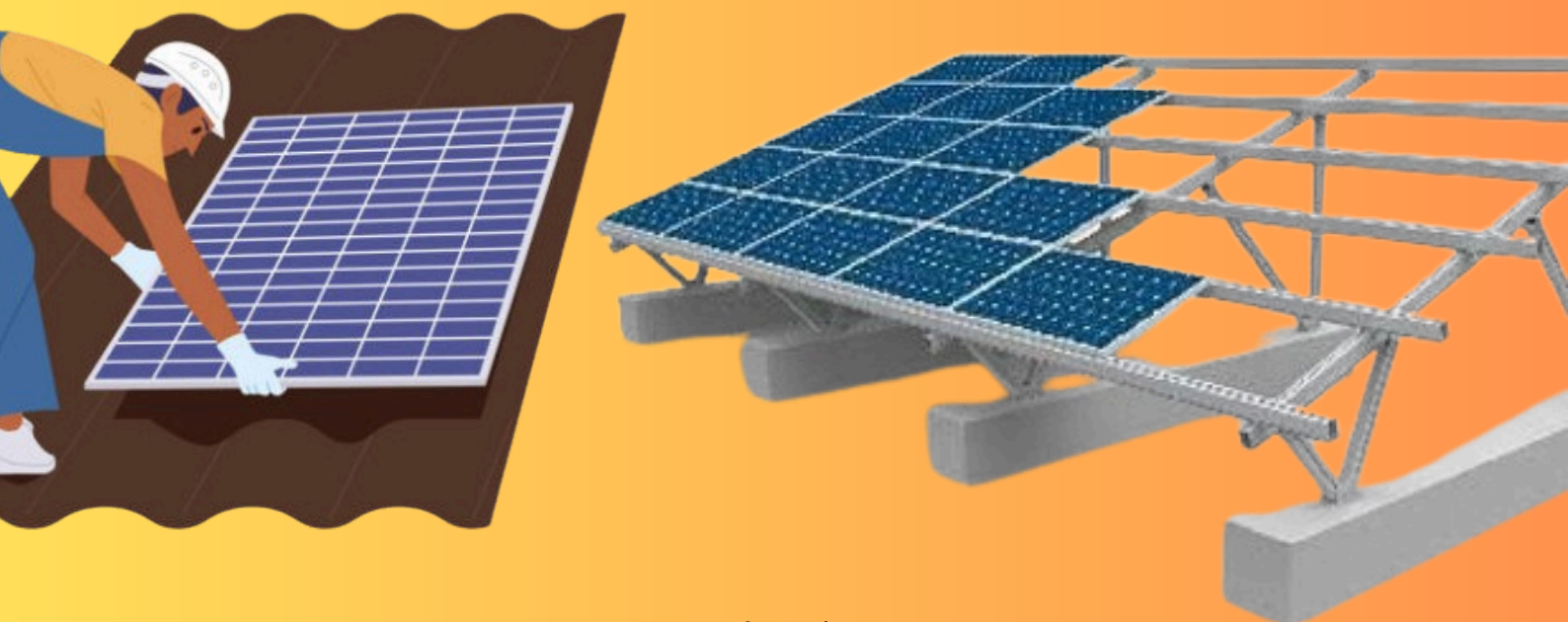


Draft Study Material

Job Role: Solar PV Installer - Civil (QUALIFICATION PACK: SGJ/Q0103)

SECTOR: GREEN JOBS

Grade XI



PSS CENTRAL INSTITUTE OF VOCATIONAL EDUCATION

(a constituent unit of NCERT, under Ministry of Education, Government of India)

Shyamla Hills, Bhopal- 462 002, M.P., India

<http://www.psscive.ac.in>

SOLAR PV INSTALLER – CIVIL

(Job Role)

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Preface

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

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

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

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Deepak Paliwal
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Date: 30th July 2025

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MODULE 1**INTRODUCTION TO SOLAR PV INSTALLER -CIVIL****Module Overview**

This module introduces the basics of energy with a focus on renewable sources, especially solar energy. It explains the concept and working of Solar Photovoltaic (PV) systems, their evolution, and the role of a Solar PV Installer – Civil. Learners will also explore key job opportunities in the solar sector and understand the skills required for solar PV installation and maintenance.

Learning Outcomes

After completing this module, you will be able to:

- Understand the concept of energy and its types
- Differentiate between renewable and non-renewable energy sources
- Explain the fundamentals of solar energy and Solar PV systems
- Describe the historical development of solar photovoltaic technology
- Identify key roles and responsibilities of a Solar PV Installer – Civil
- Explore potential career opportunities in the solar PV sector

Module Structure

- 1.1 Introduction to Energy
- 1.2 Renewable and Non-renewable Energy
- 1.3 Introduction to Solar Energy
- 1.4 Introduction of Solar Photovoltaic System (Solar PV System)
- 1.5 History & Evolution of Solar PV System
- 1.6 Roles and Responsibilities of Solar PV Installer – Civil
- 1.7 Job Opportunities for a Solar PV Installer – Civil

Have you ever wondered how the lights in your classroom turn on? A car moves when you press the accelerator? Water gets pumped to the overhead tank? The fan cools the room on a hot summer day? All these activities require energy (Fig. 1.1).

1.1 Introduction to Energy

Energy is all around us and is essential for everything we do. From switching on a fan to heating water or driving a car, every action requires energy. It exists in different forms such as heat, light, sound, electrical, and chemical energy. As our demand for energy increases, it becomes important to use clean and sustainable energy sources to protect the environment. Learning about energy helps us understand how the world works and how we can make better choices for a greener future.

Let us define Energy in simple terms, “*Energy is the capacity to do work*” and is essential for various human activities. It powers homes, industries, transportation, and communication systems.

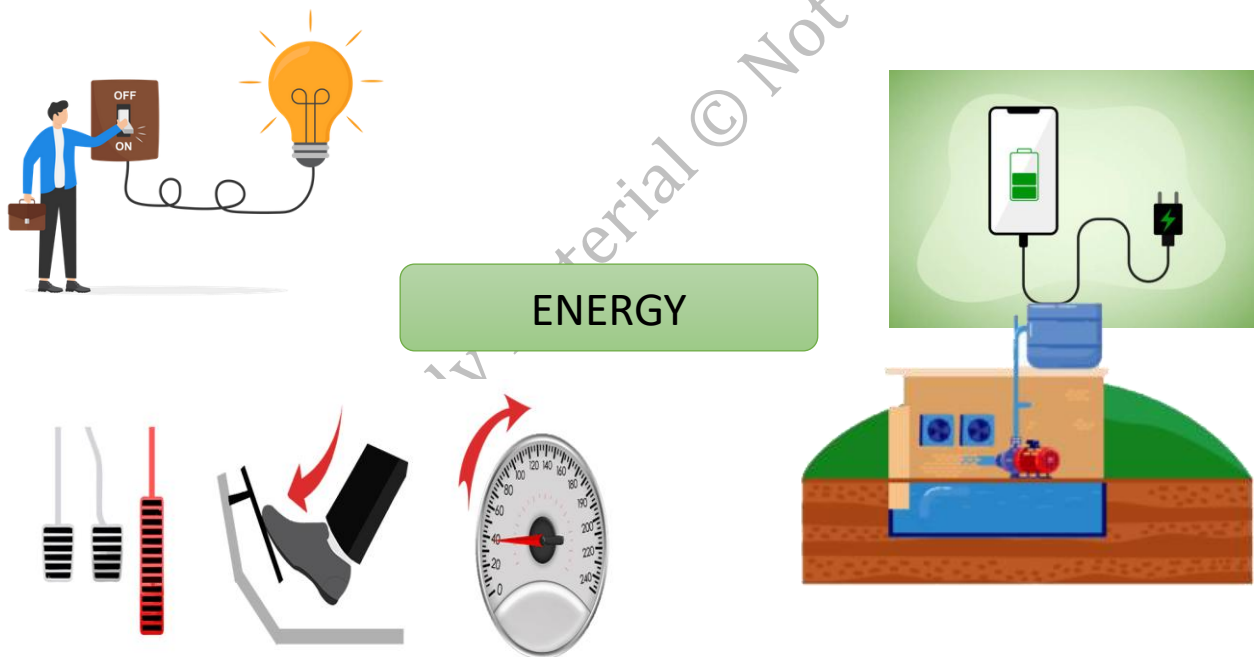


Fig. 1.1 Energy

1.2 Renewable and Non-renewable energy

Energy sources can be classified into two main categories based on their availability and impact on the environment:

1. Renewable Energy
2. Non-renewable Energy

1. Renewable Energy Sources

Have you ever felt the warmth of the sun on your skin? Or seen windmills spinning in open fields? These are everyday examples of renewable energy sources, which in turn, are the natural forms of energy that never run out and can be used again and again.

So, *Renewable energy Derived from natural sources that are continuously provided by the environment* (Fig. 1.2). This means that they won't get used up, even if we keep using them. They are clean, eco-friendly, and help protect our planet from pollution. Let us go through various examples of the renewable energy:

- **Solar Energy** – Think about solar panels on rooftops. They catch sunlight and turn it into electricity.
- **Wind Energy** – Have you seen giant windmills in villages or on hills? The wind moves their blades, which generates power.
- **Hydropower** – Water falling from a dam spins a turbine, creating electricity. That's how big dams light up entire cities.
- **Biomass** – Leftover wood, crop waste, and even animal dung can be burned to create energy. In some villages, people still cook using biomass.
- **Geothermal Energy** – In some places, heat from deep inside the Earth is used to warm homes or produce electricity.

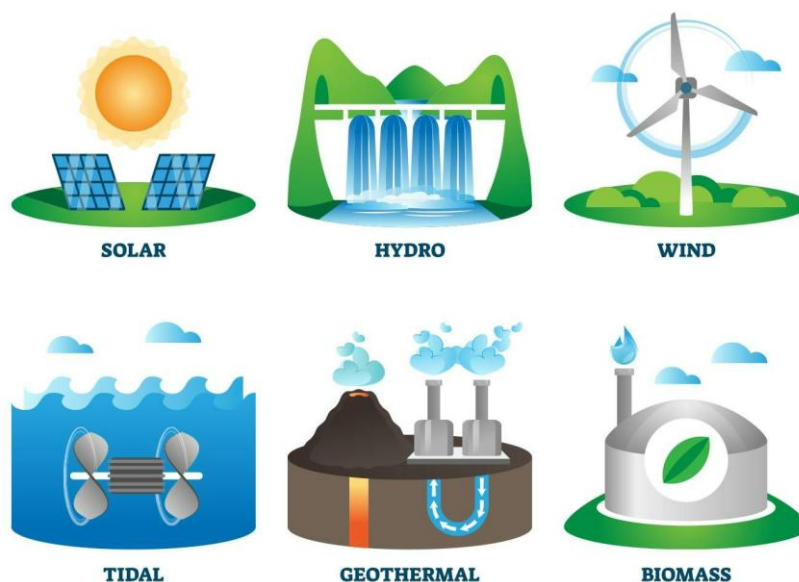


Fig. 1.2 Renewable Energy

Let's Think!

Do you use a solar-powered calculator or have seen solar street lights?

Have you been near a river dam that produces electricity?



Advantages of Renewable Energy

Following are the advantages of renewable energy sources:

- **Inexhaustible Supply:** The sources like solar, hydro, and wind are naturally replenished and will not deplete over time.
- **Eco-Conscious:** These sources generate minimal or no emissions, which results in significantly lower pollution levels and helps protect the environment.
- **Sustainable Development:** Renewable energy supports long-term energy solutions without harming natural ecosystems.
- **Low Operational Costs:** After covering the initial setup expenses, the costs for upkeep and operation remain relatively low.
- **Health Benefits:** By lowering pollution levels in air and water, they support in community well-being (health).

Limitations of Renewable Energy

Following are the limitations of renewable energy sources:

- **Dependency on Weather Conditions:** The efficiency of wind and solar energy is influenced by climatic factors such as sunlight and wind speed.
- **High Initial Investment:** Setting up renewable energy systems like wind turbines or solar panels can be expensive.
- **Land Usage:** Some renewable setups occupy large areas, potentially disturbing wildlife habitats or agricultural zones.
- **Energy Storage Challenges:** Since renewable energy production may not always align with demand, storing excess energy remains a technical and financial challenge.
- **Intermittent Supply:** Renewable energy may not provide a continuous supply of power without proper storage or backup systems.

2. Non-Renewable Energy Sources

Non-renewable energy comes from sources that take millions of years to form and cannot be replaced quickly once used. These are mostly found under the ground in the form of fossil fuels. (Fig. 1.3)

Examples You Use Daily:

1. **Coal** – Black rock found deep underground. It's burned in power plants to make electricity.
2. **Petroleum (Oil)** – Used as fuel in cars, bikes, and buses.
3. **Natural Gas (NG)** – Used for cooking in homes (LPG) and also for heating.
4. **Nuclear Energy** – Comes from Uranium, used in nuclear power plants.

Non-renewable energy sources

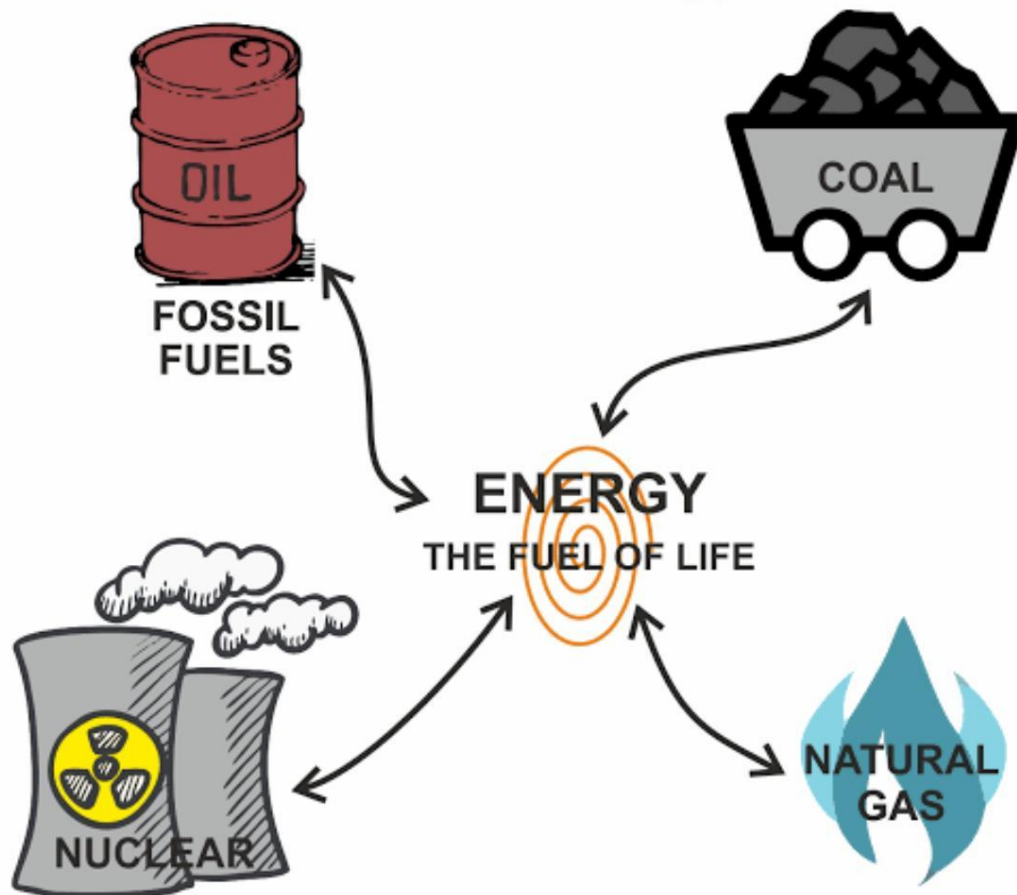


Fig. 1.3 Non-Renewable Energy Sources

Let's Think!

- Do you ride a petrol bike or see buses at the fuel station?
- Is your home gas stove running on LPG?

What type of Energy are we using in the above two examples?



Advantages of Non-Renewable Energy:

The advantages of non-renewable energy sources are:

- **High Energy Output:** Fossil fuels such as petroleum, coal, and natural gas provide a significant and reliable source of energy.
- **Efficient Storage and Transport:** These fuels are easy to store and transport using existing infrastructure.
- **Constant Availability:** Unlike some renewables, fossil fuel energy can be generated regardless of weather or time of day.
- **Well-Established Technology:** Energy systems based on fossil fuels are widely used and supported by existing technologies and networks.

Limitations of Non- Renewable Energy:

Limitations of non-renewable energy sources are:

- **Finite Resources:** Non-renewable energy sources are formed over millions of years and are limited in availability.
- **Environmental Pollution:** Burning fossil fuels releases harmful gases that contribute to air, water, and soil pollution.
- **Climate Change:** Fossil fuel combustion releases greenhouse gases that significantly drive climate change and global temperature rise.
- **Ecological Damage:** Extracting fossil fuels often results in deforestation, damage to natural habitats, and the risk of oil spills.
- **Rising Costs:** As resources become scarce, their prices may increase, making them less economically viable in the long term.

LET US TRY THIS!

Observe your home or school and make a list of at least five appliances or machines that use energy. Write down the type of energy they use (e.g., electrical, chemical, solar, etc.).

1.3 Introduction to Solar Energy**Let us read a Story!**

In a small village named Surajpur, nestled between green fields and dusty roads, lived a curious and bright 14-year-old girl named Meera.

Her family, like many others in the village, depended on farming. But every evening, as the sun set, their house would fall into darkness. The electricity was irregular and sometimes didn't come for days.

Meera loved to study, but without light, she struggled to complete her homework. One day at school, her science teacher spoke about solar energy — how the sun could be used to light up homes, power fans, charge mobile phones, and even pump water for farming. Meera was fascinated.

That evening, she told her parents all about what she learned. Her father smiled, "It sounds good, beta, but how do we do that?" Meera didn't give up. She visited the village panchayat office, where a solar energy awareness camp was being held. She learned that the government was providing small solar home systems to villagers at a low cost.

With determination, Meera helped her family apply for the scheme. Within a month, a solar panel was installed on their roof. It charged during the day and gave bright LED light and even ran a small fan at night. Meera's joy knew no bounds — she could study comfortably, and her mother no longer had to cook by the light of a smoky kerosene lamp.

The best part? Their electricity was now free from the sun - no monthly bills, no pollution, and no blackouts.

Soon, other villagers followed Meera's example. Surajpur slowly became known as a "solar-powered village," all because one girl believed in the power of the sun.



Energy emitted by the sun is known as solar energy. This energy source is widely available and exists in abundance across the Earth. As a renewable energy source, it means that it does not get exhausted and can be used again and again. Solar energy is transformed into usable electricity via solar panels through the process of the photovoltaic effect.

One of the best things about solar energy is that it is available everywhere the sun shines whether it's a city rooftop or a remote village. It does not release harmful gases or pollutants, making it an eco-friendly alternative to fossil fuels like coal and petrol.

With improvements in technology, solar panels have become more affordable and efficient. Today, people use solar energy to light up homes, power fans, run water pumps, and even charge electric vehicles. Solar power may also be stored in batteries to provide electricity when sunlight is unavailable.

As the world moves towards sustainable and clean energy, solar energy plays a key role in reducing carbon emissions and protecting the environment. Because it is renewable, clean, and becoming more accessible, solar energy is a vital part of the future of energy production.

1.3.1 Environmental and Economic Benefits of Solar Energy

Solar energy delivers several environmental paybacks that make it one of the most sustainable choices for energy production. Firstly, it is a clean energy source that does not release harmful pollutants or greenhouse gases. This helps in reducing air pollution, slowing down climate change, and improving overall health in communities. Unlike coal or gas plants, solar power does not harm natural habitats or pollute water sources.

From an economic perspective, solar energy is becoming more affordable every year. Despite the high initial investment required for solar panel installation, the operating cost is very low. Once installed, Solar panels operate with little maintenance and can produce energy for 20–25 years or more. This helps families and businesses save money on electricity bills.

Moreover, the solar industry creates jobs in installation, manufacturing, and maintenance. It helps both urban and rural areas by offering employment opportunities and reducing dependency on expensive fuels. Governments around the world are also supporting solar energy with subsidies, making it easier for people to adopt this technology.

The rising global population is driving up energy requirements. Presently, much of this energy comes from non-renewable fuels such as coal, oil, and natural gas, which are in limited supply and have a significant negative impact on the environment. In this context, solar energy has become a key solution to meet rising energy demands sustainably.

Solar energy is available in abundance, especially in sun-rich countries like India, where there is sunlight for most of the year. It can be used in homes, schools, hospitals, farms, and industries, making it a flexible and reliable energy source.

With innovations in technology, large-scale solar farms and rooftop solar systems are now being used to power entire cities and industries. Countries are setting targets to increase their share of solar energy in their national energy mix.

By 2030, India plans to expand its renewable energy capacity to 500 gigawatts, with solar being a major contributor. Solar energy reduces the pressure on fossil fuels and provides a stable and long-term energy solution. It helps ensure energy security, improves access to power in developing regions, and supports economic growth without harming the planet.

1.4 Introduction of Solar Photovoltaic System (Solar PV System)

The Solar PV system refers to a method of generating electricity by converting sunlight through photovoltaic technology. The word "photovoltaic" is derived from "*photo*" means light and "*voltaic*" means electricity. So, it simply means creating electricity from light.

At the heart of a Solar PV system are solar panels, also known as PV modules. These panels are made from semiconductor materials, most commonly silicon. When sunlight falls on these panels, a phenomenon called the photovoltaic effect, takes place this is where the sunlight excites and energizes the electrons in silicon cells, prompting their movement, and create an electric current (Fig. 1.4).

This generated current is direct current (DC), but the majority of home appliances are designed to run on alternating current (AC). So, to make the electricity usable, the system incorporates a component known as an inverter to convert DC power into AC.

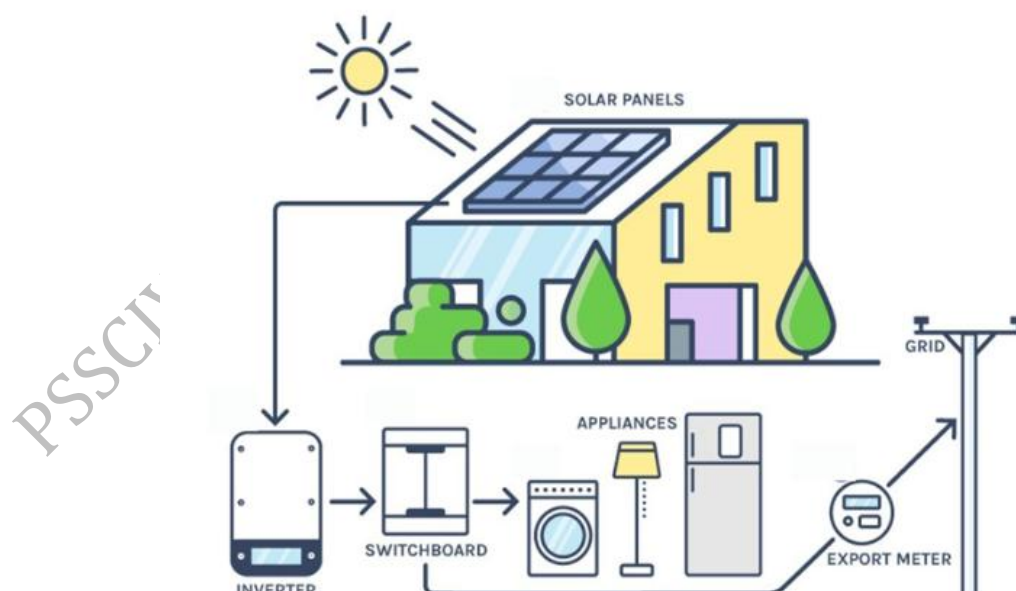


Fig. 1.4 Solar Photovoltaic System

1.4.1 Types of Solar PV Systems

Solar Photovoltaic (PV) systems are generally classified into three main types: grid-connected, off-grid, and hybrid. These types are based on how the system uses and stores electricity, and whether it is connected to the main power supply (electricity grid) or not. Each type works in a different way to give power to homes, schools, or other places (Table 1.1).

Table 1.1 Types of Solar PV System

Type	Description
<i>Grid-Connected</i>	Linked to the power grid, allowing excess electricity to be exported and enabling energy consumption from the grid when required.
<i>Off-Grid</i>	Functions separately from the main electrical grid. These systems Rely on batteries to retain power for night time consumption or cloudy days. Ideal for remote or rural areas.
<i>Hybrid</i>	A mix of both systems. It connects to the grid but also includes batteries to store power for backup.

1.5 History & Evolution of Solar PV System

Have you ever wondered how we started using sunlight to make electricity? Let's take a quick view on how solar energy was utilized into electricity before:

Long Ago – The First Spark

It all started in 1839, when a young French scientist named Edmond Becquerel discovered something amazing. He discovered that some materials generate a small electric current when exposed to light. This was called the "photovoltaic effect" the science behind solar power.

1900s – Getting Closer

Scientists kept experimenting, and by 1954, a big step was taken by Bell Labs in the USA. They made the first real solar cell using silicon. It could turn sunlight into enough electricity to power small devices like toys or radios.

1960s – Reaching for the Stars

Guess where solar panels were used first in a big way? Answer is in SPACE. Solar panels powered satellites and space missions, because there's lots of sunlight and no power plugs in space.

1970s–2000s – Coming Down to Earth

As technology improved, solar panels got cheaper and better. People started using them on homes, calculators, and in villages with no electricity. Governments also began to support clean energy.

Today, solar power is all around us on rooftops, in solar farms, even on streetlights. We now have grid-connected, off-grid, and hybrid solar systems. With better batteries and smarter systems, solar PV is helping build a cleaner and greener world.

1.6 Roles and Responsibilities of Solar PV Installer – Civil

A Solar PV Installer – Civil contributes greatly in ensuring that the physical infrastructure for a solar photovoltaic system is properly prepared and safely installed as shown in Fig. 1.5. While the electrical team handles the wiring and connections, the civil installer ensures the foundation, support structures, and site readiness are handled correctly.



Fig. 1.5 Solar PV Installer – Civil

1. Visit the installation site to study the terrain, soil type, rooftop structure (if rooftop), and available space.
2. Ensure the surface is properly levelled and cleared before starting installation.

3. Construct civil foundations for solar panel mounting structures on ground-mounted or rooftop setups.
4. Ensure the structures are aligned to the right angle and direction (usually south-facing in India) for maximum solar exposure.
5. Supervise the unloading and placement of heavy equipment like solar panels, mounting rails, and inverters.
6. Follow all safety protocols at the site including wearing PPE (Personal Protective Equipment).
7. Coordinate with electricians during cable routing and panel alignment.
8. Ensure all civil work is synchronized with electrical and mechanical tasks.
9. Maintain records of work progress.
10. Ensure that civil work meets industry standards and project specifications.

1.7 Job Opportunities for a Solar PV Installer – Civil

As the renewable energy sector continues to grow rapidly, career opportunities for Solar PV Installer – Civil are increasing across the country and globally. The Government of India, through schemes like PM-KUSUM, Solar Park Projects, and Rooftop Solar Initiatives, is promoting solar energy installations, creating a surge in demand for skilled manpower.

Possible Career Paths:

1. Solar PV Installer – Civil (Entry Level):

Involved in basic construction and support work at solar power sites.

2. Site Supervisor / Civil Foreman:

Supervises a team of workers and ensures the project stays on track and within safety norms.

3. Project Coordinator (Civil):

Coordinates between the civil, electrical, and mechanical teams for smooth execution.

4. Quality Control Officer – Civil Works:

Monitors and ensures the structural integrity of foundations and mounting structures.

5. Entrepreneurship:

With training and experience, one can start their own solar installation service, especially in rural or semi-urban areas.

6. Government and NGO Jobs:

Engage in public projects, rural electrification programs, or community-based energy projects.

CHECK YOUR PROGRESS**A. Multiple Choice Questions**

1. Which among the following is an example of a non-renewable energy resource?
 - a) Solar
 - b) Hydropower
 - c) Natural Gas (NG)
 - d) Wind energy
2. What is the main component in solar panels that helps generate electricity?
 - a) Aluminum
 - b) Silicon
 - c) Plastic
 - d) Iron
3. Which of these is an advantage of renewable energy?
 - a) High pollution levels
 - b) Expensive fuel imports
 - c) Inexhaustible supply
 - d) Requires fossil fuels
4. The Solar PV system that includes battery storage to supply power during nights or cloudy weather is called:
 - a) Grid-connected
 - b) Off-grid
 - c) Smart-grid
 - d) Centralized
5. What government scheme promotes solar energy installation in rural India?
 - a) Swachh Bharat Abhiyan
 - b) PM-KUSUM
 - c) Make in India
 - d) Start-up India

B. Answer the following

1. Define energy in simple terms.
2. What is the main difference between renewable and non-renewable energy sources?
3. Write two environmental benefits of solar energy.
4. What is the photovoltaic effect?
5. What can be possible career paths for a Solar PV Installer – Civil. State and explain any two.

C. Match the following**Column A****Column B**

A.	Solar Energy	1.	Black rock used in power plants
B.	Coal	2.	Found in LPG cylinders
C.	Windmill	3.	Renewable source using sunlight
D.	Natural gas	4.	Converts wind to electricity
E.	Inverter	5.	Convert DC to AC

MODULE 2**BASICS OF SOLAR PHOTOVOLTAIC SYSTEM****Module Overview**

This module provides an understanding of how the sun's movement affects solar energy generation. It introduces key terminologies used in the solar industry and explains the working and structure of a Solar PV system. Learners will gain knowledge of different solar panels, types of PV stations, and mounting structures used in installations.

Learning Outcomes

After completing this module, you will be able to:

- Understand the movement of the sun and its relevance in solar energy generation
- Explain essential terminologies used in the solar PV industry
- Describe the basic working principle of a Solar PV system
- Enlist the key components of a Solar PV system.
- Differentiate between various types of solar panels
- Recognize different types of solar PV stations.
- Describe the types and materials of solar panel mounting structures

Module Structure

- 2.1 Understanding the Movement of Sun
- 2.2 Basic Terminologies
- 2.3 Basic of Solar PV System
- 2.4 Components of Solar PV System
- 2.5 Classification of Solar Panels
- 2.6 Types of Solar PV Station
- 2.7 Solar Panel Mounting Structures

It is well known that the sun provides both light and warmth. But did you know we can also use sunlight to make electricity? Yes, it is possible as we have learnt in the Unit 1 *i.e.* using a Solar PV system. Let us discuss from the scratch about this Solar PV system.

2.1 Understanding the Movement of Sun

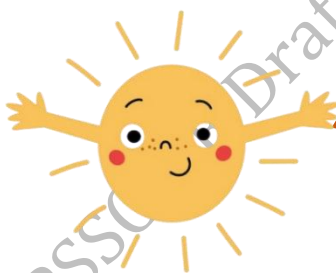
We need to understand one important thing that the sun is always moving across the sky during the day. This movement affects how much sunlight reaches the system and how well it works. For example, if the sun moves and the system doesn't follow it, we may lose some sunlight or if a shadow falls on it, it won't work as well.



How can movement of the sun and shadows change the power we get from sunlight? What if the sun didn't appear to rise in the east and set in the west? How would that affect the power your home receives from a solar plant?

Let us first talk about movement and how it affects the working of a solar power plant.

Have you ever thought about why the Sun rises in the east and sets in the west? Is the Sun actually moving across the sky, or is there another reason? Picture Earth as a giant spinning ball, rotating around an invisible line known as its axis. This spinning motion is called **rotation**. It takes 24 hours for Earth to make one full turn, which gives us day and night.



Try This Activity!

Take a globe (or imagine one). Stick a toothpick through the top and bottom - that's the axis. Now slowly spin it from left to right. That's how Earth spins - from west to east!

Now, place a torch on one side of the globe. As the globe rotates, the side facing the torch is illuminated - that's daytime. The side turned away remains in darkness - that's night time.

The Sun doesn't truly travel across the sky, but it appears to do so from our perspective - this illusion is known as the Sun's apparent motion.

Let's follow the Sun through the day, from the same spot:

1. **Morning – Sunrise:** The Sun appears on the eastern horizon. It seems low in the sky and the light is soft and orangish. That's why we call it sunrise.
2. **Noon – High in the Sky:** Around noon, the Sun appears to be right above our heads (or close, depending on where we are). It feels hotter because the Sun's rays hit the Earth more directly.
3. **Evening – Sunset:** Now the Sun is going down, and it looks like it's setting in the west. Again, we get beautiful orange and pink skies. This is called sunset.

Remember: The Sun is not actually rising or setting - it is Earth that is spinning.

The Sun's varying height in the sky and the changing length of days occur due to two key factors:

1. Earth not only spins (rotates), but it also moves around the Sun - this is called revolution.
2. Earth's axis is tilted (not straight up and down), at an about 23.5° angle.

As Earth orbits the Sun throughout the year, its tilted axis causes the Sun to appear at varying angles in the sky during different months. This tilt means that different parts of Earth receive sunlight more directly at certain times, resulting in changes in the Sun's position and the length of daylight (Fig. 2.1). This is why:

- In summer, the Sun appears higher in sky and days are longer.
- In the winter, the Sun appears lower and days are shorter.

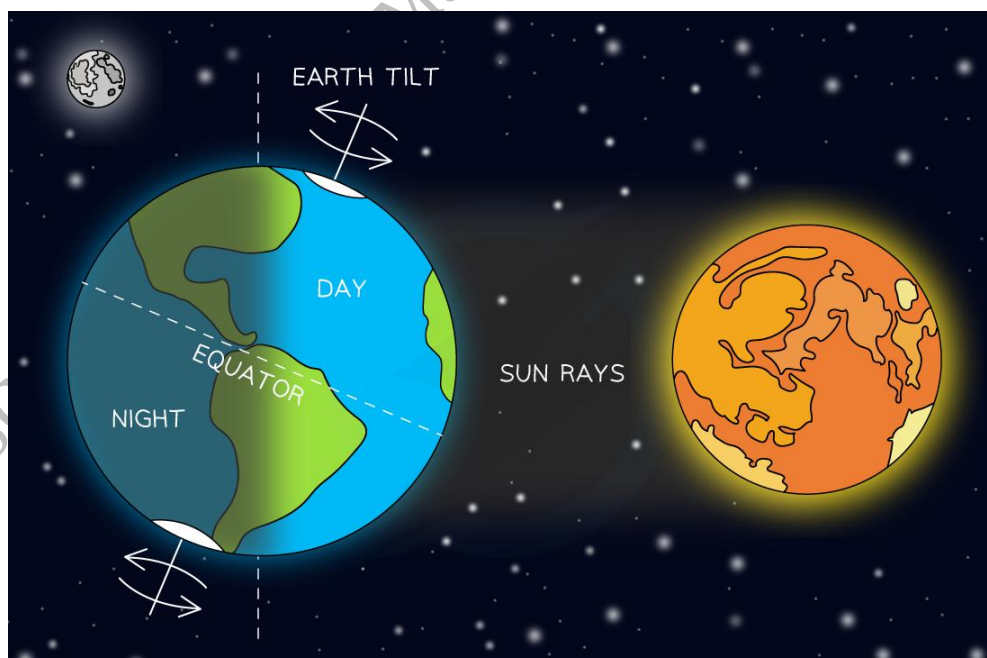


Fig. 2.1 Understanding the concept of day and night

2.2 Basic terminologies

To understand how solar energy system work, it's important to learn some basic terms that are commonly used in the solar industry. Following are the terms:

1. Direct Normal Irradiance (DNI)

DNI refers to amount of sunlight that directly hits a surface placed at a 90° angle (perpendicular) to the sun's rays. This type of sunlight comes straight from the sun without being scattered by clouds or particles. It's the strongest form of solar energy and is especially important for systems using solar concentrators or tracking panels. If clouds or pollution block the sunlight, DNI reduces (Fig. 2.2).

LET'S TRY THIS!

Activity: Simulating Direct Normal Irradiance (DNI)

Materials: Flashlight, a flat surface (like a wall or a book), measuring tape or ruler.

Procedure:

1. Darken a room and turn on a flashlight (this represents the sun).
2. Hold the flashlight perpendicular (straight) to surface and notice how bright and focused the light is.
3. Slowly tilt the flashlight or move it farther away and observe how the light becomes dimmer or more spread out.
4. This shows that the closer and more directly the light hits the surface, the higher the DNI.

2. Diffuse Horizontal Irradiance (DHI)

DHI defines as sunlight that has been scattered by clouds, dust, or air particles and reaches the surface of earth indirectly. Even when sun is behind clouds, some light still reaches us – that's diffuse light. This type of sunlight is weaker than DNI but still useful for fixed solar panels that don't track the sun. (Fig. 2.2).

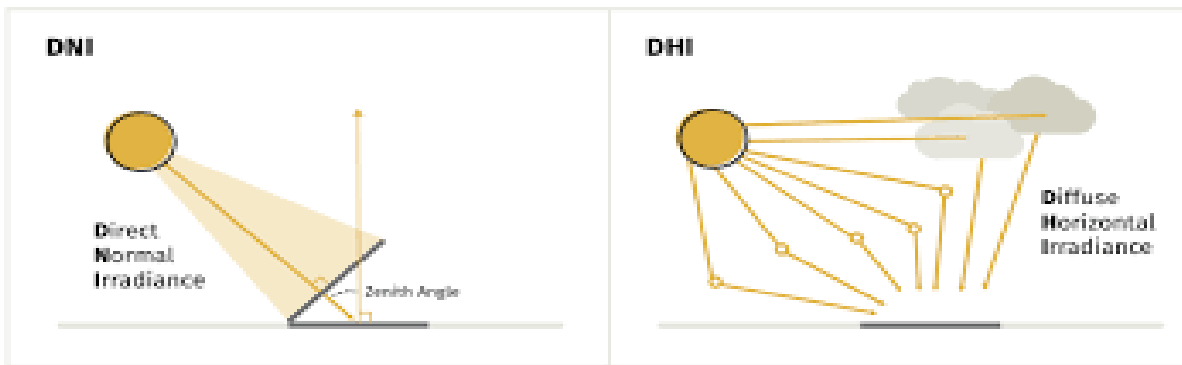


Fig. 2.2 Understanding the terms DNI

3. Global Horizontal Irradiance (GHI)

Global Horizontal Irradiance (GHI) is defined as the total solar radiation received on a horizontal surface. It consists of the sum of Direct Normal Irradiance (DNI) projected onto the horizontal plane and Diffuse Horizontal Irradiance (DHI), which is sunlight scattered by the atmosphere reaching the surface from all directions. In simpler terms, it includes both direct and scattered sunlight. GHI is most commonly used in designing rooftop solar PV systems because rooftops are usually fixed and flat.

4. Solar Altitude Angle

The angle between the sun and the ground is Solar Altitude Angle. It changes throughout the day – it's lowest in the morning and evening and highest at noon when the sun is directly overhead. This angle helps determine how much sunlight a place receives and affects the design and tilt of solar panels.

LET US TRY THIS!

Activity: Measuring Solar Altitude Using Shadows

Materials: Stick (about 1 meter), tape measure, notebook, clock.

Instructions:

1. Go outside with students on a sunny day and plant a stick vertically in the ground.
2. Measure the length of the stick's shadow at different times (morning, noon, afternoon).
3. Note down the time and shadow length in a table.
4. Shortest shadow usually occurs around noon – this means the solar altitude angle is highest at that time.

2.3 Basic of Solar PV System

Solar Photovoltaics (PV) is a clean and renewable technology that generates electricity directly from sunlight. It operates on the photovoltaic effect, a process where light energy is transformed into electrical energy using special materials called semiconductors (Fig. 2.3).

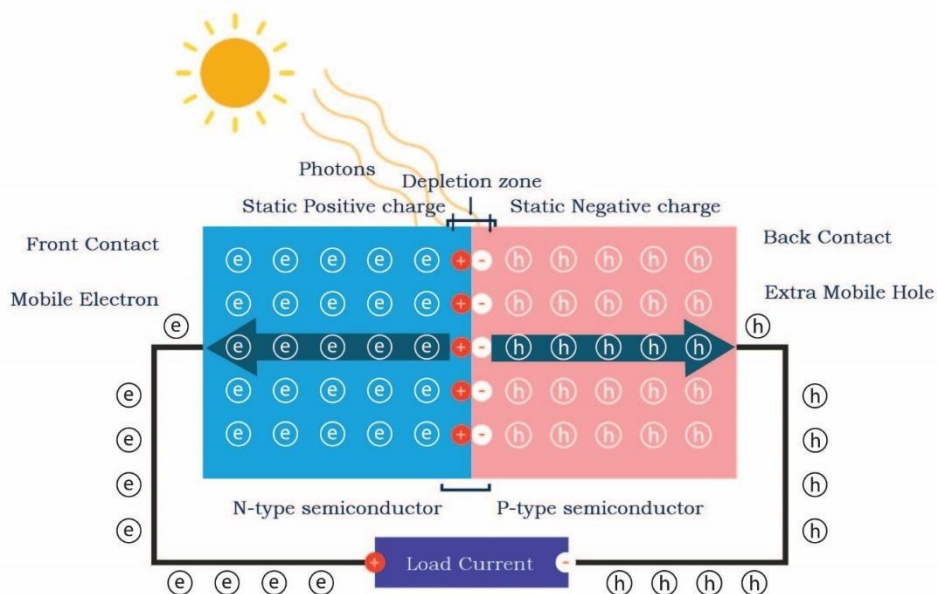


Fig. 2.3 Photovoltaic Effect

What Happens When Sunlight Hits a Solar Cell? Let us discuss that step by step:

1. A solar cell, also known as a photovoltaic cell, is made from a semiconductor material such as silicon.
2. When sunlight strikes the cell, it energizes the electrons within the material
3. The energized electrons begin to move, generating an electric current.
4. This current is captured by metal contacts on the top and bottom of the cell and can be used to operate electrical devices.

Think about it: What do you think happens to a solar cell on a cloudy day?

A single cell produces a small amount of electricity. To generate more power:

- Several solar cells are linked together to create a **Module**, commonly known as a solar panel.
- Several modules are grouped and it is collectively called as a **Solar array**.
- Arrays are designed to meet different electricity needs from a single light bulb to an entire building (Fig. 2.4).

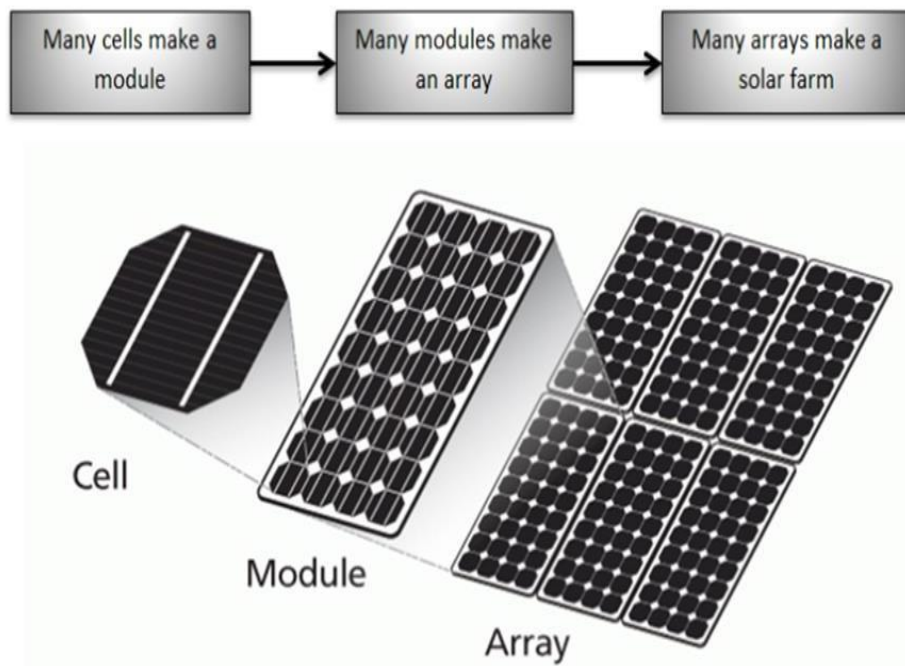


Fig. 2.4 Cell, Module and Array

2.3.1 Classification of PV Systems

PV Systems can be classified into two basic categories:

1. Flat-Plate Systems

- Capture sunlight across a large, flat surface.
- Work in most weather conditions, including cloudy days.
- Simple and widely used.

2. Concentrator Systems

- It concentrates sunlight onto a small area using mirrors or lenses.
- Need strong, direct sunlight.
- More complex and require sun-tracking devices.

Think about it: Why might concentrator systems not work well on a rainy or foggy day?

The schematic diagram of Solar PV system enable house is shown in below Fig. 2.5.

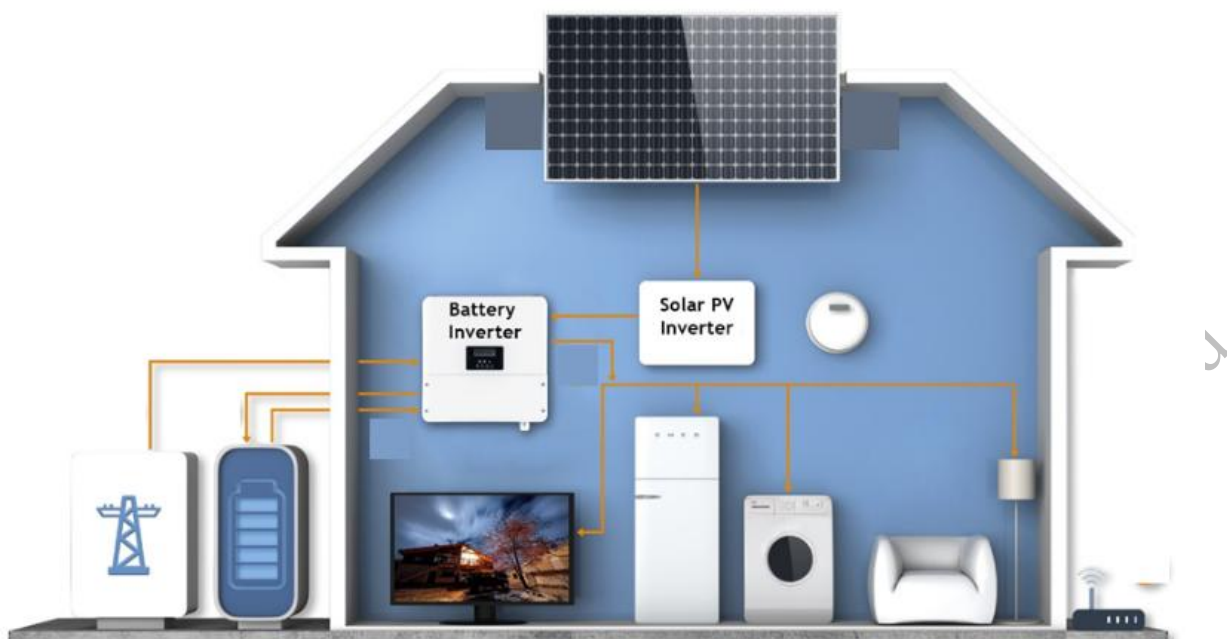


Fig. 2.5 Schematic diagram of a Solar PV System

2.4 Components of Solar PV System

Now, let us discuss about the basic components of a solar PV System:

1. Solar Photovoltaic (PV) Modules / Panels

Solar panels are the most recognizable component of a photovoltaic (PV) system. They consist of numerous solar cells that use the photovoltaic effect to transform sunlight into direct current (DC) electricity. These panels (Fig. 2.6) are usually installed on rooftops or open spaces to receive maximum sunlight.

They come in different types such as monocrystalline, polycrystalline, and thin-film. The size and number of panels depend on the energy requirement of the system. They perform most efficiently under direct sunlight, though they can still produce a certain amount of electricity even on cloudy days. Solar panels have no moving parts, making them easy to maintain and highly durable. Their efficiency determines how much sunlight is converted into electricity.



Fig. 2.6 Solar Panels

2. Mounting Structure

The mounting structure (Fig. 2.7) supports the solar panels, whether installed on rooftops or at ground level. It is built to endure various weather conditions like wind, rain, and snow. Mounting systems are mainly of two types: fixed-tilt and tracking.

Fixed structures are set at a specific angle to get the best average sunlight, while tracking systems move to follow the sun for more energy. The material used is usually corrosion-resistant, like galvanized steel or aluminium.

Proper mounting ensures panels stay secure and are positioned to maximize sunlight exposure. A well-installed mounting system also helps in cooling the panels by allowing airflow underneath.



Fig. 2.7 Mounting Structures in Solar Panels

3. Solar Inverter

Solar panels generate electricity in the form of direct current (DC), while most household and commercial appliances operate on alternating current (AC). An inverter is used to convert the DC electricity into usable AC power. It also synchronizes with the grid if the system is connected to it. There are different types: string inverters, microinverters, and hybrid inverters. Inverters may also provide system monitoring features, showing how much electricity is being generated. They must be properly sized according to the power output of the panels. Inverters are crucial for the safe and efficient functioning of a solar PV system. Some advanced inverters can also help with load management and energy storage (Fig. 2.8).

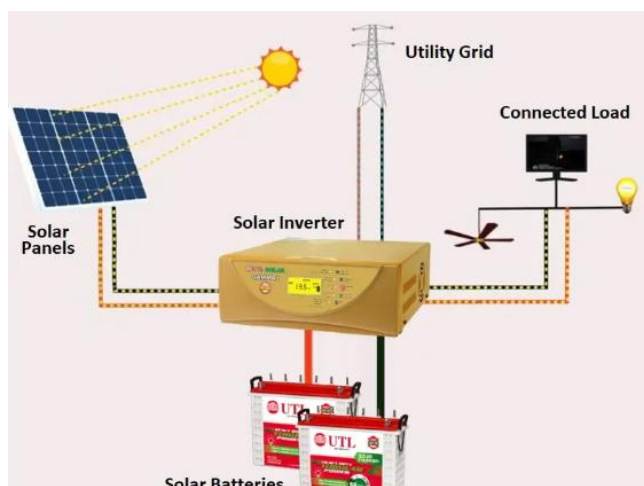


Fig. 2.8 Solar Inverter

4. Battery Storage System (Optional)

Batteries store surplus electricity produced during the day for use at night or during power cuts. They are especially important in off-grid setups or regions with unstable power supply. Common battery types include lead-acid and lithium-ion, each offering different costs and durability. The battery system must be properly sized to match the energy usage and panel output. It adds independence to the solar setup, making it less dependent on the grid. Battery management systems (BMS) are used to monitor health, charge, and safety. While batteries increase the overall cost, they enhance the system's reliability and flexibility. Ensuring proper ventilation and correct installation is essential for maintaining battery safety and extending their lifespan (Fig. 2.9).



Fig. 2.9 Battery Storage

5. Charge Controller

A charge controller manages the voltage and current flowing from the solar panels to the battery, ensuring safe charging by preventing overcharging or deep discharging. The two main types are PWM (Pulse Width Modulation) and MPPT (Maximum Power Point Tracking), with MPPT controllers offering higher efficiency and being preferred in modern solar systems. Charge controllers protect batteries from damage and extend their lifespan. They also disconnect loads or panels when voltage levels go out of the safe range. Some charge controllers have display units to show battery status and charge levels. It is a key component in battery-based systems, especially in off-grid applications.

6. Maximum power point tracker (MPPT)

A Maximum Power Point Tracker (Fig. 2.10) is a DC to DC electronic converter that maximizes the power transfer between the solar array (PV panels) and the battery bank or utility grid. In many systems, the charge controller or grid-tied inverter also includes MPPT functionality, combining both roles in a single device.

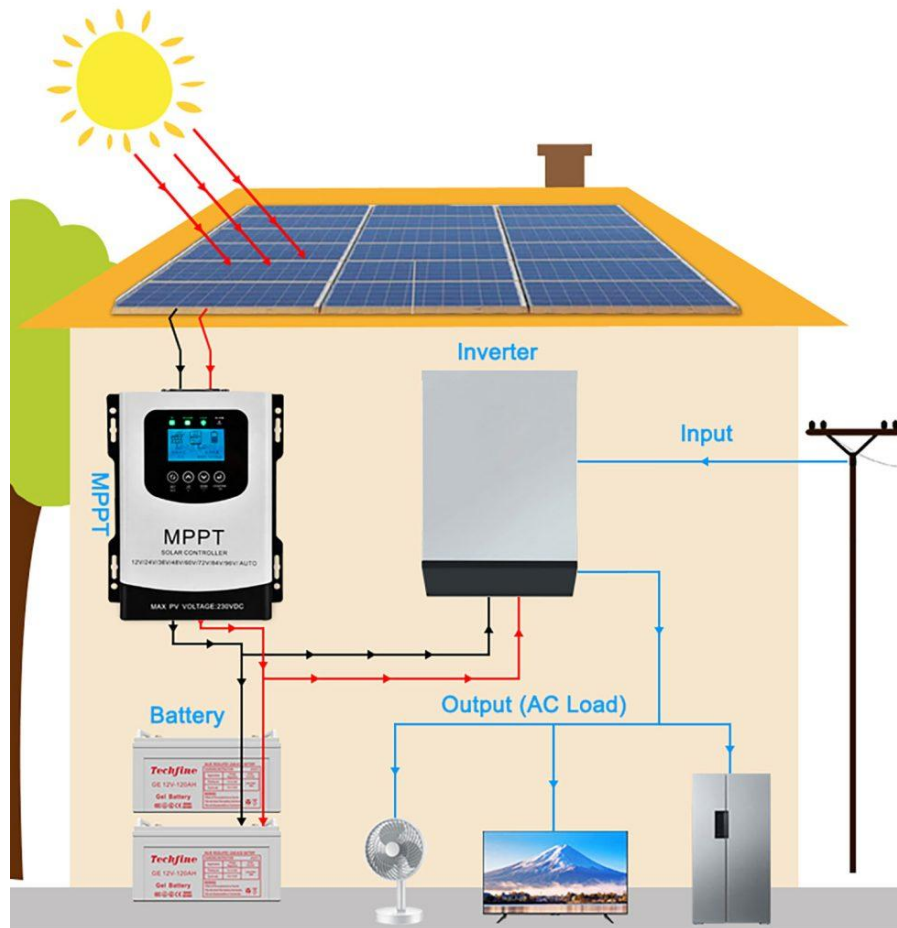


Fig. 2.10 Maximum Power Point Tracker (MPPT)

2.5 Classification of Solar Panels

Various types of solar PV panels are available in the market; each made from different materials. The type of solar module is named after the material used in its specific technology. Since these materials have distinct properties, each type of module varies in parameters such as efficiency, voltage, and current. The four types of photovoltaic technology are

1. Bifacial Solar Panels
2. Monocrystalline Solar Panels
3. Polycrystalline Solar Panels, and
4. Thin film Solar Panels

These four types of PV cells vary in terms of size, efficiency, and cost, as explained below:

1. Bifacial Solar PV Panel

Bifacial solar panels are designed to absorb sunlight from both their front and rear sides. They typically feature a transparent back, allowing sunlight to pass through, reflect off the ground, and reach the solar cells on the backside. This design increases overall electricity generation compared to conventional solar panels (Fig. 2.11).

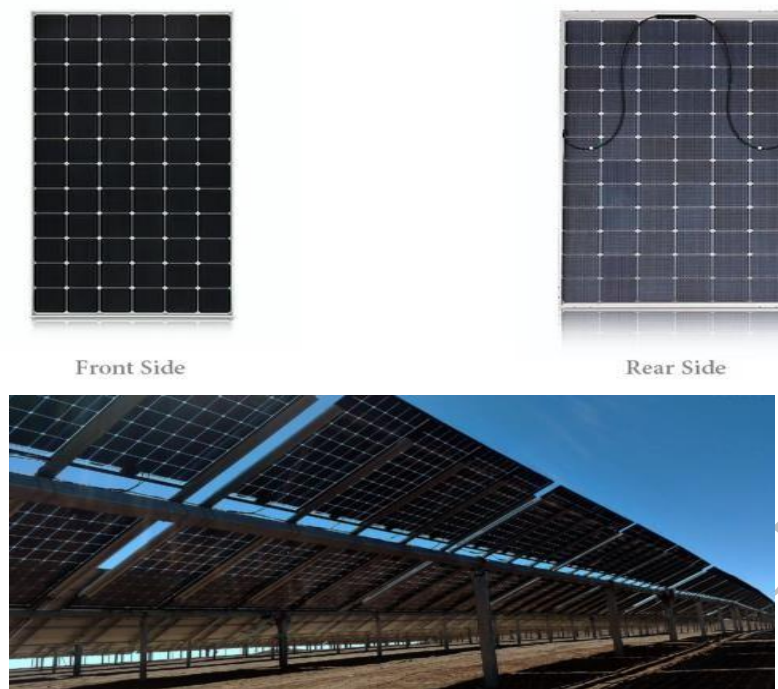


Fig. 2.11 Bifacial Solar PV Panel

2. Monocrystalline Solar Panels

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 cost compared with the amount of output they give.

Modules made with monocrystalline silicon PV cells typically achieve commercial efficiency levels ranging from 15% to 20%.

These panels are made of pure silicon and undergo a complex process of development and therefore are expensive. The cells are manufactured by slicing long silicon rods into thin discs or wafers, typically 0.2 to 0.4 mm thick, which are then connected and assembled into panels, as illustrated in Figure 2.12.

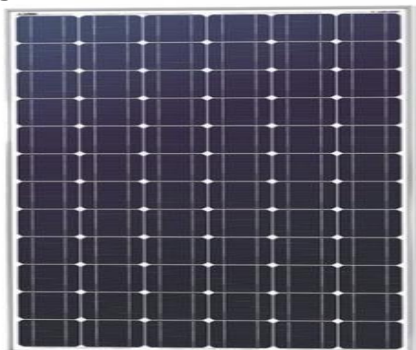


Fig. 2.12 Monocrystalline Solar PV Panel

3. Polycrystalline Solar Panels

Polycrystalline solar cells are composed of many small silicon crystals, giving them a shattered, glass-like appearance as shown in Fig. 2.13. They are more affordable due to lower manufacturing costs compared to monocrystalline cells, although they are slightly less efficient. Despite this, their cost-effectiveness makes them widely popular. These cells are connected to form solar panels, with polycrystalline modules dominating the market for offering good efficiency around 15% at nearly half the price of monocrystalline modules.



Fig. 2.13 Polycrystalline Solar PV Panel

4. Thin Film PV (Amorphous) Panels

These panels are not made of silicon crystals fully. Thin Film PV Panels as shown in Fig. 2.14 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 polycrystalline panels. As illustrated in the Fig. 2.14, these panels are composed of a combination of materials. For instance, thin hybrid silicon cells blend amorphous and microcrystalline technologies to achieve improved efficiency levels.



Fig. 2.14 Thin Film PV Panels

2.5.1 Solar Panel Layer

A Solar PV Panel consists of a multi-layered unit of the following items (Fig. 2.15).

- **Aluminium frame:** To protect glass from cracks.
- **Cover:** A transparent layer made of glass or plastic that protects the solar cell from environmental elements.
- **Adhesive:** Bonds the protective cover to the rest of the solar cell structure.
- **Anti-reflective Coating:** Minimizes light reflection, ensuring maximum sunlight is absorbed into the cell.
- **Front Contact:** Conducts and transmits the electric current generated by the cell.
- **N-Type Semiconductor Layer:** A silicon layer doped with phosphorus to create an excess of electrons.
- **P-Type Semiconductor Layer:** A silicon layer doped with boron to create a deficiency of electrons (holes).
- **Back Contact:** Conducts and carries the electric current out of the solar cell.
- **Junction Box:** Power collection junction from the solar cell (Fig. 2.15).

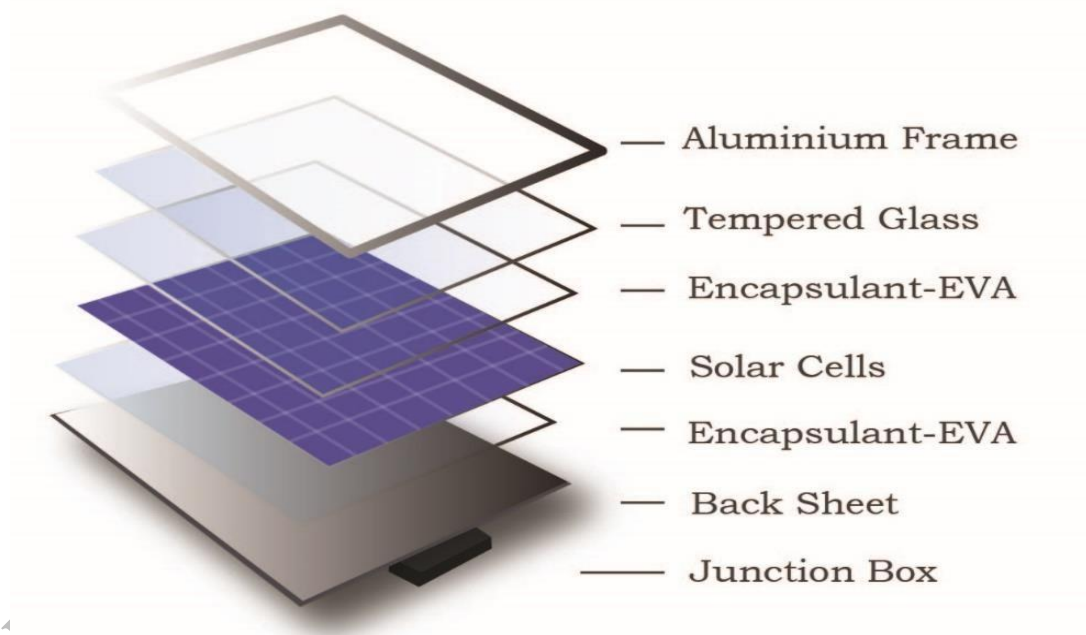


Fig. 2.15 Solar Panel Layers

Table 2.1 Comparison between different types of Solar Panels

Type of PV Cell	Module Efficiency	Surface area needed for 1 KWp (Power)	Advantages	Disadvantages
Bifacial Solar PV Panel	20 Plus %	5-6m ²	Less Area required, Highly standardised.	Very Expensive
Monocrystalline silicon	15-19 %	7-9 m ²	High efficiency PV Modules, Widely available in the market, Well standardized	High Cost, Silicon Material loss during manufacturing
Polycrystalline silicon	13-16 %	8-9 m ²	Lower Energy and Time Requirements for Production compared to Monocrystalline Cells (Cost-Effective), Readily Available in the Market, Highly Standardized	Slightly Lower Efficiency Compared to Monocrystalline Silicon Modules
Thin film	10-12 %	9-11 m ²	Less Impact from High Temperatures and Shading on Performance	Requires More Space to Produce the Same Amount of Power

2.6 Types of Solar PV Station

There are three primary types of solar power systems:

1. **On-Grid System** – Also called grid-tie or grid-feed, this system is connected directly to the electricity grid.
2. **Off-Grid System** – Also known as a stand-alone power system (SAPS), it operates independently without a connection to the utility grid.
3. **Hybrid System** – A grid-connected solar system that also includes battery storage for backup power.

1. On-grid Solar PV System-

A grid solar system, also known as an on-grid system, is the most widely used solar setup for residential and commercial applications. This system is connected directly to the electricity supply from your local power company (the grid). It doesn't need any batteries to store energy (Fig. 2.16).

How does it work?

1. Solar panels generate electricity from sunlight during the day.
2. Any excess electricity produced is sent to the power grid.
3. You receive credits or compensation for the surplus energy through a process called Net Metering.
4. At night or during cloudy weather, when solar production is low, you can draw electricity from the grid.

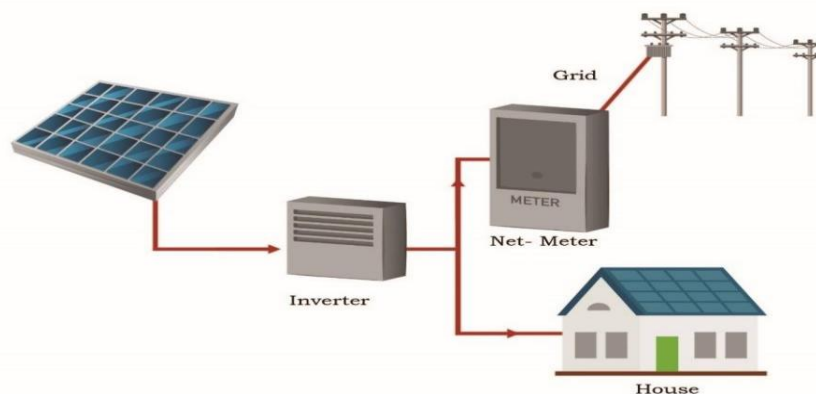


Fig. 2.16 On-Grid Solar PV System

Advantages of a Grid-Tied Solar System

1. Cost-Effective Installation

Grid-tied systems are generally more affordable to install compared to other types of solar systems, as they do not require batteries or additional energy storage equipment.

2. Efficient Use of Energy

Excess electricity produced by the solar panels is fed into the power grid, preventing energy waste and enabling users to earn credits or compensation through net metering programs.

3. Grid Support During Low Solar Generation

During times when solar production is low, users can seamlessly draw electricity from the grid, ensuring an uninterrupted power supply.

4. Reliable Backup Source

The electrical grid acts as a virtual storage system, providing reliable backup power without the need for physical battery storage.

5. Incentives and Revenue Opportunities

In many regions, owners of grid-tied systems can benefit from solar incentives or earn additional income through programs such as Solar Renewable Energy Credits (SRECs).

Disadvantages of a Grid-Tied Solar System

1. No Power During Grid Outages

For safety reasons, a grid-tied solar system automatically shuts down during a power outage.

2. Dependence on the Electrical Grid

Although solar panels reduce electricity bills, users are still dependent on the grid for power during non-sunny periods, which limits complete energy independence.

2. Off Grid Solar PV System

An off-grid solar system functions entirely independently from the main electricity grid. It is designed to produce and store enough energy to meet a household's year-round electricity needs, even during winter months when solar output is reduced. These systems depend heavily on battery storage to maintain a consistent power supply, especially at night or during long periods of cloudy weather.

Because of the higher costs associated with batteries and off-grid inverters, these systems are typically more expensive than grid-connected setups. While they have traditionally been used in remote or rural areas without grid access, falling battery prices are now making off-grid solutions increasingly attractive in urban environments as well.

There are two main configurations of off-grid systems:

1. AC-Coupled Systems

These systems integrate a standard solar inverter with a multi-mode battery inverter, allowing for greater flexibility and control. They are commonly used in larger or more advanced solar installations.

2. DC-Coupled Systems

These systems are more cost-effective, particularly suited for small-scale applications. They utilize solar charge controllers to manage battery charging and a basic inverter to convert DC power into AC for household use.

In off-grid systems as shown in Fig. 2.17, battery banks are a crucial component. Once the energy demand of household appliances is met, any excess solar power is directed to charge the batteries.

In addition, a backup generator (commonly called a gen-set) is often incorporated to supply electricity during prolonged cloudy periods when solar output is low, and the batteries are depleted. The generator must be properly sized to handle both the household's energy needs and recharge the battery bank at the same time.

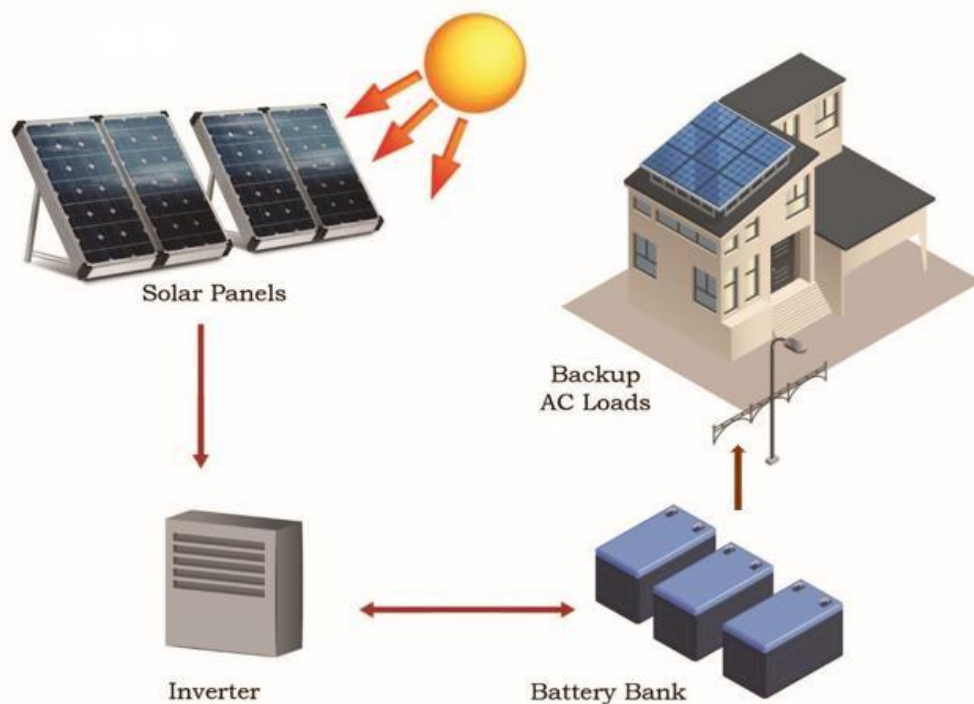


Fig. 2.17 Off-Grid Solar PV System

Advantages of an Off-Grid Solar System

- **Complete Energy Independence**

Off-grid systems provide total autonomy from the electricity grid, offering a reliable power source in remote or underserved areas.

- **Ideal for Remote Areas**

These systems are especially advantageous in areas where connecting to the utility grid is either challenging or not cost-effective.

Disadvantages of an Off-Grid Solar System

- **High Initial Cost**

The inclusion of batteries and specialized inverters significantly increases the system's overall cost.

- **Battery Dependency**

Reliable power depends entirely on the batteries, which require regular maintenance and have a limited lifespan.

- **Energy Waste**

Any excess energy generated during peak sun hours that exceeds the storage capacity may go unused.

- **Lifestyle Adjustments**

Users may need to reduce or manage their energy consumption carefully, especially during seasons with limited sunlight.

- **No Grid Backup**

In the absence of sunlight or stored energy, and without a backup generator, there is no alternative power source available.

3. Hybrid Solar PV System

A hybrid solar system combines features of both on-grid and off-grid setups. It includes solar panels, a battery storage unit, and a connection to the main power grid. This configuration offers the flexibility to store excess solar energy for later use, while also allowing access to grid electricity when needed. It enables users to utilize solar power during the day, store the surplus in batteries for use at night or during peak demand, and rely on grid power as a backup, ensuring a stable and uninterrupted energy supply.

As shown in Fig. 2.18, hybrid systems can also be programmed to charge batteries using off-peak grid electricity typically available at lower rates during late night or

early morning hours. This dual-source model helps reduce electricity bills by optimizing the use of stored solar energy and cheaper grid power.

Working Principle:

- During daylight hours, solar panels generate electricity.
- This energy first powers the immediate needs of household appliances.
- Surplus energy is stored in the batteries.
- Once batteries are fully charged, any additional power may be exported to the grid (if allowed).
- At night or during high demand, stored battery power is used.
- If battery power runs out, the system draws electricity from the grid to maintain continuous supply.

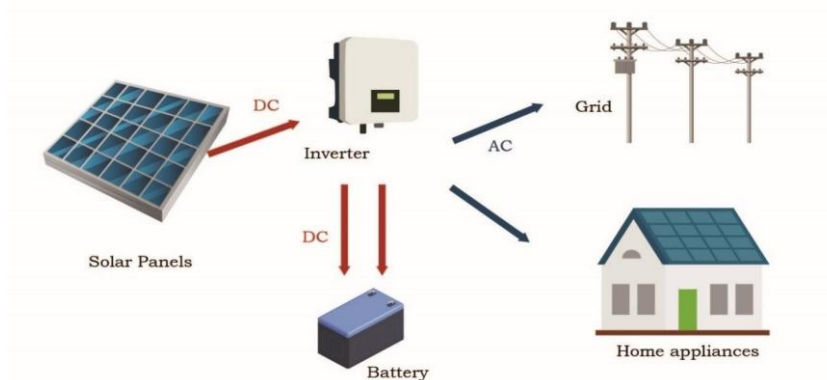


Fig. 2.18 Hybrid Solar PV System

Advantages of a Hybrid Solar System

- **Energy Independence with Grid Backup:** It gives the reliability of grid electricity while reducing your dependence on it through solar and battery usage.
- **Efficient Use of Solar Power:** Solar energy is stored and used during peak demand times, reducing reliance on costly grid electricity.
- **Cost Savings:** Hybrid systems help lower electricity bills by reducing grid consumption and using cheaper off-peak grid electricity to charge batteries if needed.
- **Power Supply During Outages (with backup feature):** Some hybrid systems can provide power during blackouts, depending on their configuration and inverter capabilities.
- **Environmental Benefits:** By using solar energy efficiently, hybrid systems help reduce carbon emissions and promote renewable energy usage.

Disadvantages of a Hybrid Solar System

- **More Initial Cost:** The inclusion of batteries and hybrid inverters makes the system more expensive compared to traditional grid-tied systems.
- **Battery Maintenance and Lifespan:** Batteries require regular maintenance and need to be replaced after a certain period (typically 5-10 years), which adds to long-term costs.
- **Complex System Design:** Hybrid systems involve more components and require careful planning and sizing to ensure proper functioning.
- **Limited Battery Capacity:** If not sized properly, batteries might not store enough energy to meet night-time or extended power outage needs.

2.7 Solar Panel Mounting Structures

Mounting structures are an important part of a solar power plant. They hold and support the solar panels in place. These structures help lift the solar panels at the correct angle so that they get the most sunlight during the day. The better the sunlight, the more electricity the solar panels can produce.

Mounting structures are usually made from three main materials:

- Hot Dip Galvanized Iron (GI)
- Aluminium
- Mild Steel (MS)

Galvanizing is process where a layer of zinc is coated on iron or steel. This helps protect the metal from rusting, which increases its life. In solar mounting systems, galvanized iron is often used to make the structures strong and long-lasting.

2.7.1 Solar Panel Mounting Structures- Classification

There are three primary types of mounting structures, categorized based on the location of solar panel installation:

1. Rooftop Mounting Structure
2. Ground Mounted Structure
3. Pole Mounted Structure

1. Rooftop Mounting Structure

In this type of installation, solar panels are mounted on the roof of a building whether it's a house, office, factory, or any other structure.

a) Standard Rooftop Mounting Structure

There are three common ways to fix solar panels on rooftops. These methods work well on all types of roofs flat roofs, sloped roofs, or RCC (cemented) roofs. However, one type of method called the ballasted system is not used on tin sheds. This is because the ballasted system uses concrete blocks to hold the panels in place, and it's hard to use these blocks on a lightweight tin shed roof (Fig. 2.19).



Fig. 2.19 Standard Rooftop Mounting Structure

b) Railed Mounting System

In a railed mounting system, as illustrated in Fig. 2.20, solar panels are secured onto multiple aluminium rails using specialized clamps. These rails are firmly fastened to the roof structure with the help of drilled anchors and bolts. This method is the most widely used for installing solar panels due to its durability and reliability.

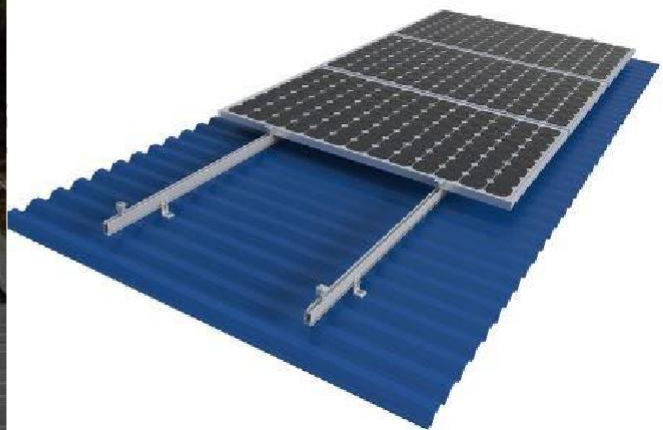


Fig. 2.20 Standard Rooftop Mounting Structure

c) Rail-less/Ballasted Mounting System

The rail-less mounting system, also referred to as the ballasted mounting system, eliminates the need for rails in securing solar panels. In this approach, the panels are directly mounted onto the roof using specialized hardware, which is firmly fastened with nuts and bolts. This method is more economical and simplifies the installation process. (Fig. 2.21).

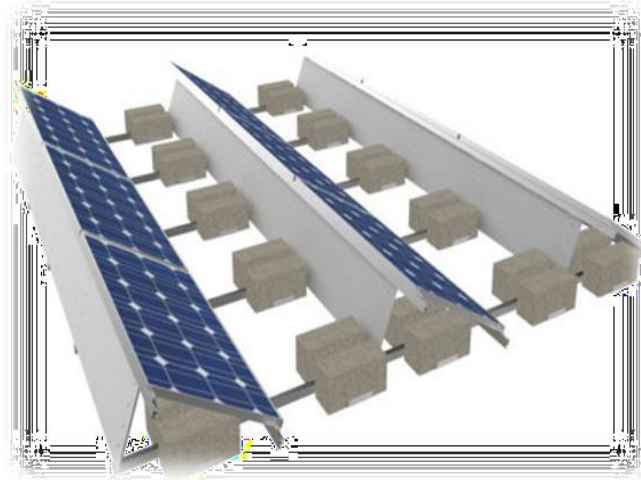


Fig. 2.21 Rail-less/Ballasted Mounting Structure

d) Shared Rail Mounting System

The shared rail mounting system is a variation of the standard railed system, with a key difference in the number of rails used. In a traditional railed setup, two rows of solar panels require four rails two for each row. In contrast, the shared rail system uses just three rails, as the middle rail is utilized by both rows. This reduces the amount of mounting material needed, making the installation more efficient and cost-effective (Fig. 2.22).

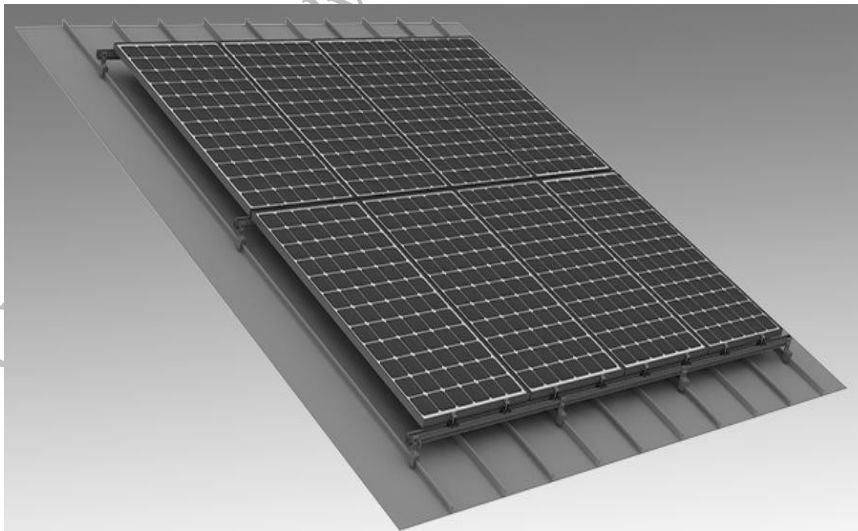


Fig. 2.22 Shared Rail Mounting Structure

2. Ground Mounted Structure

A ground-mounted solar structure is used when there is enough open land available to install solar panels on the ground, rather than on rooftops. These structures are usually made of strong materials like galvanized iron or aluminium to support panels withstand wind and weather (Fig. 2.23).

- Panels are installed on metal frames that are fixed into the ground, either with concrete foundations or driven piles.
- The angle and direction of the panels can be adjusted to get maximum sunlight throughout the year.
- Ground-mounted systems are ideal for large-scale solar plants and for homes or buildings with limited roof space.
- These systems are easy to clean and maintain as they are accessible from ground level.
- It also allows better airflow around the panels, which helps in maintaining cooler panel temperature and improving efficiency.



Fig. 2.23 Ground Mounting Structure

3. Pole Mounted Mounting Structure

Pole mounting structures are well-suited for small-scale solar systems, particularly in residential settings. These systems are built on a basic foundation using one or more poles. They can be classified as single pole mounting systems (Fig. 2.24) or multiple pole mounting systems (Fig. 2.25), depending on the size and configuration of the solar array.

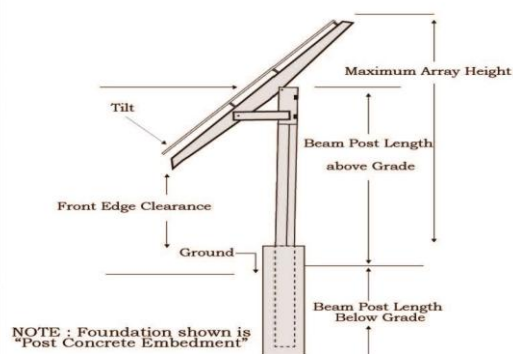


Fig. 2.24 Single Pole Mounting Solar PV Structure

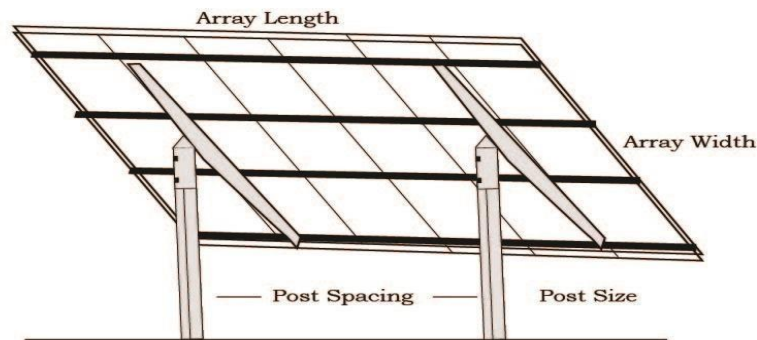




Fig. 2.25 Multi Pole Mounting Solar PV Structure

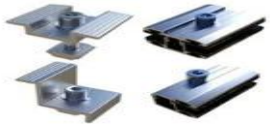

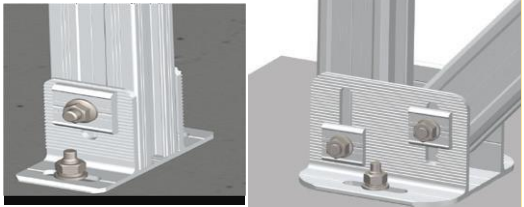

2.7.1.1 Materials required for Mounting Structure of Solar PV system

A strong and durable mounting structure is essential for supporting the weight of solar panels and withstanding harsh weather conditions such as strong winds, heavy rain, and floods. Over time, different materials like wood, plastic, and metals have been used for building these structures. However, metals are the most preferred due to their strength and long life.

In India, the primary materials used for solar mounting structures include stainless steel, aluminium, and galvalume. Traditionally, stainless steel has been the preferred choice because of its strength and long-term cost efficiency. However, in recent years, aluminium and galvalume have gained popularity due to their lightweight nature, resistance to corrosion, and simpler installation process. The choice of material often depends on the plant's location, weather conditions, budget, and desired lifespan of the solar installation.

Table 2.2 Materials required for Mounting Structure of Solar PV system

S. No.	Parts name	Uses	
1	Rail	Solar mounting system	
2	L foot	Tin Roof PV Mounting System	
3	Clamp/Mid clamp/End clamp	Holding Panel to Purlin or rail	

			
4	Spring Nut	Fastening	
5	Earth clamp/ Leg cap	Join earth and leg of solar structure	
6	Different type Screw	Fastening	

CHECK YOUR PROGRESS

A. Fill in the blanks

1. The transformation of sunlight into electrical energy using semiconductor materials is known as the _____ phenomenon.
2. Electricity produced by solar panels is in the form of _____ current, which must be converted for domestic use.
3. The device responsible for changing DC into AC within a solar PV setup is known as a _____.
4. _____ type of panels is capable of absorbing sunlight from both the front and rear surfaces.
5. A mounting structure made of _____ or aluminium is used to hold solar panels in place.

B. Answer the following

1. Define solar photovoltaic (PV) system?
2. Write the components of a solar PV system.
3. Name the four main types of solar panels.
4. Why is an inverter important in a solar PV system?
5. Enlist the advantages of using bifacial solar panels.

MODULE 3**TOOLS AND TACKLES FOR SOLAR PV INSTALLATION****Module Overview**

This module provides an overview of the different tools and equipment involved in installing solar PV systems. It includes mechanical, electrical, and civil tools necessary for the installation process, as well as key safety tools and guidelines to maintain a safe and secure work environment.

Learning Outcomes

After completing this module, you will be able to:

- Identify mechanical tools used for mounting and fixing solar panels.
- List and describe electrical tools required for solar PV wiring and connections.
- Recognize civil tools necessary for site preparation and foundation work.
- Understand the importance and use of safety tools and PPE in solar PV installation.

Module Structure

- 3.1 Mechanical Tools used for Solar PV installation
- 3.2 Electrical Tools used for Solar PV installation
- 3.3 Civil Tools used for Solar PV installation
- 3.4 Safety Tools used for Solar PV installation

Have you ever been curious about how solar panels are set up on rooftops or in open areas? Behind every strong and safe Solar PV system, there is a set of tools that help technicians and installers to do the job with precision. Most of these tools are not highly complex and they are commonly available and easy to use with the right guidance.

Different types of tasks in solar installation require different kinds of tools. For example, there are mechanical tools like spanners and wrenches to tighten bolts and fasten panel supports. Electrical and electronic tools such as wire strippers, multimeters, and crimping tools are used to connect wires and check electrical flow. Civil tools like hammers, trowels, and spirit levels help with setting up the foundation, while measuring tools such as measuring tapes and laser levels ensure everything is aligned and correctly placed.

Knowing how to identify, choose, and safely handle these tools is just as important as knowing what the tools are. Using the wrong tool or using the right tool in the wrong way can lead to delays, mistakes, or even accidents. That's why learning about these tools, their uses, and how to take care of them is a key step in understanding the practical side of Solar PV Installer (Civil).

3.1 MECHANICAL TOOLS USED FOR SOLAR PV INSTALLATION

I have seen a technician using tools like a spanner and screwdriver to fix things at our school. He said these are called **Mechanical Tools**.



Mechanical tools help in applying force, holding parts tightly, or making things move. When installing solar panels on rooftops, these tools help assemble the metal frames and tighten the bolts securely.







Let us discuss various mechanical tools used in the installation of the Solar PV system:

- a. **Screwdriver:** - A screwdriver is a tool used to turn screws in or out. It has a handle, a metal rod, and a tip that fits into the screw head to twist it (Fig. 3.1).



Fig. 3.1 Screwdriver

Table 3.1 presents the different types of screwdrivers for various applications.

Table 3.1 Different types of Screwdrivers	
Screwdrivers	
	Flat Head (or Slotted Head) Screwdriver
	Phillips Screwdriver
	Pozidriv Screwdriver
	Robertson or Square Screwdriver
	Torx Screwdriver
	Hex Screwdriver or Hexagon Screwdriver

- b. **Hand Drill:** A drill is a tool used to make holes or to fix things together using screws. It holds a drill bit or driver bit that spins when pressed against a surface. The spinning tip cuts into the material to create a hole or drive in a fastener. Battery-less drills are now available for remote solar sites without an electrical connection (Fig. 3.2).



Fig. 3.2 Hand Drill

- c. **Spanner (Wrench):** Spanner is a tool used to provide grip and mechanical advantage in applying torque to turn objects usually rotary fasteners, such as nuts and bolts, or keep them from turning? In solar system installation, the spanners are used mainly to fasten panels with purlins through nuts and bolts (Fig. 3.3).



Fig. 3.3 Spanner

Socket Wrench: A socket wrench (Fig. 3.4) has special round heads called sockets that fit all around a bolt. This helps you turn bolts faster and with less effort than a normal wrench which only holds two sides.



Fig. 3.4 Socket Wrench

d. Hammer: A hammer is a tool used to hit or strike objects, usually to drive nails, break things, or shape materials. It is used very often for different purposes in solar installations (Fig. 3.5).



Fig. 3.5 Hammer

e. Hacksaw: A hacksaw is a saw with small, sharp teeth mainly used for cutting metal. It can also be used to cut materials like plastic and wood (Fig. 3.6).

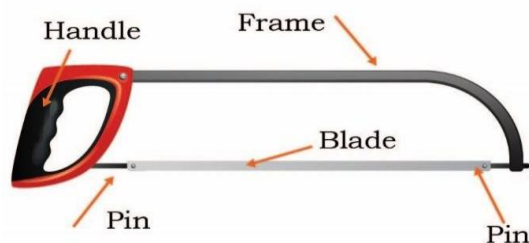


Fig. 3.6 Hacksaw

- f. **Chisels:** A chisel is a hand tool with a long blade and a sharp, angled edge, used for cutting or shaping wood, stone, or metal. It is typically struck with a hammer or mallet during use (Fig. 3.7).



Fig. 3.7 Chisel

- g. **Nipper:** A nipper is a tool similar to scissors or pliers, used to cut or pull-out small pieces of hard material. In solar installation, it serves as a supporting tool for various cutting and trimming tasks (Fig. 3.8).



Fig. 3.8 Nipper

- h. **Gimlet:** A gimlet is a small hand tool used to drill tiny holes in wood. It is designed to make holes without causing the wood to split. Such a handy tool offers ease of operation when the site needs only a few holes to carry on the further task (Fig. 3.9).



Fig. 3.9 Gimlet

- i. **Pipe cutter:** A pipe cutter is a handy tool for cutting through pipes. It makes cleaner and quicker cuts than a hacksaw, which makes it easier and neater to use during work (Fig. 3.10).



Fig. 3.10 Pipe Cutter

- j. **Grinder:** It is the power tool or machine tool used for grinding. This power tool is available in different shapes and sizes, but its main functions remain the same cutting, grinding, and polishing various materials (Fig. 3.11).



Fig. 3.11 Grinder

- k. **Pliers:** Pliers are a basic hand tool used to grip objects tightly. They also help in bending or pressing materials during small tasks (Fig. 3.12).



Fig. 3.12 Plier

- l. Crimping tool:** A crimping tool is used to connect two metal parts, like a wire and a connector, by pressing or shaping them so they stay tightly joined (Fig. 3.13).



Fig. 3.13 Crimping tool

Table 3.2 shows the details of mechanical tools and their usage in Solar PV Installation.

Table 3.2 Mechanical tools and their usage in Solar PV Installation

S. No.	Tool	Usage in Solar PV Installation
a.	Screwdriver	To tighten or loosen screws on panels and mounting structures.
b.	Hammer	To drive nails or fix small parts during mounting.
c.	Hand Drill	To make holes in metal or wood for fixing solar panel mounts.
d.	Socket Wrench	To tighten or loosen bolts quickly with less effort.
e.	Wrench	To hold or turn nuts and bolts during assembly.
f.	Hacksaw	To cut metal pipes or frames to the required size.
g.	Chisel	To shape or cut small parts of wood or metal as needed.
h.	Nipper	To cut wires or small metal pieces cleanly.
i.	Gimlet	To make small holes in wood or plastic parts for screws.
j.	Pipe Cutter	To cut metal or PVC pipes used in mounting structures.

3.2 ELECTRICAL TOOLS USED FOR SOLAR PV INSTALLATION

Electrical tools are the tools used for working with wires, electricity, and circuits. In solar PV installation, electrical tools are very important because they help in connecting the solar panels with inverters, batteries, and other components safely and correctly. Using the right electrical tools ensures the system works efficiently and reduces the risk of short circuits, loose connections, or electric shocks.

Let's explore some commonly used electrical tools and its usage in solar PV installation:

- a. **Multimeter:** A multimeter, also called a multi-tester or VOM (Volt-Ohm-Milliammeter), is a tool used to measure electrical values. It can check voltage, current, and resistance in one device. Analog types use a moving needle to show results, while digital ones display numbers and sometimes a bar graph for better clarity (Fig. 3.14).

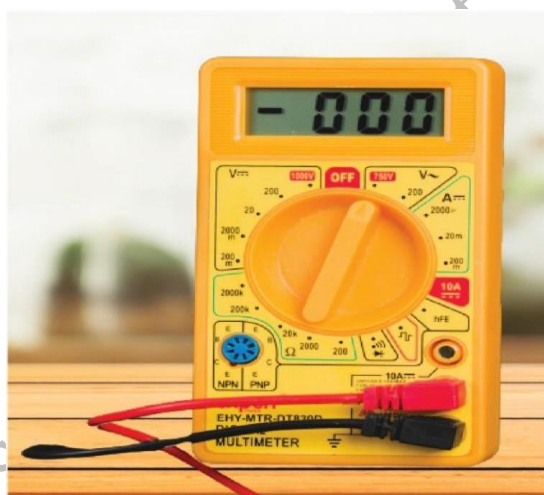


Fig. 3.14 Multimeter

- b. **Earth Tester:** An earth tester is a device used to measure how much resistance the earth has to electrical current. In a power system, all equipment is connected to the ground using an earth electrode. This connection helps safely carry fault current into the ground, protecting both equipment and people. Since the earth's resistance is very low, it allows the fault current to pass through easily, reducing the risk of damage to the system (Fig. 3.15).



Fig. 3.15 Earth Tester

- c. **Electrical resistance tester:** This tool is used to perform an insulation resistance (IR) test, which checks the resistance between two points separated by electrical insulation. It helps determine how well the insulation prevents the flow of electrical current. In solar panel systems, this test helps manufacturers, installers, and inspectors ensure that the insulation between the panel's electrical parts and its frame is safe and effective (Fig. 3.16).



Fig. 3.16 Electrical Resistance Tester

- d. **Clamp Meter:** A clamp meter is an electrical testing device that combines the functions of a digital multimeter with a built-in sensor to measure current. It allows current to be measured without directly touching or disconnecting the wires (Fig. 3.17).



Fig. 3.17 Clamp Meter

- e. **Megger Insulation Meter:** A megger meter (Fig. 3.18), also called an insulation tester, is used to check the quality of electrical insulation. It measures resistance to find any faults or weakening in the insulation that could lead to electrical problems. It uses high voltage to test insulation. A portable instrument called a Megger meter is used to measure high electrical insulation resistance. Table 3.3 shows the details of Electrical tools and their uses in solar PV installation.



Fig. 3.18 Megger Insulation Meter

Table 3.3 Electrical tools and their usage in Solar PV Installation

S. No.	Electrical Tool	Usage in Solar PV Installation
a.	Multimeter	Measures voltage, current, and resistance to check electrical connections and performance.
b.	Earth Tester	Checks the quality of the earthing system to ensure safe discharge of fault current.
c.	Electrical Resistance Meter	Measures the resistance of wires and connections to identify any faults or inefficiencies.
d.	Clamp Meter	Measures current flowing through a wire without disconnecting it (non-contact measurement).

3.3 CIVIL TOOLS USED IN SOLAR PV INSTALLATION

Have you ever wondered how solar panels are fixed so neatly on rooftops or open fields? Before installation begins, it's important to prepare the land or structure properly and that's where civil tools come into play. These tools help in measuring, marking, aligning, and laying foundations to make sure the solar panels are placed in the best position and stay strong for years.

Civil tools used in solar PV installation can be grouped into three main categories:

- 1. Surveying tools:** Surveying tools are essential for setting up a solar PV system, as they help ensure proper alignment, positioning, and layout before installation begins, especially when panels are installed on the ground. These tools help in measuring the land, marking accurate positions, and ensuring proper alignment of mounting structures before any physical work begins. Before fixing the panels, it's important to:

- Know the dimensions of the site
- Make sure the surface is level and even
- Decide the exact layout for solar panel rows
- Ensure that all structures are aligned properly to avoid tilt or shading issues

That is where surveying tools help. They make sure that what is drawn on paper is exactly followed on the ground. Following are some of the surveying instruments used:

- a. Measuring Tape:** A measuring tape, or tape measure, is a flexible tool used to measure dimensions such as length, width, height, or distance in various tasks. It is one of the most commonly used tools in construction (Fig. 3.19).



Fig. 3.19 Measuring Tape

Laser Distance Meter: It is a modern measuring tool that uses laser light to measure the distance between two points quickly and accurately. It is a hand-held device that sends a laser beam to a surface, and the device calculates how long it takes for the light to bounce back. Based on this, it shows the exact distance on a digital screen (Fig. 3.20).



Fig. 3.20 Laser Distance Meter

- b. **Spirit level** A spirit level or bubble level is a tool used to check if a surface is flat or upright. It is important in solar installations to make sure the mounting structure is straight and properly aligned (Fig. 3.21).



Fig. 3.21 Spirit Level

Digital Clinometer: A clinometer is a tool used to measure the angle or tilt of a surface or object compared to a flat line. It is a simple but effective tool often used in fields like surveying, geology, forestry, and construction (Fig. 3.22).



Fig. 3.22 Digital Clinometer

- c. **Plumb Bob:** A plumb bob is a pointed weight tied to a string. It helps find a straight vertical line, called a plumb line. It's a tool for ensuring vertical accuracy in construction, surveying, and other applications (Fig. 3.23). Table 3.4 presents the details of Civil Surveying tools and their usage in Solar PV Installation.



Fig. 3.23 Plumb Bob

Table 3.4 Civil Surveying tools and their usage in Solar PV Installation

S. No.	Tool Name	Purpose / Usage in Solar PV Installation
a.	Measuring Tape	Used to measure lengths and distances on the ground for marking the layout of solar panel structures.
b.	Laser Distance Meter	Measures longer distance quickly and accurately using a laser beam — helpful in large-scale installations.
c.	Spirit Level	Checks whether a surface is level (horizontal) or not — ensures proper panel alignment.
d.	Digital Inclinometer	Measures angles or slopes — helps set the correct tilt angle for solar panels to capture maximum sunlight.
e.	Plumb Bob	Used to find a vertical line from a fixed point — ensures posts and mounts are straight and vertical.

2. Sun-Related Tools: These tools help decide the best direction and tilt angle of solar panels to get maximum sunlight. Following is some of such tools:

- a. **Sun path Finder:** The Solar Pathfinder gives a quick view of solar radiation for the whole year. The time or date of reading does not affect the result. It works better on cloudy or overcast days as it reduces sunlight glare (Fig. 3.24).

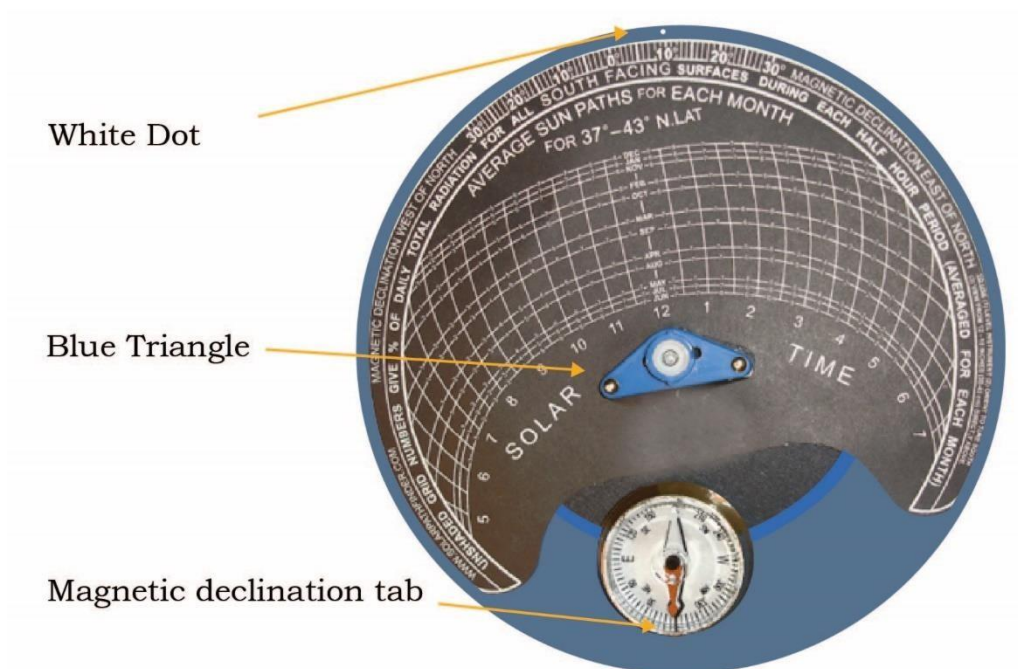


Fig. 3.24 Sun Path Finder

- b. **Solar Power Meter:** Handheld portable Solar power meters are also used as pyranometers. The solar radiation flux density has a direct correlation with the performance of a solar photovoltaic power plant. This product comes with a sensor that receives falling solar energy on it. The display unit provides digital data of solar irradiance (Fig. 3.25).



Fig. 3.25 Sun Power Meter

- c. **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 should be placed at a tilt angle equal to the latitude of the location for better sunlight capture and power generation. Angle finder helps set solar panels

at appropriate tilt angles for the right performance (Fig. 3.26).

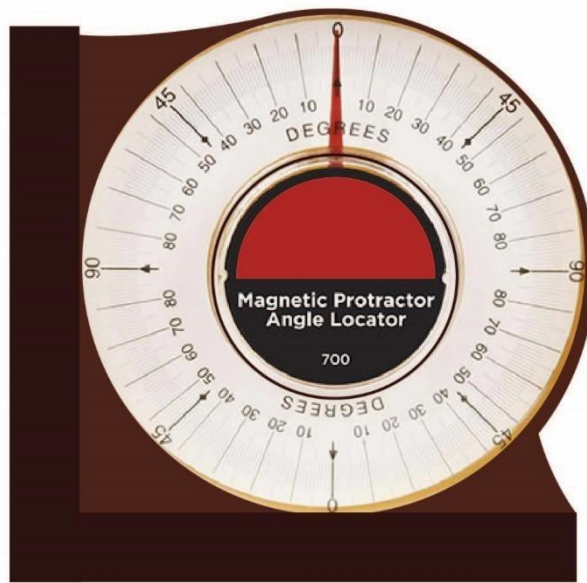


Fig. 3.26 Angle Finder

- d. Pyranometer:** It is a device used to measure the amount of solar energy received on a flat surface. It captures sunlight from all directions in the sky (180° view) and shows how much solar radiation is present in watts per square meter (W/m^2). It measures both direct and scattered sunlight within the range of 0.3 to 3 micrometers (Fig. 3.27).



Fig. 3.27 Pyranometer

- e. Compass:** Compass is used to locate the south direction for the installation of solar panels (Fig. 3.28). Table 3.4 shows the sun related tools and its usage for Solar PV installation.



Fig. 3.28 Compass

Table 3.5 Sun related tools and its usage for Solar PV installation

S. No.	Tool Name	Purpose / Usage in Solar PV Installation
<i>a.</i>	Sun Path Finder	Helps to find movement of the sun in the sky - used to choose the best direction and location for panels.
<i>b.</i>	Solar Power Meter	Checks how much sunlight reaches a surface to find the best place for installing solar panels.
<i>c.</i>	Angle Finder	Used to measure the tilt angle of solar panels - helps adjust panels for maximum sunlight.
<i>d.</i>	Pyranometer	Accurately measures solar radiation (sunlight energy) at the location - helps in planning and performance check
<i>e.</i>	Compass	Shows directions (North, South, East, West)- used to position solar panels facing the sun correctly.

3. Civil Work-related tools: Civil tools are used to prepare and build the foundation or structure that supports the solar panels. They ensure the solar panel structures are strong, stable, and safely fixed to the ground or rooftop.

- a. **Pickaxe:** A pickaxe is a T-shaped hand tool with a metal head and a long handle, often made of wood or fiberglass. It is used to dig deep trenches during solar panel installation (Fig. 3.29).



Fig. 3.29 Pickaxe

- b. **Spud:** It is made of iron pointed at one side for making holes in the soil (Fig. 3.30).

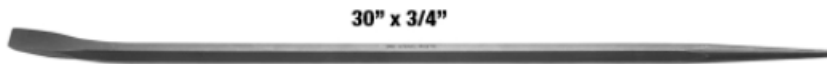


Fig. 3.30 Spud

- c. **Mortar pan:** A mortar pan is a container made of steel or hard plastic used for holding or carrying materials like sand, cement, mortar, or concrete. It should be filled with a manageable amount and lifted carefully (Fig. 3.31).



Fig. 3.31 Mortar Pan

- d. **Spade:** A spade is a digging tool used for making straight-edged trenches, lifting soil, and shaping edges of lawns or beds. It is made of a metal sheet and a wooden handle. It is a common tool used in small solar installations (Fig. 3.32).



Fig. 3.32 Spade

- e. **Tractor post hole digger:** This is a tractor-driven hole digger used to make pits in all types of soil quickly and with less effort. It is helpful during the installation of ground-mounted solar systems (Fig. 3.33).



Fig. 3.33 Tractor Post Hole Digger

- f. **Crowbar:** It is a manual tool used for separating or pulling apart two joined objects (Fig. 3.34).



Fig. 3.34 Crowbar




3.4 SAFETY TOOLS FOR SOLAR PV INSTALLATION

Installing a Solar PV system involves handling electrical components like PV arrays, inverters, and other essential parts, which can pose several safety hazards. Workers, especially during rooftop installations, face potential risks such as:

- a. Falls from elevated surfaces like rooftops
- b. Electric shocks or other electrical hazards
- c. Injuries like cuts, sprains, or repetitive stress issues due to physical strain
- d. To ensure safety, it is important to use proper equipment such as:
- e. Ladders and scaffolding of the correct type and size
- f. Fall protection systems for working at heights
- g. Personal Protective Equipment (PPE) includes items like gloves, helmets, and safety harnesses. This help protect workers from injuries and ensure safety during solar installation tasks.

According to the Occupational Safety and Health Administration (OSHA), employers must provide safety training and implement protective measures. Installers must assess the site beforehand to identify any potential hazards and create a safety plan. This includes selecting the right tools and equipment for safely lifting and handling solar panels. Table 3.5 presents the list of Safety and Protective Equipment.

Table 3.5 List of Safety and Protective Equipment

S.No.	Items Description	Application	Sample Photo
1	Safety helmet	Head protection	
2	Safety Goggles with Clear Glass	Eye protection gear shields the eyes from dust and other small particles during general work. It helps prevent irritation and possible injury while working.	
3	Earplug	Hearing Protection: Protection against noise	
4	Leather cum cotton hand gloves	Hand protection gear, like gloves, is used during material handling to protect hands from cuts, abrasions, and rough surfaces.	
5	High Visibility Vest	Body protection gear, such as high-visibility vests or jackets, helps workers stay visible and safe, especially in busy or low-light areas.	
6	Double Lanyard Full Body Harness	Safety harness is used while working at height to prevent falls.	



7	Double-density PU sole Safety shoe	Foot protection: Worn for general safety during work.	
8	Electrical hand gloves	For Arcflash and cut protection for the voltage (>260V and <= 690 V)	

Fig. 3.35 shows the details and purpose of PPE kit.



Fig. 3.35 Personal protective equipment (PPE) kit for work

ACTIVITY

Activity 1: Tool Station Walk

Aim: Hands-on learning of tool names and handling.

Materials Needed: Measuring tape, hammer, level, spanner, gloves, labels.

Instructions:

1. Set up 4-5 “Tool Stations” around the classroom.
2. At each station, place one real tool (or a model/picture) with a short explanation.
3. Students rotate between stations, hold the tool, and read/explain its use.
4. At the end, ask them to write down the name of each tool and one use.

CHECK YOUR PROGRESS

A. Multiple Choice Questions (MCQs)

1. Which tool is used to measure voltage, current, and resistance in a Solar PV system?
 - a) Clamp Meter
 - b) Crimping Tool
 - c) Multimeter
 - d) Earth Tester
2. Which mechanical tool is used to cut metal or PVC pipes in solar installations?
 - a) Hacksaw
 - b) Pipe Cutter
 - c) Grinder
 - d) Spade
3. Which of the following tools is used to ensure a surface is level or plumb?
 - a) Angle Finder
 - b) Plumb Bob
 - c) Spirit Level
 - d) Compass
4. The tool used to fasten or loosen nuts and bolts using sockets is called a:
 - a) Allen Key
 - b) Socket Wrench
 - c) Chisel

d) Screwdriver

5. Which equipment is used to protect the person from falling during work at height?
 - a) Safety goggles
 - b) Safety helmet
 - c) Full body harness
 - d) High visibility vest

B. Answer the following

1. What is the function of a crimping tool in Solar PV installation?
2. Why is a compass important during solar panel installation?
3. What is the purpose of using a megger insulation tester?
4. Name any two tools used for civil foundation work in ground-mounted solar PV systems.
5. How does a clamp meter help during installation?

C. Fill in the blanks

1. A _____ is used to measure solar radiation or sunlight falling on the surface.
2. The _____ wrench is quicker and more efficient than a normal wrench for tightening bolts.
3. A _____ bob is used to ensure that a structure is vertically align
4. _____ gloves are used for protection from arc flashes and high voltage.
5. A Sun _____ is used for determining movement of sun across sky.

MODULE 4	FUNDAMENTALS OF CIVIL ENGINEERING FOR SOLAR PV INSTALLER
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Module Overview

This module provides an understanding of the key civil works involved in solar PV installations. It includes the study of materials, concrete work, anchoring techniques, use of prefabricated structures, and civil work requirements for various types of mounting structures.

Learning Outcomes

After completing this module, you will be able to:

- Identify materials used in civil works for Solar PV systems.
- Explain the concrete work process required for secure installation.
- Understand anchoring techniques for stable Solar structures.
- Describe the use and advantages of Prefabricated structures.
- Compare civil work requirements for rooftop, tin-shed, and ground-mounted systems.

Module Structure

- 4.1 Materials Used in Civil Works for Solar PV Installation
- 4.2 Concrete Works for Solar PV Installation
- 4.3 Anchoring in Structures
- 4.4 Prefabricated Structures in Solar PV Systems
- 4.5 Civil Work Required for Classification of Mounting Structures

In the previous Modules, we have gone through the fundamentals of solar photovoltaic (PV) systems and understood the tools and tackles used in electrical, mechanical, and civil work. We have also explored how different types of work come together during the installation of a solar PV system.

But, how do we ensure that solar panels stay firmly in place *whether they are on a rooftop or in an open field*? *What prevents them from tipping over in strong winds or getting damaged due to poor support?*

These questions lead us to the civil engineering work required for solar PV installations. Civil engineering deals with the planning, preparation, and construction of structures. In the case of solar PV systems, civil work begins even before a single panel is installed. It includes activities like selecting a proper site, leveling the ground or checking the rooftop surface, measuring and marking the layout, and building the foundations and mounting structures.

As solar energy use continues to expand in homes, schools, farms, and other public spaces, understanding the role of civil engineering becomes more important.



How do we make sure the place where solar panels are fixed is strong enough and safe?

How do we choose the right type of support or structure for solar panels in different locations?

4.1 Materials Used in Civil Works for Solar PV Installation

Solar panels need strong and steady support whether they are placed on rooftops or on the ground. To build these supports, certain civil engineering materials are used. These materials help keep the panels safe and stable, even during bad weather like wind or rain. These basic materials make sure the solar system works well. Table 4.1 presents the basic civil engineering materials commonly used for different types of installations (including rooftop installation). Table 4.2 presents the primary materials required for civil works of ground-mounted solar PV installation. Fig. 4.1 compares the Ground Mounted *and* Roof Top Solar PV Installation setups.

Table 4.1 Basic Material Required for Civil Works Of Rooftop Solar PV Installation

S. No.	Materials Required	Usage
A. Concrete Works		
1.	Cement, Sand, and Aggregate (for PCC work)	These materials are used to make concrete blocks or pedestals if extra support is needed on the roof.
2.	Concrete Bricks or Blocks	These are used as counterweights in systems where the panels are placed without drilling or fixing.
B. Structural Materials		
1.	Mild Steel (MS) or Galvanized Iron (GI) Sections	These metal sections are used to make the frames, rails, and brackets that hold the solar panels on the roof.
2.	Anchor Fasteners / Expansion Bolts	Anchor Fasteners / Expansion Bolts These are used to tightly fix the mounting structure to the concrete roof so that it stays in place.
3.	Base Plates and Clamps	These helps to safely mount and lock the solar panels onto the structure.
C. Waterproofing & Sealants		
1.	Waterproofing Membrane / Compound	Applied to the roof to stop water from leaking through after the installation is done.
2.	Silicone Sealants / Epoxy	These are used to seal small holes or gaps around bolts to prevent water from entering.

Table 4.2 Basic Materials Required for Civil Works of Ground-Mounted Solar PV Installation

S. No.	Materials Required	Usage
A. Foundation works		
1.	Cement, Sand, Aggregate, and Water	These are used to make concrete foundations or pedestals where the support structure is fixed.
2.	Reinforcement Steel Bars (TMT)	These rods are placed inside concrete foundations to make them stronger.
3.	Precast Concrete Blocks (Optional)	These ready-made blocks can be used instead of casting concrete on-site.
B. Structural Materials		
1.	Steel Angles, Channels, and Pipes	These are used to make the support structure that carries the weight of the panels.
2.	Mild Steel (MS) or Galvanized Iron (GI) Sections	These metal sections are used to make the frames, rails, and brackets that hold the solar panels on the roof.
C. Earthworks & Site Preparation		
1.	Earthwork Materials (Soil, Sand, Gravel)	These materials are used to level the site, fill gaps, and support proper drainage.

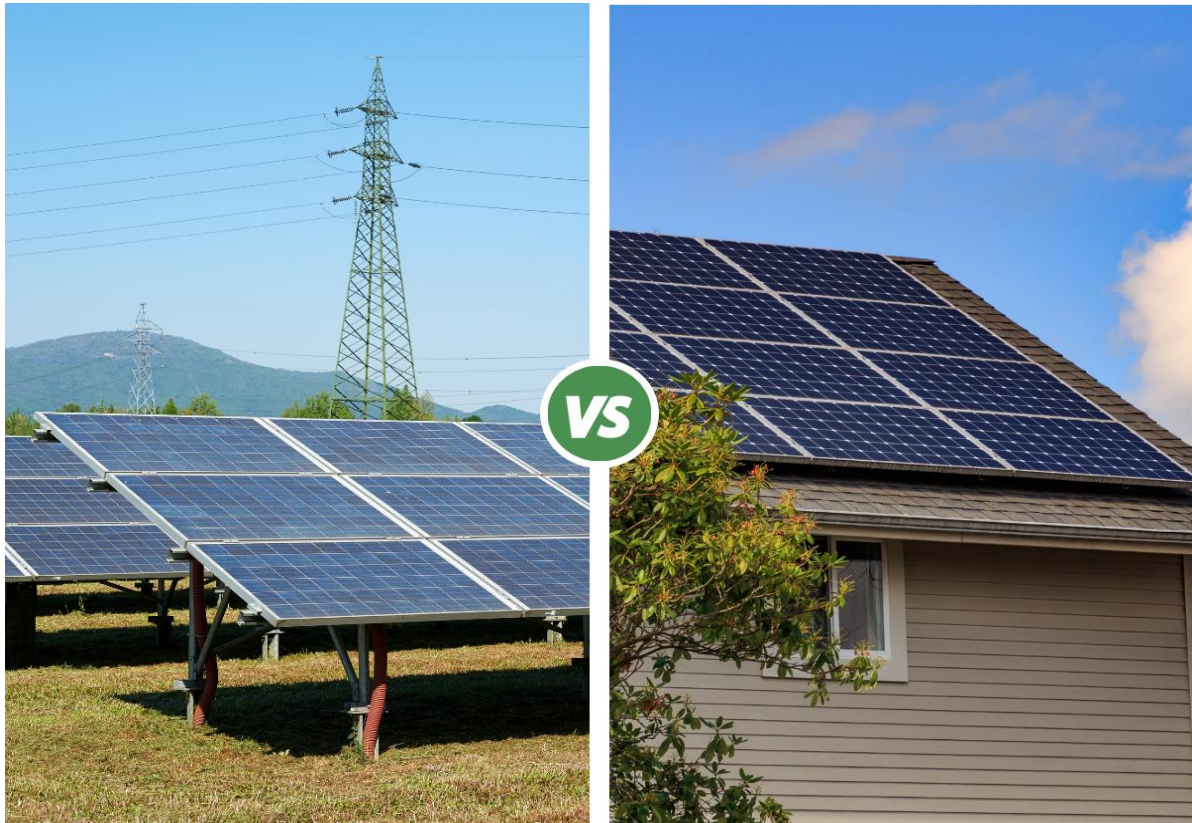


Fig. 4.1 Ground Mounted vs Roof Top Solar PV Installation

Now, let us take a closer look at each of the Civil Engineering materials used in solar PV installations. We will understand their purpose and how they help in both rooftop and ground-mounted systems.

4.2 Concrete Works for Solar PV Installation

Concrete is commonly used in construction to create strong and stable foundations. It helps support structures and ensures they stay in place for a long time. The quality of concrete depends on how it is mixed and the amount of each material used. Proper use of concrete is important for safe and lasting construction work.

4.2.1 Concrete and its types

Have you ever wondered what helps solar panel structures stay strong and steady for many years? One of the most important materials used is concrete. But what exactly is concrete made of? *Concrete is formed by combining cement, water, and coarse aggregates such as gravel or crushed stones.* When these materials are mixed, they form a paste that slowly hardens into a solid, rock-like material. This hardened concrete is what gives strength to the foundations and support structures in solar PV installations.

Refer Fig. 4.2 for the understanding the composition of the concrete.



Fig. 4.2 Composition of Concrete

The amount of water and cement are very important in concrete because it affects how strong and long-lasting the concrete will be. If the mix is just right, the concrete will be strong, durable, and easy to work with. These properties are very important when we are building supports for solar panels, especially on rooftops or in open fields.

In what ratio should the water and cement needed to be mixed for getting the proper strength and durability in concrete?



The water-cement ratio shows how much water is mixed with cement when making concrete. It is written as a decimal number, like 0.5, which means 50 kg of water is mixed with 100 kg of cement. This ratio is very important because it affects how strong the concrete will be. Too much water makes the concrete weak and prone to crack. Too little water makes it hard to mix and shape.

Let us Relate and Solve

If you mix –

- i. 50 kg of water in 100 kg of cement
- ii. 70 kg of water in 100 kg of cement

Write the water cement ratio of both of the above and which of the above mix is stronger and why?

Concrete can be shaped easily when it is fresh and wet. It can be poured into different shapes like squares, circles, or rectangles. This helps in making parts such as pedestals, columns, and beams that support solar panels.

Because concrete can be made to meet different strength requirements, it is divided into different grades like M10, M15, and M20.

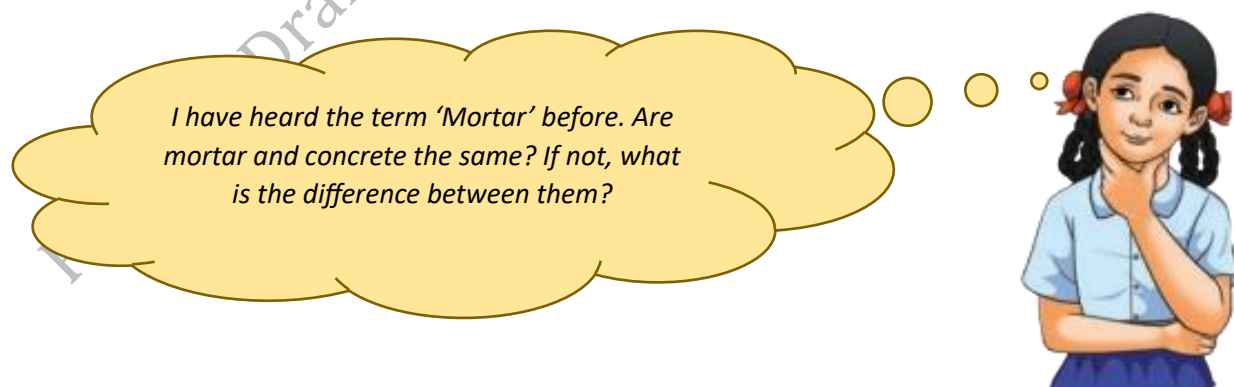
The “M” stands for mix, and the digit ahead shows the strength of the concrete measured in megapascals (MPa).

4.2.1.1 Common Concrete Mix Ratios and Their Uses

Table 4.3 shows some common concrete grades, their mix ratios, and characteristic strengths.

Grade	Mix Ratio (Cement: Sand: Coarse Aggregate)	Characteristic Strength (MPa)	Typical Use
M10	1: 4: 8	10	Flooring, pathways
M15	1: 3: 6	15	Foundations, small slabs
M20	1: 1.5: 3	20	Residential slabs, beams

Note: M10 concrete is used for simple works like flooring or pathways, while M20 is stronger and suitable for slabs or foundation work, such as those needed in solar PV installations.



Here's a clear difference between **mortar** and **concrete**, along with their typical uses (Table 4.4).

Table 4.4 Difference Between Mortar and Concrete

Feature	Mortar	Concrete
Composition	Cement, sand, and water (no coarse aggregates)	Cement, sand, coarse aggregates (gravel), and water
Texture	Smooth and paste-like	Coarse and rough due to gravel
Strength	Weaker compared to concrete	Strong and durable
Usage	Used to bind bricks, stones, and blocks together	Used for building strong structures like foundations, beams, slabs, and floors

4.2.1.2 Workability of Concrete

Workability refers to the ease with which concrete can be mixed, handled, placed, and molded before it sets. If the concrete is too dry, it's hard to mix and shape. If it's too wet, it becomes weak after setting. So, the concrete should be just right easy to work with and strong after it sets.

Workability is important while making foundations, pedestals, or slabs for things like solar panel structures. It helps workers pour and level the concrete properly.

There are several tests used to check how workable concrete is. Let's go through about the one test that is used most often.

Slump Cone test for Workability (Fig. 4.3)

Apparatus required:

1. Slump Cone – A metal cone (also called Abrams cone) with:
 1. Height: 30 cm
 2. Bottom diameter: 20 cm
 3. Top diameter: 10 cm
2. Tamping Rod – A steel rod about 60 cm long for removing air voids.
3. Measuring Scale – Used to measure how much the concrete slumps.
4. Base Plate – A flat surface to keep the cone steady.

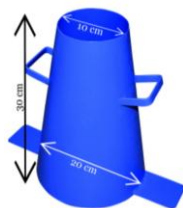


Fig. 4.3 Slump Cone test Apparatus



Step-by-Step Method (Fig. 4.4):

1. Place the cone upright on a flat base.
2. Fill the cone with fresh concrete in 3 equal layers.
3. Tamp each layer 25 times with the rod to remove air gaps.
4. After filling and tamping the top layer, level the concrete with the cone top.
5. Lift the cone straight up, slowly and carefully (do not shake it).
6. The concrete inside the cone will slump or settle down.
7. Use a ruler to measure the height gap between the top of the cone and the slumped concrete.

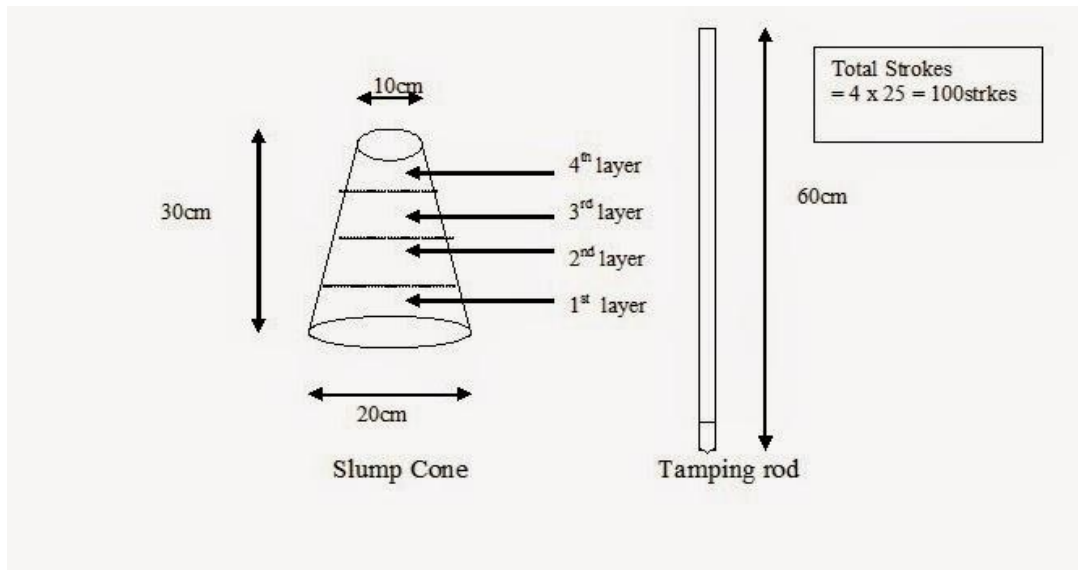


Fig. 4.4 Slump Cone and Tamping rod

Result:

- The difference in height (in mm) is called **slump value**.
- This value depicts workability of the concrete:
- - **Low slump (25–50 mm)** → Dry, less workable
 - **Medium slump (50–100 mm)** → Good workability for solar PV work)
 - **High slump (100–150 mm)** → Too wet, may be weak



4.2.1.2 Types of Concrete

Let us understand the basic types of concrete which are as follows:

1. Plain Cement Concrete (PCC)

A simple mix of cement, sand, aggregate (gravel), and water.

Use in Solar PV: Used for making flat surfaces like pedestals or foundation pads on rooftops or ground.

2. Reinforced Cement Concrete (RCC)

It is same as PCC but with steel bars (TMT rods) inside to make it stronger.

Use in Solar PV: Used where extra strength is needed, like in ground-mounted solar structures, especially in high wind or load areas.

3. Precast Concrete

Concrete that is cast and hardened at a factory or another place, then transported to the site is called as a Precast Concrete.

Use in Solar PV: Precast blocks are used as ready-made foundations for solar panel stands. These save time during installation.

DO YOU KNOW?

- In **rooftop solar** projects, **PCC** is often used for small blocks that hold up metal frames.
- In **ground-mounted systems**, **RCC** foundations provide strong support for heavy solar panels.
- **Precast concrete blocks** help in quick setups, especially in remote areas where pouring fresh concrete is difficult.



4.2.1.3 Curing of Concrete

When concrete is first made, it looks like a thick paste. After pouring, it slowly becomes hard and strong over several days. But did you know that concrete needs water even after it's set? This process is called curing.

Curing is the process of keeping concrete moist and at the right temperature after it has been poured and shaped. It helps the concrete gain full strength and last longer.

Note: If concrete dries too quickly, it may develop cracks and become weak.

Curing is important because of the following reasons:

- Helps concrete gain maximum strength
- Prevents cracks and shrinkage
- Improves durability and resistance to weather
- Makes the structure safe and long-lasting

LET US TRY THIS!
Dry Sponge vs. Wet Sponge

1. Take two sponges.
2. Keep one wet and the other dry in sunlight for a day.
3. What happens to each one?

Just like the dry sponge becomes brittle, concrete without curing becomes weak and may crack!

Here are some simple methods used at construction sites (Table 4.5):

Table 4.5 Different Methods of Curing

Method	How It Works	Where It's Used
Water curing	Sprinkling or pouring water over concrete regularly	On roads, roofs, pavements, solar PV pads
Wet covering	Covering with jute bags, gunny bags, or straw soaked in water	Where direct water is not available
Steam curing	Using steam in closed chambers	In factories to cure concrete blocks quickly
Plastic sheets	Covering concrete with plastic to stop moisture loss	For small slabs or rainy weather



LEARNING BEYOND CLASSROOM

Visit a local construction site or a solar panel installation and observe how curing is being done. Look for: Are any parts covered with wet cloth or plastic

Take photos or notes and discuss in class.

4.2.2 Reinforcing Bars

In construction, especially when building strong concrete structures like columns, beams, or solar panel foundations, steel bars (also called reinforcement bars or *rebars*) are used inside concrete. This gives concrete the **extra strength** it needs because concrete works strong in compression whereas, it is weak in tension, and wheresoever the steel balances it (Fig. 4.5).

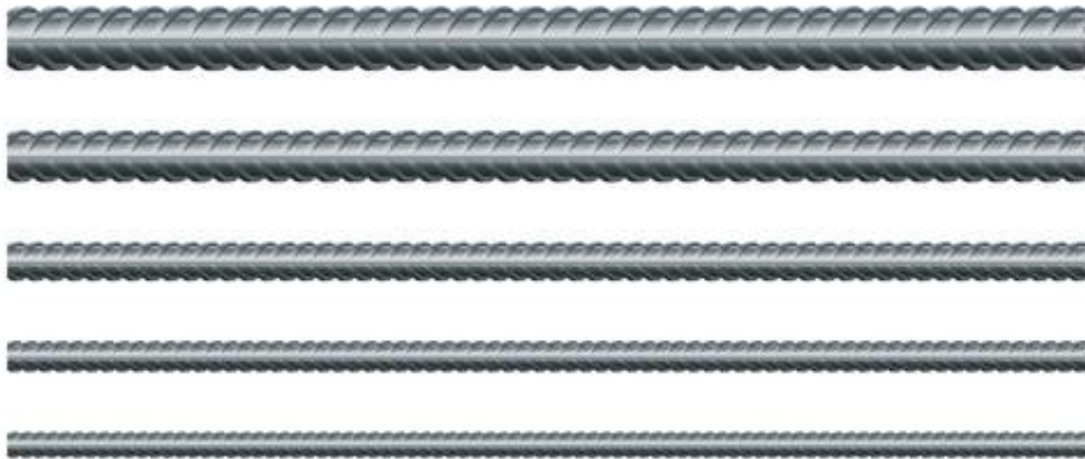


Fig. 4.5 Reinforcing bars of different diameter

4.2.2.1 Types of Reinforcing Steel

There are mainly **three types of steel** used in construction:

1. Mild Steel

- It is smooth and has a plain surface.
- It is flexible but not as strong as others.
- Used in small construction works or for tying.

2. HYSD (High Yield Strength Deformed) Bars

- Have ridges or ribs on the surface for better grip with concrete.
- Stronger than mild steel.
- Used in large structural works.

TMT (Thermo-Mechanically Treated) Bars

- These are the most commonly used in modern construction.
- They have high strength, flexibility, and are resistant to corrosion.

- Used in all major construction, including solar PV structures (like ground-mounted panel supports).

LET US TRY THIS!

Build It to Hold It – A Steel Strength Challenge

Objective: Understand how different steel bars support loads in construction.

Procedure:

1. **Create mini beams** using cardboard strips to act as concrete, and use Mild Steel wire, twist ties, and string as “reinforcement bars.”
2. **Insert different materials** (steel wire, twist tie, string) into your beams before taping them shut.
3. **Add weight** (books or pencil boxes) to the centre of each beam slowly and observe which one bends or breaks first.
4. **Note your findings**—Which material gave the strongest support? Which bent the most?
5. **Discuss as a class** how real steel bars (Mild, HYSD, TMT) help buildings and solar panel structures stay strong and safe.



4.2.2.2 Grades of Steel

Steel is also classified into **grades**, which show how strong it is especially how much **force** it can take before it bends or breaks. This is called **yield strength** (measured in N/mm^2).

Here are some common grades:

Table 4.6 Grade of steel and its usage

Steel Grade	Yield Strength (N/mm^2)	Used In
Fe 250	250	Small buildings
Fe 415	415	Normal structures
Fe 500	500	High-load buildings
Fe 550	550	Bridges, heavy structures

Note: Higher the grade = **Stronger the steel.**

LET US KNOW MORE

When we mix cement, sand, water, and aggregates to make concrete, sometimes we also add special materials to improve how the concrete behaves. These special materials are called admixtures.

Admixtures are added in small amounts to concrete or mortar during mixing to change or improve certain properties, flow better, or become more durable.

Admixture are used:

- To increase strength or make concrete set quicker or slower depending on the weather.
- To reduce the amount of water needed in the mix (this improves strength).
- To make concrete more workable which means it's easier to place and spread.
- To make the concrete last longer, even in harsh weather or salty areas.

4.2.3 Water in Concrete

Water is one of the most important ingredients in a concrete mix. It usually **reacts with cement** to form a glue-like paste that **binds** the sand and aggregates together. This chemical reaction is called **hydration**.

The following chemical reaction takes place:

Cement + Water → Calcium Silicate Hydrate (C-S-H) + Calcium Hydroxide + Heat

- **Calcium Silicate Hydrate (C-S-H):** This is the main binding material that gives concrete its strength.
- **Calcium Hydroxide:** This helps in creating an alkaline environment, which protects the steel inside reinforced concrete from rusting.
- **Heat:** The reaction also releases heat, which is why freshly poured concrete can feel warm.

But the **amount of water** used must be **just right**:

- **Too little water:** The mix will be dry and hard to work with.
- **Too much water:** The concrete will be weak and may develop cracks later.

4.2.4 Sand in Concrete

Sand is the **fine aggregate** used in concrete (Fig. 4.6). It fills the small spaces between the larger pieces of gravel or stones (called coarse aggregates), making the mix dense and strong. There are two common types of sands:

- **River sand:** Smooth and clean; often used for good quality work.
- **Manufactured sand (M-sand):** Crushed from rocks; used as a substitute where river sand is not available.

Good sand for concrete should be:

- **Clean** (free from mud, clay, or organic matter)
- **Well-graded** (a mix of fine and coarse grains)
- **Angular** (so it binds well with other materials)

If poor-quality sand is used, it can **weaken the concrete** and cause problems like cracking or low strength.



Fig. 4.6 Sand

4.3 Anchoring in Structures

Anchoring ensures that the structure doesn't **tilt, shake, or fall** due to wind, vibrations, or other forces. In solar PV systems, anchoring plays a **very important role**. Without strong anchoring, the solar panels may shift or get damaged, reducing their performance or even causing safety hazards.

4.3.1 Importance of Anchoring

Following are the importance of anchoring in structures:

1. It increases the stability of the structure.
2. Prevents movement due to wind, rain, and vibrations.
3. Ensures the structure lasts longer without needing frequent repairs.
4. Keeps people and property safe from falling parts.

In solar PV installations, anchoring helps the panels stay at the correct tilt angle to capture maximum sunlight.

What happens if we don't anchor a solar panel properly? Why do you think wind or rain can be dangerous for a weakly fixed solar panel? How does anchoring help in capturing more sunlight? Can you name any other structure that needs strong anchoring?



4.3.2 Types of Anchoring

To make sure solar panels stay strong and steady, two main types of anchoring methods are used:

1. Mechanical Anchoring

This method uses metal parts like bolts, nuts, and fasteners. These parts are tightened into concrete or brick surfaces to hold the structure firmly (Fig. 4.7).

Materials Used: Anchor bolts, L-shaped brackets, Nuts and washers and Screws.

How It Works:

- A hole is drilled into the concrete or brick surface.
- A metal fastener or anchor bolt is inserted and tightened.
- This creates a strong grip that holds the panel frame in place.

Example: On a rooftop, L-shaped brackets are fixed using anchor bolts into the roof slab to support the solar panel frame.



Fig. 4.7 Mechanical Anchoring in Structures

2. Chemical Anchoring

- This method uses special adhesives or resins to hold rods or bolts in place (Fig. 4.8). It creates a very strong bond, especially useful where bolts might get loose over time.
- Example: In ground-mounted solar PV systems, chemical anchoring helps the structure resist strong winds and vibrations.



Fig. 4.8 Chemical Anchoring in Structures

LET US KNOW MORE

In both rooftop and ground-mounted solar installations, anchoring:

- **Fixes the solar panel supports** (called solar mounting structures) to the base.
- Helps the panels maintain their direction and **tilt** toward the sun.
- It is selected based on site conditions **lightweight rooftop** systems may use mechanical anchors, while **heavy-duty ground structures** may use chemical anchoring or deep concrete blocks.

4.4 Prefabricated Structures in Solar PV Systems

Prefabrication is the process of manufacturing building components in the factory or workshop and then transporting them to the site for quick assembly. Instead of building everything from scratch at the site, prefabricated parts (pre-made parts) are simply assembled at the location.

4.4.1 Benefits of Prefabrication

Following are the benefits of prefabrication:

- **Time-saving** – Structures can be installed faster.
- **Consistent quality** – Factory-made parts are made with precision.
- **Less labour on site** – Fewer people are needed for assembly.
- **Reduced waste** – Less material is wasted during construction.

- **Faster installation** – Ideal for urgent or remote solar PV projects.


Example: In a solar PV system, metal frames, mounting brackets, and panel supports are often prefabricated and then assembled on rooftops or open fields (Fig. 4.9).






Fig. 4.9 Prefabricated Structures for Solar PV System

4.4.2 Types of Prefabricated Elements

Here are some commonly used prefabricated components in solar PV installations:

Prefabricated Element	Description & Use	
Mounting Frames	Support structures to hold solar panels	
Pre-drilled Rails	Rails with pre-made holes for easy fixing of panels	

Concrete Blocks	Used as base supports in non-penetrating systems	
Cable Trays & covers	Preformed trays to organize and protect electrical wires	
Roof Stands or Supports	Special stands prefabricated for angled rooftop installations	

4.4.3 Assembling Prefabricated Components

Following are the Steps to assemble prefabricated components:

1. **Transport to Site:** Parts are transported from the factory to the project location.
2. **Foundation Setup:** Depending on the system (rooftop or ground), a foundation is prepared.
3. **Place Prefabricated Base:** Concrete blocks or metal stands are positioned as the base.
4. **Mount Support Frames:** Prefabricated metal frames are fixed using bolts or anchors.
5. **Attach Solar Panels:** Panels are mounted on the frame using clamps and brackets.
6. **Connect Wiring:** Pre-designed cable trays help manage wiring efficiently.
7. **Testing:** The system is tested to ensure it works correctly.

Key Point: No cutting, welding, or major drilling is needed at the site - just assembly of ready parts.

LEARNING BEYOND CLASSROOM

A real-life site visit to observe a prefabricated solar PV structure can be very helpful for students. During such a visit, students can:

- Identify different prefabricated components (frames, brackets, panels).
- Observe how parts are assembled (bolting, clamping, wiring).
- Interact with engineers or technicians working on installation.
- Understand safety practices, quality checks, and layout planning.
- Sketch the solar PV layout and label parts for better understanding.

Suggested Activity During Visit:

- Distribute a worksheet with labelled diagrams of prefabricated components and ask students to match them on-site.
- Ask students to record 3 observations about how prefabrication saved time or effort.

4.5 Civil Work Required for Different Types of Mounting Structures in Solar PV Systems

Solar panels need strong and stable support structures to remain fixed in one position, especially under outdoor conditions like wind and rain. The type of civil work depends on where the solar panels are installed and what kind of structure is used to support them. Let us discuss each of them in detail:

1. Roof-Mounted Structures: These are installed directly on the rooftops of buildings (Fig. 4.10).

Civil Work Involved:

Step 1: Structural Analysis: Before installation, engineers must assess whether the roof can safely hold the weight of the solar panels and supporting structures.

Step 2: Waterproofing Check: Civil work ensures no leakage occurs due to anchoring.

Step 3: Anchor Bolt Fixing: Drilling into the roof slab to fix anchor bolts using mechanical or chemical anchoring.

Step 4: Support Stand Installation: Installing prefabricated support stands or angle brackets.

Step 5: Weatherproofing: Sealing around bolts to prevent water seepage.

Step 6: Grouting (if required): Filling holes or gaps around bolts for extra stability.

Observation During Site Visit

- Observe how holes are drilled and bolts are fixed into the concrete slab.
- Note how solar panel frames are aligned at the correct angle.



Fig. 4.10 Rooftop Mounted Solar PV System

2. Ground-Mounted Structures

These are installed in open areas where the panels are supported directly from the ground (Fig. 4.11).

Civil Work Involved:

Step 1: Soil Testing: To check soil strength for foundation design.

Step 2: Excavation: Digging trenches or pits for foundation footings.

Step 3: Foundation Construction:

- **Concrete Footings:** Pouring concrete into excavated pits.
- **Pile Foundation (for loose soil):** Driving long rods deep into the ground.

Step 4: Mounting Structure Erection: Fixing galvanized iron (GI) or aluminum structures onto the foundations.

Step 5: Leveling & Compacting: The ground must be levelled and compacted for stability.

Step 6: Cable Trenches: Dug for routing power and data cables underground.

Observation During Site Visit

- Identify different foundations – concrete blocks or metal piles.
- Watch how structures are fixed to the foundations.
- Observe curing process if fresh concrete was poured.



Fig. 4.11 Ground Mounted Solar PV System

3. Pole-Mounted Structures

Used for small-scale or rural installations, these use one or more vertical poles to hold the panels.

Civil Work Involved

Step 1: Pole Foundation: Digging a narrow deep pit.

Step 2: Pole Insertion: Inserting a steel pole vertically.

Step 3: Concrete Pouring: Filling the pit with concrete to hold the pole.

Step 4: Panel Mounting: Fixing panel brackets at the top of the pole.

Step 4: Backfilling & Leveling: Filling the area around the base and leveling.

Observation During Site Visit

- Observe the upright alignment of poles before concrete is poured.
- Notice how tilt angles are adjusted for best sunlight capture.



Fig. 4.12 Pole Mounted Structures

4. Elevated Structures (Solar Carports, Walkway Shades, etc.)

These structures serve dual purposes: providing shelter and supporting solar panels.

Civil Work Involved:

Step 1: Strong Foundation: Deep concrete footings or pedestal footings.

Step 2: Heavy Steel Column Installation: Larger steel sections need heavy machinery for positioning.

Step 3: Slab or Base Work: Concrete base may be required under the carport or walkway.

Stepn 4: Structural Framing: Beams and cross members are installed on top.

Observation During Site Visit

- Look at the steel columns and how they are anchored in concrete.
- Observe alignment techniques used for large-span structures.

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. What does the "M" in M10 or M20 concrete grade represent?
 - a) Mass
 - b) Mix

- c) Measurement
- d) Metal

2. Which material is used to improve the strength of concrete foundations in high-wind zones?

- a) Mild Steel Plates
- b) Jute Bags
- c) Reinforcement Bars (TMT Steel)
- d) Silicone Sealant

3. Which method is commonly used on construction sites for curing concrete when water is not available?

- a) Steam curing
- b) Wet covering with gunny bags
- c) Plastic sheets
- d) Air drying

4. Which of the given below is not a component of concrete?

- a) Cement
- b) Water
- c) Bricks
- d) Coarse Aggregate

5. What is the function of silicone sealant in rooftop solar PV installation?

- a) To hold panels together
- b) To seal gaps and prevent leakage
- c) To connect cables
- d) To polish the surface

B. Answer the following

1. What is the purpose of concrete in Solar PV installations?
2. Why is curing of concrete important after pouring?
3. What is the difference between Mortar and Concrete?
4. What are the benefits of using precast concrete in Solar PV installations?
5. What materials are commonly used for civil works in rooftop Solar PV systems?

ANSWER KEY**Unit 1: Introduction to Solar PV Installer – Civil****A. Multiple Choice Questions**

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

C. Match the following

A-3 B-1 C-4 D-2 E-5

Unit -2: Basics of Solar Photovoltaic System**A. Fill in the blanks**

1. Photovoltaic
2. Direct
3. Inverter
4. Bifacial
5. Galvanized Steel
- 6.

Unit 3: Tools and Tackles for Solar PV Installer -Civil**A. Multiple Choice Questions**

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

C. Fill in the blanks

1. Pyranometer
2. Socket
3. Plumb
4. Electrical hand
5. Pathfinder

Unit 4: Fundamentals of Civil Engineering**A. Multiple Choice Questions**

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

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GLOSSARY

Installation – *The process of setting up equipment or systems at a site.*

Foundation – *The base or groundwork that supports a structure like a solar panel frame.*

Pedestal – *A raised support that holds up structures like solar panel stands.*

Leveling – *Making a surface even and flat, especially before placing any structure.*

Anchor – *A strong device used to fix something firmly in place.*

Structure – *A framework built to support or hold something, such as solar panels.*

Panel Mounting – *The method of attaching solar panels to a fixed base or frame.*

Waterproofing – *Applying a material or coating to stop water from seeping through.*

Support System – *The parts (like frames or brackets) that keep the solar panels stable.*

Sealant – *A substance used to block the passage of fluids through surfaces or joints.*

Durability – *The ability of a material or structure to last a long time without damage.*

Workability – *How easy it is to mix, shape, or use materials like concrete.*

Precast – *A material or item (like a concrete block) that is made in advance and brought to the site.*

Surface Preparation – *The steps taken to clean, level, or ready a site before construction begins.*

Mounting Frame – *The part of the solar structure where panels are fixed for support and proper alignment.*



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