Draft Study Material

Job Role: Solar PV Installer - Civil

(QUALIFICATION PACK: SGJ/Q0103)

SECTOR: GREEN JOBS

Grade XII

विद्ययाऽमृतमश्नुते

एन सी ई आर टी
NCERT

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

PREFACE

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

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

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

Deepak Paliwal
(Joint Director)
PSSCIVE, Bhopal

Date: 16th April 2026

STUDY MATERIAL DEVELOPMENT COMMITTEE

Members

- Akhil Khare, *Consultant (Civil Engineering),* India Gandhi Manav Sanghralaya Shyamla Hills, Bhopal - 462002, Madhya Pradesh, India Antim Sharma, *Quality Engineer,* Greenmax Technology, Aakriti Ecocity, Bhopal, Madhya Pradesh, India.
- Ayushi Seeliya, AN Paarch Consultancy Services, Bhopal, Madhya Pradesh, India.
- Neeraj Bhandari, *Assistant Professor (Contractual) - Civil Engineering,* Department of Engineering and Technology, PSS Central Institute of Vocational Education (PSSCIVE), NCERT, Shyamla Hills, Bhopal - 462002, Madhya Pradesh, India.
- Er. Shaiwesh Singh, Founder & Proprietor, M/s Pushpa Infra Developer, Bhopal (MP), India.

Member- Coordinator

Vinod Kumar Yadav, *Associate Professor*, Department of Engineering and Technology, PSS Central Institute of Vocational Education, Bhopal, Shyamla Hills, Madhya Pradesh, India

CONTENTS

Module 1	SITE SURVEY FOR SOLAR PV INSTALLATION

Module Overview

This module explains the process of surveying the site for installing the solar Photovoltaic (PV) systems over the rooftops and other sites. It will learners to understand the purpose and importance of site investigation before installing solar panels. The module also describes the steps involved in checking site conditions such as roof direction, tilt angle, shading, and available installation area. In addition, it explains the role of the installer in inspecting structural safety and planning the panel layout for efficient and safe solar PV installation.

Learning Outcomes

After completing this module, the students will be able to:

- Explain the principles of a site survey in solar PV installation.
- Describe the purpose of site investigation before installing a solar PV system.
- Describe the importance of site investigation for safe and efficient solar PV installation.
- Identify the steps involved in checking important parameters during site investigation.
- Check and calculate important site parameters such as roof area, orientation, shadow conditions, and structural safety.
- Demonstrate the role and responsibilities of a Solar PV Installer (Civil) during site investigation.

Module Structure

1.1 Introduction to Site Survey
1.2 Purpose of Site Investigation
1.3 Importance of Site Investigation in Solar PV Installation
1.4 Steps for Checking Important Parameters During Site Investigation for Solar PV Installation
1.5 Important Parameters to be Calculated or Checked During Site Investigation for Solar PV Installation
1.6 Role of a Solar PV Installer (Civil) During Site Investigation

Have you ever noticed solar panels installed on rooftops, open fields, or along highways? Even though the solar panels look the same, why do some solar panel systems generate more electricity than others?

In many places they produce electricity throughout the day. In some locations the panels generate high power, while in others the output is much lower. Sometimes the difference is not due to the solar panels themselves but due to the conditions of the place where they are installed.

Over the past few decades, solar energy has moved from small experimental systems to large scale power generation. Historically, solar panels were primarily utilised in specialised applications like satellite systems, secluded telecommunications hubs, and rural settlements lacking reliable grid access. With advancement in technologies, the cost of manufacturing dropped, and consequently, the solar energy transformed as a viable solution for residential properties, academic institutions, industrial facilities, and massive utility-scale installations. The governments at global level and India are promoting solar power as an essential pillar of clean and green solution for the production of energy.

India, with a strong potential for solar energy, due to the availability of solar power throughout the year, is also progressing well in the direction of sustainable development. As of March 2026, India's solar capacity has reached at 150.2 GWAC, placing it at third rank globally after China and US. In Indian cities, the rooftop solar powered systems are gaining popularity. Furthermore, several solar parks are also developed in Indian cities with open areas that have better access to solar radiation.

The installation of solar PV systems not only requires the placement of solar panels but also requires a careful selection of the site-specific parameters that affects the efficiency and performance. In the preceding section, we will discuss different variables that affects the performance of the solar PV systems in detail.

1.1 Introduction to Site Survey

Site surveying is the process of choosing the ideal location and thoroughly inspecting the site prior to the installation of the solar PV system. The site study assists in determining whether the chosen location receives enough sunlight, whether the ground or roof is suitable for installation, and whether any objects could cast shadows on the panels.

Thus, one of the first and most crucial jobs for a solar PV installer is to properly survey the site. As previously discussed, a thorough investigation or study of the suggested site is necessary prior to the installation of a solar PV) system in order to guarantee the system's optimal effectiveness. It entails monitoring, quantifying, and documenting significant environmental and physical aspects of the location. In order to ensure that the final solar array functions with both peak performance and excellent safety requirements, the data collected during this initial phase is crucial for careful installation design.

A critical and thorough site evaluation enables the installers to determine the optimal sites for panel placement, confirm the mounting surface's structural soundness, and determine the site's exact solar irradiance (the instantaneous rate at which solar energy reaches a specific surface area, expressed in W/m^2). The site evaluation is a critical task as it identifies the potential obstructions like utility fixtures, neighbouring architecture, dense foliage (leaves of plants) that could cast shadows over the solar PV systems.

Since, the photovoltaic cells depend entirely on the direct sun light, even a small light or minor shadow may create disproportionate reduction in the power production of the solar PV plant. Hence, a comprehensive site evaluation is mandatory before installing any solar PV plant or system.

In order to ensure that the panels receive the maximum amount of sunshine from sunrise to sunset, preparing a precise plan for the installation of solar PV system is crucial, which in turn, facilitates in constructing the array's optimal shape and orientation. Beyond placement, the survey's findings offer a guide for a safe installation and the system's long-term technical stability.

Activity: Observation of a site for Solar PV Installation

In order to identify whether a potential site is suitable for a solar PV array, you should do a professional assessment of the site's environmental and physical features. Observe the plants carefully and the components present in the site. Discuss with your classmates how these conditions may affect the performance of a solar PV system.

Activity: Site Survey Questionnaire

Visit a nearby building or open area where solar panels are installed or could be installed. Observe the site carefully and generally discuss observations with your classmates about the following:

1. In which direction is the roof or open area facing?
2. Does the location receive direct sunlight for most of the day?
3. Are there any trees, buildings, poles, or water tanks that may create shadows on the site?
4. Is there sufficient space available for installing solar panels?
5. Is the roof or ground strong and suitable for supporting solar panels and mounting structures?

1.2 Purpose of Site Investigation

Site investigation is carried out to collect reliable information about the location where a solar PV system is planned to be installed. The observations and measurements made during this process help in planning the installation in a safe and efficient manner.

Why is it necessary to study a site before installing solar panels? Why can we not simply place the panels on any roof or open space? These questions are important to understand the role of critical site investigation.

Consider a simple situation. A school planned to install a rooftop solar PV system to reduce its electricity cost. The roof appeared large enough to install many solar panels. There were certain structural weaknesses in some parts of the roof identified in the survey. As a result, the project design was re-modelled to shun such weak points with the array focusing only on the most resilient points which also provided optimal solar exposure. This strategic change did not only optimize the power generation of the system, but ensured a structurally sound and stable installation.

These issues could have been identified and addressed early in case a proper check of the site had been conducted prior to the commencement of the work. A thorough examination of the field would have assisted the installer to select a more appropriate position or to alter the manner in which the panels were set up to avoid shadows. This example demonstrates that it is extremely important to check the site prior to going. It assists in the correct decisions, ensuring the solar system is functioning effectively, is safe, and producing the maximum amount of electricity.

The following is a less technical explanation of why we will test a site first before we install some solar panels:

1. Identifying the Suitable Location for Solar Panels

Among the largest reasons to check a site is to locate the ideal location of the solar panels. The installer examines the entire area to determine which areas receive the most sunlight throughout the day. It is always preferable to select those spots not shaded by shadows. By choosing the appropriate location we ensure that the panels are able to capture as much sunlight as possible and this way they are able to produce more electricity.

2. Examining Roof or Ground Condition

It is quite important to ensure that the roof or the ground is good prior to the installation of the solar panels. The installer examines carefully whether the surface can support the excessive weight of the panels, the metal stands and all the wiring.

In this examination, they observe any issues such as cracks, old, or weak areas or broken components that may cause future problems. When the panels are laid on the ground, the installer too inspects whether the soil is firm and the land is stable. This is done to ensure the entire system remains secure and is not affected by time and falls or cracks.

3. Checking Availability of Sunlight and Possible Shading

Solar panels will only generate power when the sun is shining on them. The installer will keep an eye on the spot during a visit to the site to make sure that the spot remains in the sun throughout the day. They search around such objects as tall trees, other buildings, water tanks, or even power poles.

These objects have the ability to cast shadows which change with the movement of the sun in the sky over the panels. Early detection of these "sun blockers" will help the installer to locate the panels in a different location that will not be covered under the shade.

4. Measuring Available Installation Area

Another reason to visit the site is to check the amount of space available. The installer uses his/her length and width of the roof or the ground to know precisely the amount of space available. This assists them to calculate the number of panels that can be fitted.

It is not simply the matter of packing in as many panels as you can, the installer also leaves sufficient spacing between the rows. The additional space is needed in order to avoid a shadow cast on the row behind by a row of panels. Moreover, it provides ample space so that workers can move freely when they have to clean or repair the panels at the subsequent level.

5. Planning the Layout and Panel Arrangement

After all the notes and measurements have been completed, the installer then takes that information to construct a plan of the entire solar system. They determine the precise location of the panels, the location of the metal stands to be installed, and the place to leave walking paths to clean. They also select the most appropriate location of electrical boxes and wires.

The installer can ensure that every inch of the roof or ground is put to good use by planning the layout. This assists the system to remain safe as well as generate as much electricity as possible.

6. Ensuring Safe and Efficient Installation

Inspecting the site is also used to locate any dangers prior to the work. The team examines such issues as how the workers can safely get up to the roof, whether the workers will have enough space to move about, and whether the panels will be blown off in case of strong winds.

By having this information in advance, the workers will be safe as they assemble all this. It further ensures that the solar system remains robust and continues to be effective over a number of years.

1.3 Importance of Site Investigation in Solar PV Installation

The installer must be aware of what the site will be like before he/she installs up a solar PV system. Although a spot may look good on the surface, it may be hiding some issues such as lack of space, roof that is not sturdy or shadows cast by trees and other buildings.

The solar PV installer can identify these problems early by conducting a proper site check prior to the commencement of any work. This assists them in laying out all the plans in a right manner that will make the solar panels complete on the first day.

1. Helps in Selecting the Right Location for Panels

When the solar PV installer visits the location, he/she inspects the area attentively to identify the ideal place to install the solar panels on the roof or on the ground. In practice, you cannot take any part of the roof. Things such as water tanks, cooling fans or short walls (parapet walls) on the edges already occupy many of these spots.

The solar PV installer is able to map out a plan by measuring the area and verifying it. This assists them to position the panels in areas where the sunshine is maximum and still allowing space where people can move about when they want to clean or repair them.

2. Helps in Checking Roof Strength and Safety

The metal stands on which the solar panels are mounted and the frames in which they are fixed, all contribute to the additional weight of a building. When the solar PV installer is on the site, he should ensure that the roof is sufficiently tough to support this heavy load.

The professional will examine the indications of trouble such as cracks, fractured surfaces or tender areas that can collapse with pressure. These weak areas need to be identified prior to commencing any work. This is a quick test to prevent harming the house itself and to ensure that the solar system and the building remain safe over a long period.

3. Identifying Shading Problems

Shadows are a significant issue in the real-life setups. The installer during a site visit will ensure that objects such as tall trees, other buildings, poles, antennas or even water tanks do not cast shades on the roof.

A tiny shadow falling on but one corner of a panel may considerably diminish the quantity of electricity produced by the entire system. The installer can then identify these "sun blockers early enough to relocate the panels or adjust the layout so as to ensure that the panels will remain in the sunlight throughout the day.

4. Helps in Planning Panel Layout and Spacing

A site check aids the installer in determining the precise number of panels he may fit and how to make them fit in the most ideal way. There should be a lot of space between the rows of panels. When they are too close, the front row will cast a shadow on the row above it, preventing them to make electricity.

The installer also ensures that there are well laid walking paths. Such routes will be required to enable the workers to have a smooth access to the panels in an attempt to clean it or correct any issues. Through such planning, all the bits of the roof or land are utilized in the optimal manner.

5. Helps in Easy Installation and Future Maintenance

A site investigation ensures that laborers can access the roof as well as move securely during the time they are either installing or repairing the panels. The professionals will ensure that there is sufficient space to move around, transport equipment, and clean the panels when they become dusty.

When considering these real life needs when conducting the survey, the team will be able to make the system easy to maintain. With a solar system that is easy to clean and service, it remains in good condition and continues to produce power over an incredibly long period of time.

6. Helps in Deciding the Orientation of Solar Panels

During the site investigation, the installer checks the direction of the roof or installation area. In countries located in the Northern Hemisphere such as India, solar panels generally produce better results when they face towards the south. If the roof faces a different direction, the installer must adjust the panel mounting structure accordingly. Proper orientation ensures that panels receive sunlight for a longer duration during the day.

7. Helps in Determining the Correct Tilt Angle

The tilt angle of solar panels plays an important role in capturing sunlight efficiently. During site investigation, the installer studies the roof slope and decides whether additional mounting structures are required to achieve the correct tilt angle. If panels are installed at an improper angle, they may receive less sunlight and also accumulate dust and water more easily.

8. Helps in Estimating System Capacity

The available space at the site determines how many solar panels can be installed and therefore how much electricity the system can produce. During site investigation, installers measure the roof or ground area and calculate the possible system size. Knowing all these details helps the user or house owner understand exactly how much electricity the system will produce and how much money they will save on their power bills. When a site is checked properly, the installer can give a very good estimate of the energy the panels will make. This helps the family or the school plan their budget, as they will know how much less they have to pay the electricity board every month.

9. **Estimating the Cost of Installation**

A site check also helps the installer figure out the total cost of installing the solar PV system. By looking at the area, they can decide what kind of metal stands are needed, how much wire will be required, and if any extra parts are necessary.

If the roof needs to be fixed or if special supports are needed to hold the panels, these costs can be calculated before the work starts. This way, the owner gets a clear and correct price for the project, and there are no "surprise costs" that pop up later.

Activity: Site Investigation Observation Chart

Visit a nearby building rooftop or open area that could be used for solar PV installation. Observe the site carefully and fill the following chart by putting a **✓ (tick)** in the appropriate column.

S. No.	Observation Point	Yes (✓)	No (✓)	Remarks
1	Is sufficient open space available for installing solar panels?			
2	Does the site receive direct sunlight for most of the day?			
3	Are there trees, buildings, or other objects causing shadows?			
4	Is the roof or ground surface strong and suitable for installation?			
5	Is the direction of the roof suitable for solar panel installation?			
6	Is there enough space for workers to move during installation and maintenance?			
7	Can solar panels be arranged properly with adequate spacing?			
8	Is the location suitable for installing electrical components such as inverter and cables?			
9	Does the site appear suitable for installing a solar PV system?			
10	Is the roof surface free from cracks, leakage, or structural damage?			
11	Is there easy access to the roof or installation area?			
12	Is sufficient space available for installing batteries (if required)?			
13	Is sufficient spacing available to avoid shading between rows of panels?			
14	Is there enough space for future expansion of the solar PV system?			

After completing the chart, discuss your observations with your classmates and suggest whether the site is suitable for solar PV installation or if improvements are required.

Did you Know?

How to identifying the Load to be Connected to the Solar PV System?

During the site survey, the installer observes the building and prepares a load list of all appliances that require electricity.

After identifying the appliances, the installer calculates the daily energy consumption. This calculation helps determine how much electricity the solar PV system must generate every day. The daily energy consumption of an appliance can be calculated using the following relation:

Daily Energy Consumption (Wh) = Power Rating of Appliance (W) × Number of Hours Used per Day

For example, consider a small house where a fan of 75 W operates for 8 hours in a day. The daily energy consumption of this fan will be:

Energy Consumption = 75 × 8
Energy Consumption = 600 Wh

Similarly, if an LED light of 20 W operates for 5 hours in a day:

Energy Consumption = 20 × 5
Energy Consumption = 100 Wh

By calculating the energy consumption of all appliances and adding them together, the installer can estimate the total daily energy requirement of the building.

Example: Load Calculation for a Small House

Appliance	Power Rating (W)	Hours Used	Energy (Wh)
LED Lights	20 × 4	5	400
Fans	75 × 2	8	1200
Television	100	3	300
Refrigerator	150	6	900

Total Daily Energy Consumption = 2800 Wh (2.8 kWh)

This value helps the installer estimate the required solar PV system capacity.

Another important concept is *Peak and Off-Peak Load*.

Peak load is the time when many electrical gadgets are used at the same time, leading to the highest demand for power. For example, in most Indian homes, the peak load happens in the evening. This is when everyone is back from school or work, and the lights, fans, TV, and kitchen appliances are all switched on at once. Because everything is running together, the house needs much more electricity during these few hours than it does during the rest of the day.

Off-Peak Load is the time when only a few basic things are running, and the house needs very little electricity. For example, late at night when everyone is sleeping, only the fridge or a few night bulbs might be on. This is when the demand for power is at its lowest.

Activity: Load Identification and Calculation

Visit your School or home building and prepare a list of the electrical appliances that are fitted in one room.

1. Enlist five electrical appliances that are fitted in the room.
2. Make a record of their power ratings (Wattage capacity). Refer the label of the appliance.
3. Calculate the time in hours each appliance is used in a day.
4. Calculate the daily energy consumption.
5. Estimate the total daily energy requirement for the room and Discuss how this energy demand can be supplied using a solar PV system.

1.4 Steps for Checking Important Parameters During Site Investigation for Solar PV Installation

During a site investigation, the installer follows a systematic process to observe, measure, and evaluate the proposed installation site. These steps help in identifying whether the location is suitable for installing a solar PV system and how the panels should be arranged for maximum performance.

Step 1: Identifying the Exact Location of Installation

The first step is to identify the exact area where the solar PV system will be installed. This may be a rooftop, terrace, or open ground. The installer observes the surrounding environment and confirms whether the location receives sufficient sunlight during the day.

Step 2: Determining the Orientation of the Installation Area

The direction in which the installation surface faces is determined. In countries located in the Northern Hemisphere such as India, solar panels generally perform best when they face towards the south. Therefore, the installer checks the orientation of the roof or land to decide the best direction for placing the panels.

Step 3: Measuring the Available Installation Area

The installer measures the length and width of the roof or ground surface that can be used for installing solar panels. Areas occupied by obstacles such as water tanks, ventilation pipes, chimneys, or other structures are excluded from the usable space.

Step 4: Checking the Tilt or Slope of the Surface

The slope or tilt of the roof is examined to determine whether it is suitable for installing solar panels. If the roof slope is not suitable, mounting structures may be required to adjust the tilt angle so that panels can receive sunlight efficiently.

Step 5: Observing Shading Conditions

The installer carefully observes whether nearby objects such as trees, buildings, electric poles, antennas, or water tanks cast shadows on the installation site. The pattern of shadows during different times of the day is also considered.

Step 6: Estimating the Number of Solar Panels

Based on the available installation area, the installer estimates how many solar panels can be installed. The installer also makes sure there is enough gap between the rows of solar panels. If they are placed too close together, the front row will cast a shadow on the row behind it. This is called "row-to-row shading." By keeping the right distance, every panel gets full sunlight, which helps the system produce the most electricity.

Step 7: Planning the Layout of Solar Panels

Once the installer knows how many panels are needed, they draw a plan to show exactly where each panel will sit on the roof or the ground. This is called the system layout. A good layout makes sure that every bit of available space is used in the smartest way possible. It also leaves enough "walking space" or paths between the panels. This is very important because it allows workers to reach every panel easily when they need to wash off dust or check the wires.

Step 8: Checking Structural Strength of the Roof or Ground

The installer takes a very close look at the roof or the ground to make sure it is strong enough to hold the weight of the whole system. Solar panels might look light, but when you add the metal frames and the stands (mounting structures), they create a lot of extra weight that the building has to carry for many years.

During the survey, the expert looks for "warning signs" like cracks in the concrete, rusted metal beams, or weak wooden rafters. If they find any of these problems, they write them down so they can be fixed before the panels are put up. This keeps the building safe and prevents the roof from sagging or leaking in the future.

Step 9: Observing Environmental Conditions

The installer also looks at the environment around the site to see how nature might affect the panels. They check how strong the wind blows, how much dust is in the air, and if there are nearby factories or busy roads that create smoke and pollution.

These environmental factors are very important because they change how the system is built and how often it needs to be cleaned. For example, in a very dusty area, the panels might need to be washed every week instead of every month to keep them working at their best.

Step 10: Recording Observations and Preparing the Site Survey Report

Finally, all observations and measurements made during the site investigation are recorded in a site survey report. This information is later used for designing the solar PV system and planning the installation process.

1.5 Important Parameters to be Calculated or Checked During Site Investigation for Solar PV Installation

During site investigation, the installer must observe, measure, and calculate several important parameters before installing a solar photovoltaic (PV) system. These parameters help determine the

- best position,
- orientation, and
- arrangement of solar panels.

This will enable the solar PV system to generate maximum electricity. Proper measurements and calculations also help in selecting suitable mounting structures and planning the layout of the system.
The most important parameters checked during site investigation are explained below.

1. Orientation of Solar Panels

Orientation refers to the direction in which the solar panels face. The direction of the panels determines how much sunlight they receive during the day.

In the Northern Hemisphere, including India, solar panels generally perform best when they are facing towards the south. This orientation allows the panels to receive sunlight for a longer duration during the day.

Apparatus Used for the orientation of solar panels

a) Magnetic compass or digital compass
b) Smartphone compass application
c) Site layout map or roof plan

a) Magnetic Compass or Digital Compass

A magnetic compass is one of the simplest tools used to find the direction. During the site investigation, the solar PV installer places the compass on a flat surface and observes the direction indicated by the needle (Figure 1.1). The needle always points towards the magnetic north, which helps the installer identify the south direction (opposite to the needle indicating north). Once the directions are known, the installer can determine whether the roof or installation area is facing the appropriate direction for solar panel placement.

Figure 1.1: (a) Magnetic Compass

Figure 1.1: (b) Digital Compass

b) Smartphone Compass Application

Most smartphones have built-in sensors that allow them to work as a digital compass. During site investigation, the installer can open the compass app and hold the phone flat to check the direction of the roof or installation site (Figure 1.2). Some apps also show the sun path, which helps estimate sunlight exposure at different times of the day.

Figure 1.2: Smartphone Compass Application

c) Site Layout Map or Roof Plan

A site layout map or roof plan provides a visual representation of the building or installation area. It shows the dimensions, surrounding structures, and orientation of the roof. During site investigation, the installer studies the layout to understand the position of obstacles such as water tanks, parapet walls, and ventilation units.

Procedure

1. Stand at the proposed installation site on the roof or open land.
2. Use a compass to identify the four cardinal directions (North, South, East, West).
3. Determine the direction which the roof surface or installation area is facing.
4. Record the orientation in the site survey report.
5. If the roof does not face south, mounting structures may be adjusted to achieve the desired direction.

Practical Note

Panels facing **south-west or south-east** can also work effectively in case exact south orientation is not possible.

2. Tilt Angle of Solar Panels

The tilt angle is the angle between the solar panel surface and the horizontal ground surface. Correct tilt helps the panel to receive maximum solar radiation. In many solar installations, the tilt angle is selected close to the latitude of the location.

For example, Latitude of Bhopal ≈ 23° North; Therefore, the tilt angle may be approximately 20°-25°.

Tilt Angle of Solar Panel ≈ Latitude of the Location

In above context,

- **Tilt Angle** → the angle at which the solar panel is installed from the horizontal surface.
- **Latitude of Location** → the geographical latitude of the place where the solar panels are installed.

Set the panel tilt angle nearly equal to the latitude of the place.

Apparatus to be used to set tilt angle

a) Clinometer
b) Digital angle meter

a) **Clinometer:** A clinometer is a simple instrument used to measure the angle of slope or inclination of a surface (Figure 1.3). During a solar PV site survey, the installer places the clinometer on the roof surface or mounting frame to determine the roof's tilt.

Following are the uses of clinometer:

- It helps to determine whether the roof already has a suitable slope for solar panel installation or not?
- It assists in deciding if an additional mounting structure is required to achieve the correct tilt angle.
- It is useful when installing panels on sloped roofs such as metal sheet or tiled roofs.
- Clinometers are commonly used in field surveys because they are simple, portable, and easy to read.

Figure 1.3: Clinometer

b) Digital angle meter: A digital angle meter (also called a digital angle finder) is an electronic device that measures angles and displays the value directly on a digital screen (Figure 1.4). Following are the uses of digital angle meter while doing site investigation:

- It allows installers to quickly measure the tilt of the roofs, mounting rails, and panel frames.
- It provides highly accurate readings (usually in degrees).
- It helps technicians adjust the mounting structure until the desired tilt angle is achieved.

Because of its speed, accuracy, and easy readability, digital angle meters are widely used in modern solar PV installations

Figure 1.4: Digital angle meter

3. Measurement of Available Installation Area

During site investigation, the installer measures the available roof or ground area where solar panels can be installed. However, before calculating the number of panels, the installer usually first discusses with the user how much solar capacity (in kW) they want to install. This capacity depends on the user's electricity consumption and budget.

Once the required system size is known, the installer checks whether the available space is sufficient to accommodate the required number of panels. For example, a 1 kW rooftop solar system generally requires about 8-10 m^2 of shadow-free area depending on the panel type and layout.

The installer then measures the length and width of the usable roof area and excludes spaces occupied by obstacles such as water tanks, staircases, ventilation ducts, or parapet walls. Once the installer subtracts the areas taken up by water tanks, walking paths, and shadows, the part that is left is called the usable installation area.

The total area can be calculated using the formula:

$$A = L \times W$$

Where:

A = Area of the installation surface
L = Length of the roof or ground
W = Width of the roof or ground

After calculating the usable area, the installer verifies whether it is sufficient for installing the required solar capacity and then prepares the panel layout accordingly. This step ensures that the system can be installed safely and can generate the expected amount of electricity.

Example Calculation
Suppose the roof length is 10 m and the width is 6 m.
Total roof area = 10 × 6 = 60 m^2
If 10 m^2 of the roof is occupied by water tanks and other obstacles, then the usable installation area becomes 50 m^2.

Note: After determining the usable area, the installer compares it with the size of the solar panels. A typical solar panel occupies about 1.8 to 2 m^2. However, panels cannot be placed touching each other. Small gaps must be left between rows for maintenance, cleaning, and airflow.

Before measuring the installation area, the installer usually discusses with the user how much solar capacity (in kW) they want to install. This depends on factors such as monthly electricity consumption, available budget, and available space.

Note: It is to be noted that 1 kW solar PV system requires approximately 8-10 m^2 of shadow-free area. This value may slightly vary depending on panel efficiency and installation layout.

For Example:
If a user wants to install a 3-kW solar system, the approximate area required will be:

$$\text{Required Area} = 3 \times 10 = 30\ m^2$$

During the site survey, the installer checks whether the roof or ground area can accommodate this space.

3. Calculation of Number of Solar Panels
Once the usable area is known, the installer calculates how many panels can be installed. A typical solar panel has a power rating of **400–550 W** and occupies approximately **2 m^2 of space**.

The number of panels required can be calculated as:

$$\text{Number of Panels} = \frac{\text{Required System Capacity (W)}}{\text{Power Rating of One Panel (W)}}$$

Example:
Required system capacity = **3 kW (3000 W)**
Panel capacity = **500 W**

Number of panels required = $\frac{3000}{500}$ = **6 panels**

4. Considering Panel Spacing

Even though they look like a solid wall of blue or black from a distance, solar panels are actually installed with small gaps between them. Leaving these spaces is a very important part of the setup to:

- Keeps the panels cool by allowing air circulation.
- Provide space for installation and maintenance work.
- Avoid shadowing of the panels, especially in tilted installations.

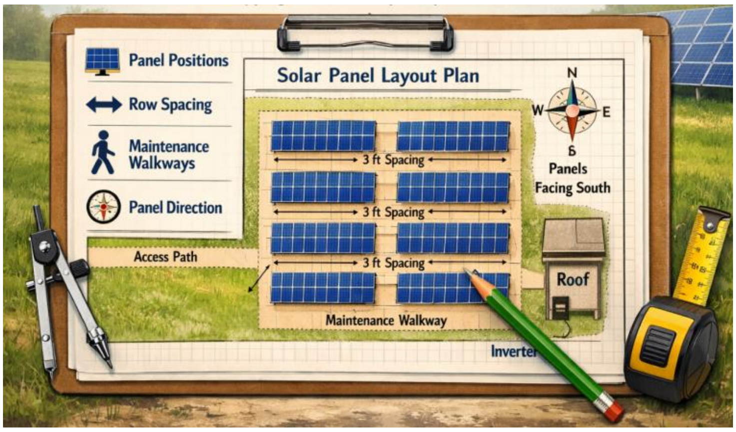
Note: Usually 0.3 m to 0.6 m spacing is maintained between rows depending on the tilt angle and roof design.

5. Planning the Panel Layout

Once the installer knows how many panels are needed and where they go, they draw a map to show exactly where each one will sit. The layout indicates:

- Panel positions
- Row spacing
- Maintenance walkways
- Direction of panels

A well-planned layout ensures maximum use of available space and efficient sunlight capture.



Case Study

A house owner in Sehore (MP) wants to install a 5-kW rooftop solar PV system

Before putting up the solar panels, a worker visits the house to check the roof. They take measurements and look around to make sure the roof is strong enough and to figure out the best spot for the panels.

Step 1: Understanding the User's Requirement

The first thing the worker asks the homeowner is how much solar power they want to install in their house. Sometimes this decision is based on the monthly electricity bill or the user's budget.

In this case, the house owner wants to install a 5-kW solar system.

The installer then estimates the approximate area required for this system.

General rule:

1 kW solar system requires about 8-10 m^2 of shadow-free area.

Required area calculation:

$$5 \text{ kW} \times 10 \text{ m}^2 = 50 \text{ m}^2$$

So, the installer must check whether the roof has at least 50 m^2 of usable space.

Step 2: Observing the Roof and Identifying Obstacles

During the site visit, the installer carefully observes the roof and notes structures that may occupy space or create shadows, such as:

- Water tanks
- Staircase rooms
- Chimneys or vents
- Antennas
- Parapet walls

These structures reduce the usable installation area.

Step 3: Measuring the Roof Area

The installer measures the length and width of the roof using a measuring tape or laser distance meter.

Roof dimensions:

Let us assume, Length = 14 m; Width = 9 m

Total roof area calculation:

$$\text{Total area} = 14 \times 9 = 126 \text{ m}^2$$

However, the installer observes that 26 m^2 of the roof is occupied by a water tank and staircase structure.

Usable area calculation:

$$\text{Usable area} = 126 - 26 = 100 \text{ m}^2$$

Since the required area was 50 m^2, the available space is sufficient.

Step 4: Calculating the Number of Solar Panels

The next step is to determine how many solar panels are required to achieve the desired capacity.

Assume the installer plans to use 500 W solar panels.

Total system capacity required = 5 kW = 5000 W

Panel calculation:

$$\text{Number of panels} = \frac{500}{50}$$

Therefore, Number of panels = 10 panels

Step 5: Checking Panel Area Requirement

Each modern solar panel occupies approximately 2 m^2 of space.

Total panel area required:

$$10 \times 2 = 20 \text{ m}^2$$

This is much smaller than the 100 m^2 usable roof area, which means there is enough space for panel installation and proper spacing.

Step 6: Planning Spacing and Layout

The installer then plans the panel arrangement on the roof. While planning the layout, the following practical points are considered:

- Small gaps between panels for air circulation

- Row spacing to avoid shadow between panels
- Walking space for cleaning and maintenance

Because the roof has sufficient available area, the panels can be installed with proper spacing and maintenance pathways.

1.6 Role of a Solar PV Installer (Civil) During Site Investigation

As a Solar PV Installer (Civil), the site investigation is not only about measuring the area. The installer must observe, inspect, and verify several civil and site-related conditions to ensure that the solar PV system can be installed safely and perform efficiently. During the site survey, the installer usually checks the following practical aspects.

1. Type of Installation Surface

The installer first observes where the solar panels will be installed. This may be:

- Rooftop installation (residential or institutional buildings)
- Ground-mounted installation (commercial or solar farms)

For rooftops, the installer checks whether the roof is RCC, metal sheet, tiled roof, or asbestos sheet, because different mounting structures are required for each type.

2. Structural Strength of the Roof or Land

One of the most important civil checks is whether the structure can support the weight of solar panels and mounting structures.

The installer observes:

- Any cracks in the roof slab
- Weak or damaged concrete
- Signs of water leakage or corrosion
- Condition of roof beams and columns

For ground installations, the installer checks the soil condition, level of the ground, and stability for constructing mounting foundations.

3. Available Shadow-Free Area

The installer carefully observes whether the installation site receives direct sunlight throughout the day.

Objects that may create shadows include nearby buildings; trees; electric poles; water tanks and antennas or chimneys.

Note: Even small shadows can reduce solar panel output, so identifying shadow-free areas is very important.

4. Roof Orientation (Direction)

The installer checks the direction in which the roof faces. In India and most Northern Hemisphere countries, solar panels perform best when they face south. If the roof orientation is different, the installer decides whether adjustable mounting structures will be required.

5. Roof Tilt or Slope

The installer observes whether the roof is flat or sloped.

- Flat roofs require mounting structures to provide the correct tilt angle.
- Sloped roofs may already provide the required inclination.

The tilt angle affects how much sunlight the panels receive.

6. Space for Panel Layout and Maintenance

Apart from panel placement, the installer ensures there is sufficient space for maintenance activities, such as cleaning solar panels; inspecting wiring and mounting structures; safe movement of technicians etc. Walking pathways are often kept between rows of panels.

7. Accessibility of the Site

The installer checks whether workers can safely access the installation area.
For rooftop systems, this includes:

- Safe staircase or ladder access
- Sufficient working space on the roof
- Safety around parapet walls

For large commercial sites, the installer checks vehicle access and equipment movement.

8. Wind and Environmental Conditions

During site investigation, the installer also observes the environmental conditions around the installation site. Factors such as strong wind exposure, high dust levels, and nearby sources of pollution can affect the performance and durability of the solar PV systems. Areas with strong winds require stronger mounting structures and proper anchoring to ensure the panels remain stable. Houses near busy roads, factories, or building sites can get very dusty. This dust blocks the sun and makes the panels work less effectively, so they need to be cleaned more often. By looking at what is around the house, the worker can build a strong base for the panels and decide how often they need to be washed.

9. Drainage and Water Flow on Roof

The PV installer also checks how rain flows off the roof. They look at where the water goes and where the drains are. Solar panels must be put up so they don't block the water. If water gets stuck on the roof, it can cause leaks, rust the metal parts, or even hurt the building. By planning carefully, the rain can slide right off, keeping the roof and the solar panels safe and strong.

Activity: Roof Inspection for Solar PV Installation

Aim: Learn how a solar worker checks a roof before they put up solar panels.

Materials Required

1. Measuring tape
2. Smartphone with compass application
3. Notebook and pen
4. Camera or mobile phone (optional for photographs)

Procedure

1. Visit the rooftop of your school building or a nearby structure with the permission of the concerned authority.
2. Observe the type of roof such as RCC roof, metal sheet roof, or tiled roof.
3. Carefully inspect the condition of the roof and check whether there are any cracks, leakage marks, or damaged areas.
4. Use a smartphone compass application to identify the direction in which the roof faces.
5. Look around the roof and identify any objects that may create shadows, such as trees, nearby buildings, water tanks, antennas, or electric poles.
6. Record all your observations in the table given below.
7. Based on your observations, write a short note explaining whether the roof is suitable for installing solar panels.

Observation Table

S. No.	Observation Point	Observation	Remarks
1	Type of roof (RCC/metal sheet/tiled)		
2	Condition of roof (cracks, leakage, damage)		
3	Direction of roof (North/South/East/West)		
4	Presence of shading obstacles		
5	Overall suitability of the roof for solar installation		

An ideal roof layout (Figure 1.5) planning ensures that solar panels are arranged properly to receive maximum sunlight throughout the day. The panels are usually placed facing the south direction in the Northern Hemisphere to improve energy generation. While planning the layout, installers avoid shading from nearby trees, buildings, or water tanks. Proper spacing and maintenance pathways are also provided for safe cleaning and inspection. A well-planned roof layout helps in efficient use of space and better performance of the solar PV system.

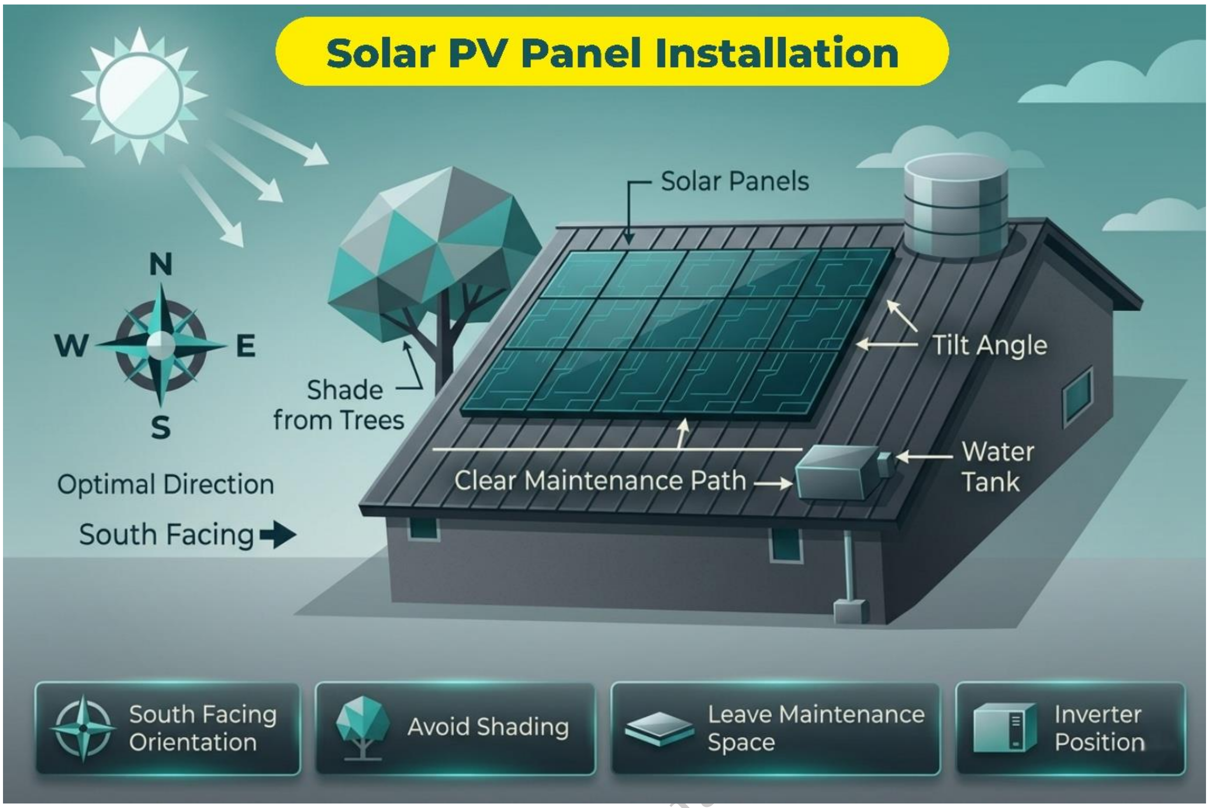


Figure 1.5: Ideal Rooftop Layout for Solar PV Panel Installation

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. During a site survey, an installer notices that a portion of the roof receives shade from nearby trees in the afternoon. Which action should the installer apply to maintain maximum energy generation?
   a) Install panels in the shaded area
   b) Select an unshaded portion of the roof for panel placement
   c) Reduce the number of panels
   d) Place panels vertically

2. A technician needs to install a 2-kW solar PV system using 500 W panels. Which option correctly calculates the number of panels required?
   a) 2 panel
   b) 3 panels
   c) 4 panels
   d) 5 panels

3. During a site survey, the installer observes that the roof faces west. Which installation strategy should the installer apply to improve solar energy capture?
   a) Install panels facing north
   b) Install panels facing south
   c) Install panels horizontally
   d) Install panels near the roof edge

4. A technician plans the arrangement of panels on a rooftop. Why should the technician include a maintenance pathway in the panel layout?
   a) To increase electricity consumption
   b) To enable inspection and cleaning of panels
   c) To reduce panel voltage
   d) To decrease sunlight exposure

5. During inspection, the installer observes that rainwater collects near the proposed panel area. What measure should the installer apply to prevent installation problems?
   a) Block the drainage outlet
   b) Install panels directly over the drainage path
   c) Ensure panels do not obstruct water flow
   d) Paint the roof surface

B. Short Answer Questions

1. During a rooftop inspection, a water tank and chimney occupy part of the roof area. Suggest how the installer should arrange solar panels while maintaining efficient panel performance.
2. A building roof receives sunlight for only half of the day due to nearby buildings. Recommend two steps an installer should take before finalizing the solar installation plan.
3. A roof measures 10 m × 6 m. If each solar panel requires approximately 2 m^2, estimate the maximum number of panels that can be installed while leaving space for maintenance pathways.
4. During inspection, the installer observes cracks in the roof slab. Explain how the installer should respond before proceeding with the solar installation.
5. In a dusty industrial area, solar panels accumulate dirt quickly. Demonstrate how this environmental condition will influence the maintenance planning of the solar PV system.

C. Long Answer Questions

1. Imagine you are a solar technician assigned to install a solar PV system on a residential building. Demonstrate how you would conduct a site survey by examining roof orientation, shading conditions, available roof area, and structural strength before installation.
2. A school building plans to install solar panels on its rooftop. Plan a suitable roof layout for solar panel installation by considering panel orientation, tilt angle, obstacles such as water tanks, maintenance pathways, and drainage flow.

D. Case Study

1. A technician conducts a site survey for installing solar panels on a house. The following observations are recorded:
   Total available roof area = 24 m^2
   A water tank occupies 4 m^2
   Each solar panel requires 2 m^2
   A nearby tree causes partial shading in one corner of the roof. On the basis of the above given case study and data, answer the following questions:
   i. Calculate the number of solar panels that can be installed after accounting for the area occupied by the water tank.
   ii. Suggest one modification in the panel layout to reduce the impact of shading caused by the tree.
   iii. Justify why leaving a maintenance pathway between panel rows is necessary during installation.

Module 2	CIVIL WORKS REQUIRED FOR SOLAR PV INSTALLATION

Module Overview

This module introduces the civil construction and planning aspects of solar PV installation. It explains the role of foundations in supporting solar PV structures and describes the different types of foundations used in solar PV installations. The module also discusses the basic steps involved in constructing these foundations at the installation site. In addition, the students will understand the basics of Single Line Diagrams (SLD), quality control and inspection practices, and the cost considerations involved in solar PV projects. The module also introduces modern business models such as RESCO and CAPEX/OPEX used in solar PV installations.

Learning Outcomes

After completing this module, the students will be able to:

- Explain the importance of foundations in solar PV installation sites.
- Identify different types of foundations used in solar PV systems.
- Apply the steps involved in constructing foundations for solar PV installations.
- Interpret the basic concept of a Single Line Diagram (SLD) used in solar PV systems.
- Examine the quality control and inspection practices in solar PV civil installation.
- Calculate the cost of installing solar PV systems.
- Differentiate between solar PV business models such as RESCO and CAPEX/OPEX used in solar power projects.

Module Structure

2.1 Foundations used for Solar PV Installations
2.2 Types of foundation used in Solar PV systems
2.3 Step for Construction of Different Foundations in Solar PV Installation
2.4 Understanding the basics of Single Line Diagram
2.5 Quality Control and Inspection in Solar PV Civil Installation
2.6 Cost Analysis and Economic Models in Solar PV Installation
2.7 New Business Models in Solar PV Installation (CAPEX/OPEX, RESCO)

Have you ever noticed the solar panels installed on the rooftops of houses, schools, hospitals, or large commercial buildings? In many places you may also see long rows of solar panels installed on open land forming large solar power plants. These panels silently convert sunlight into electricity and helps to provide clean and sustainable energy.

Now, imagine a team of solar installers arriving at a building to install a solar power system. The panels are delivered, the inverter and cables are ready, and the installation work is about to begin. But before the panels are fixed, an important question arises.

"Where and how will these panels be placed so that they remain safe and stable for many years?"

Solar panels, in general, are expected to operate for more than twenty years. During this long period, they face strong winds, heavy rainfall, dust, temperature changes, and continuous exposure to sunlight as discussed in Module 1. If the panels are not properly supported, they may tilt, loosen, or even fall during extreme weather conditions. In rooftop systems, poor installation can also damage the roof surface or lead to water leakage during rainfall.

This is the reason why civil works play a pivotal role in solar PV installation. Civil works include the preparation of the surface where the solar panels will be installed and the construction of a strong support base that can safely carry the weight of the panels and mounting structures. It also involves checking the strength of the roof or ground, preparing foundations, fixing anchor bolts, ensuring proper alignment, and maintaining safe drainage of rainwater.

For a Solar PV Installer (Civil), understanding these civil aspects is essential. The installer must know whether a rooftop is strong enough to support the system, how a mounting structure transfers load to the building, and how foundations are constructed for ground-mounted solar plants. In this chapter, you will learn how civil works are carried out for different types of solar PV installations such as residential rooftops, commercial buildings, and ground-mounted solar plants. The module will also explain how installers assess site conditions, select suitable materials, construct foundations, and ensure that the solar panels remain securely fixed for long-term operation. Before moving ahead, take a moment to think about a few questions.

When solar panels are installed on a rooftop, how does the roof support their weight?

Why do many ground-mounted solar systems use concrete foundations?

What might happen if solar panels are installed on a weak roof or on unstable soil?

How the strong and gusty winds affect the mounting structures of solar PV panels?

Critically thinking about these questions helps you to understand that putting up solar panels isn't just about wires and electricity. It also takes careful planning and building to make a strong, safe base for the whole solar system.

2.1 Foundations used for Solar PV Installations

Whenever you build something on the ground or a roof, it needs a strong base to hold its weight and keep it steady. This base is called a foundation. In building work or civil engineering work, the foundation is the bottom part that spreads the weight out so the structure doesn't sink or fall over.

For solar panels, foundations are very important because the panels and the metal frames holding them stay in the same spot for a very long time.

Did you know?

A single solar panel can weigh as much as a heavy suitcase, about 18-25 kg. When you add the metal frames and wires, the whole system becomes very heavy.

Besides this weight, the panels also have to deal with strong winds, shaking, and weather changes. Without a strong foundation, the frames could become wobbly, lean (or tilt) to one side, or even break during a big storm.

The key functions of foundations in a solar PV system are:

- To provide stability,
- To maintain alignment of the mounting structure, and
- For the safe transfer the loads to the ground or the building surface.

To understand the importance of foundations, imagine installing solar panels directly on loose soil without any concrete support. Over the time, the dirt under the panels can shift or sink, especially after it rains. If the ground moves, the panels might tilt or become crooked. When panels aren't pointing the right way, they can't catch as much sunlight and might even break. A good foundation keeps the panels steady, level, and facing the sun so they can make as much electricity as possible.

Note: It should be known that the foundation is the lowest part of a structure that transfers the entire load of the building safely to the soil. Whereas, a footing is a part of the foundation that directly spreads the load from columns or walls to the soil to prevent settlement.

2. 2 Types of foundation used in Solar PV systems

The selection of foundation depends mainly on the type of mounting system, soil condition, roof strength, and environmental loads such as wind. Proper foundation selection ensures that the solar PV structure remains stable, safe, and capable of supporting the panels throughout the expected lifespan of the solar installation. The types of foundations that are generally used are described here.

1. Anchor Bolt Foundation

The anchor bolt foundation, as shown in Figure 2.1, is the most widely used foundation method for rooftop solar PV installations. In this system, holes are drilled into the RCC roof slab, and steel anchor bolts are inserted and fixed using chemical grout or cement mortar. The solar PV installer then puts the metal base of the solar frame over these bolts. They use nuts and washers to screw everything down tightly so it stays in place.

This way of building creates a very strong link between the solar frame and the house. It keeps the panels steady even when it is very windy. Because the frame is bolted directly into the roof, the weight of the panels is safely held up by the building itself.

While working, the builder is very careful to fill the drill holes with a special waterproof glue. This stops rainwater from leaking through the roof and into the house.

Figure 2.1: Anchor Bolt Foundation

Anchor bolt foundations are generally used in:
- Residential rooftop solar systems

- School and institutional buildings
- Commercial buildings with RCC roofs

2. Isolated Concrete Footing

An isolated concrete footing is a common way to hold up solar panels on the ground. For this method, each metal leg of the solar frame sits on its own separate block of concrete buried in the dirt as shown in Figure 2.2.

The job of this concrete block is to spread the weight of the panels over a wider patch of soil. This stops the heavy frame from pushing too hard on one spot, which keeps the panels from sinking or tilting over time.

For example, a concrete base for a small solar frame on the ground might be about 60 centimetres wide, 60 centimetres long, and 60 centimetres deep. The exact size depends on how heavy the panels are and how strong the dirt is.

Anchor bolts are placed into the wet concrete. Once the concrete dries and gets hard, these bolts are stuck firmly in place. This allows the worker to bolt the metal solar frame onto the base so it stays secure.

The isolated concrete footing foundation is suitable for:

- Small solar plants
- Agricultural solar installations
- Ground-mounted solar PV systems in rural areas

v

Figure 2.2: Isolated Concrete Footing

3. **Pile Foundation**

A pile foundation, as shown in Figure 2.3, is used when the top layer of dirt is too soft or weak to hold the heavy solar frames. In this method, long poles made of steel or concrete are pushed deep into the ground until they hit a layer of dirt or rock that is strong enough to hold them.

The solar mounting frame is then fastened to the top of these poles using metal plates or brackets.

Pile foundations are very strong and can carry a lot of weight. They also do a great job of holding the panels down so that strong winds cannot pull them out of the ground. They are commonly used in large utility-scale solar power plants, especially in areas with sandy, marshy, or soft soil.

Another advantage of pile foundation is that they can often be installed quickly using specialized pile-driving machines, which helps speed up construction in large solar farms.

The pile foundation is suitable for:

- Large utility-scale solar farms where a large number of solar panels are installed.
- Areas with weak, soft, or loose soil that cannot safely support shallow foundations.
- Sites are prone to high wind loads or uneven settlement, requiring deep anchoring to stronger soil layers.
- Marshy, sandy, or flood-prone lands where surface soil is unstable

(a) (b)

Figure 2.3: (a) Pile Foundation (above the ground) **Figure 2.3: (b)** Pile foundation (above and below the ground)

Table 2.1 presents the difference between Anchor Bolt Foundation, Isolated Concrete Footing & Pile Foundation.

Table 2.1: *Difference between Anchor Bolt Foundation, Isolated Concrete Footing & Pile Foundation*

Feature / Aspect	Anchor Bolt Foundation (Rooftop RCC Roof)	Clamp-Based / Anchor Foundation (Metal Roof)	Concrete Pedestal Foundation (Medium Ground-Mounted)	Pile Foundation (Large Ground-Mounted / Weak Soil)
Construction Method	Steel anchor bolts drilled into RCC roof slab; mounting base plate fixed with nuts and washers; waterproof sealant applied	Clamps or anchors fixed to roof purlins or steel structural members; mounting frame attached without penetrating roof sheets	Vertical concrete pedestal constructed above ground on a concrete footing; base plate fixed to pedestal with anchor bolts	Steel or concrete piles driven deep into the ground to reach strong soil layers; mounting structure fixed to top of piles with base plates and bolts
Typical Applications	Residential and commercial RCC rooftops	Industrial sheds, warehouses, factories with metal sheet roofs	Medium ground-mounted solar plants, commercial installations, institutional sites	Large utility-scale solar farms, areas with weak, soft, or loose soil
Load Transfer	Load transferred directly to RCC roof slab	Load transferred to roof purlins or steel members	Load transferred from mounting structure → pedestal → footing → soil	Load transferred from structure → pile → deeper soil layers with high bearing capacity
Advantages	Strong mechanical connection; stable under	Prevents roof penetration; avoids water leakage; faster installation	Raises panels above ground; protects from water and soil	Very high load-bearing capacity; resistant to wind uplift; suitable

	wind; suitable for sloped or flat roofs		moisture; stable for medium installations	for weak or soft soil
Limitations / Challenges	Requires drilling and waterproofing; roof must be structurally strong	Less rigid than anchor bolts under extreme wind; alignment with purlins critical	Requires construction of footing and pedestal; more material and time	Expensive; requires specialized machinery; time-consuming for small installations
Environmental Suitability	Moderate to high wind; flat or sloped concrete roofs	Metal roofs; industrial areas; moderate wind	Ground-mounted areas with good drainage; medium soil strength	Large farms; soft, marshy, or sandy soil; high wind areas; weak soil

2.3 Steps for Construction of Different Foundations in Solar PV Installations

1. Anchor Bolt Foundation - Rooftop RCC Solar PV System

The purpose is to provide a strong, stable mechanical connection between the solar panel mounting structure and the RCC rooftop. This ensures that the panels remain fixed under wind loads, vibrations, and environmental conditions.

1. Materials Required

Material	Specification	Purpose
Steel Anchor Bolts	M12-M16, length 8-12 inches (depending on roof slab thickness)	To connect the mounting structure to the roof
Chemical Anchor / Epoxy	High-strength epoxy (load-bearing)	To fix anchor bolts in drilled holes
Nuts and Washers	Suitable to bolt size (M12–M16)	To secure the mounting base plate
Cement, Sand, Aggregate	M20 grade concrete (1:1.5:3) for grouting if needed	For minor grouting around bolts
Waterproof Sealant	Silicone or polyurethane-based	To seal drilled holes and prevent leakage
Tools	Rotary hammer drill, spirit level, wrench, measuring tape	For drilling, alignment, and fixing

2. Specifications

- **RCC Slab Thickness**: Minimum 120 mm for residential, 150-200 mm for commercial.
- **Anchor Bolt Diameter**: M12-M16 depending on load.
- **Concrete Grade for Grouting**: M20.
- **Bolt Length**: 8-12 inches (ensures proper embedment into slab).
- **Spacing**: According to mounting base plate design, usually 600-900 mm between bolts.
- **Tilt Angle of Panels**: Typically, 10°-30° depending on location (used for marking bolt positions).

3. Step-by-Step Construction Procedure (Refer Figure 2.4)

Step 1: Site Inspection

- Verify roof slab thickness and structural integrity.
- Ensure the roof can support weight of panels + mounting structure + live loads.
- Check for existing rooftop utilities (water tanks, AC ducts) to avoid obstruction.

Step 2: Layout and Marking

- Draw panel layout on roof using chalk or marker.
- Identify positions of mounting base plates.
- Mark exact bolt locations on roof according to mounting frame holes.
- Use a measuring tape to ensure parallel alignment and consistent tilt.

Step 3: Drilling Holes

- Use rotary hammer drill to drill holes into RCC slab.
- Hole Diameter: ~2 mm larger than bolt diameter (e.g., M16 bolt → 18 mm hole).
- Hole Depth: At least 1.5× the bolt length to ensure full embedment.
- Clean holes using a blow pump or compressed air to remove dust.

Step 4: Anchor Bolt Fixing

- Inject chemical anchor / epoxy resin into each hole.
- Insert steel anchor bolt while maintaining vertical alignment.
- Let the epoxy cure as per manufacturer instructions (usually 24 hours).
- For minor grouting, pour M20 concrete around bolt base and allow 7 days curing.

Step 5: Mounting Structure Base Plate Installation

- Place mounting structure base plate over anchor bolts.
- Secure with nuts and washers.
- Use a spirit level to ensure base plate is perfectly horizontal.
- Tighten nuts gradually in a criss-cross pattern to maintain even pressure.

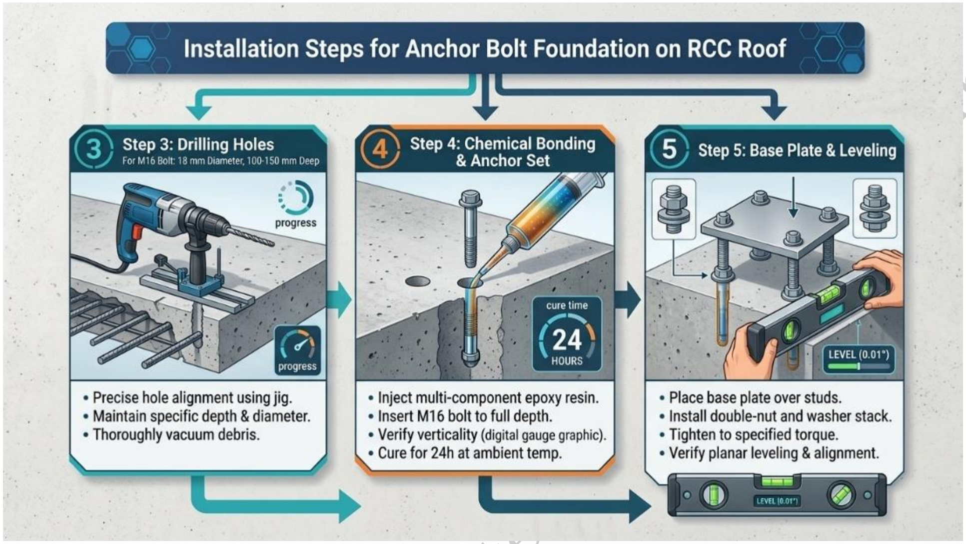


Figure 2.4: Installation steps of Mounting Structure

Step 6: Waterproofing

- Put silicone or waterproof glue around the bolts to stop rainwater from leaking through.
- Check for any gaps between base plate and roof.
- Let sealant cure for 24 hours before panel installation.

Step 7: Panel Mounting

- Attach mounting frame to base plates using the fixed anchor bolts.
- Align frame to correct tilt angle and azimuth.
- Ensure rows are parallel and level for optimal panel efficiency.

4. Technical Tips & Safety

- **Roof Load Check:** Calculate the load applied over the roof per square meter. The panels and frame cumulatively add 15-25 kg/m^2.
- **Bolt Alignment**: Check the alignment of the bolt using spirit level. The misaligned bolts may cause tilting of the frame.

- **Wind Load Considerations:** Based on the wind pressure at site, the size and embedment depth of the anchor bolts are selected.
  .

Now let us Let us consider an example of a small rooftop system with 4 panels in a row for simplicity.

Given parameters and Assumptions

- RCC Roof slab thickness: 150 mm (0.15 m)
- Panel size: 1.6 m × 1 m
- Number of panels: 4 (in a row)
- Mounting frame needs 4 anchor bolts for individual base plate
- Total base plates: 2 (one at each end of the panel row)
- Anchor bolt size: M16, 100 mm embedment
- Grouting around bolt: When you fill the hole around the bolt, you are creating a small, solid cylinder of grout. For a 16 mm bolt, you drill a hole that is 150 mm deep and 40 mm wide. This extra space (the 40 mm diameter) ensures there is enough room for the grout to completely surround the bolt and grip the roof slab tightly.

Step 1: Calculating the Number of Anchor Bolts required

4 anchor bolts per base plate × 2 base plates = **8 anchor bolts**

Step 2: Volume of Grouting per Bolt

Grouting (**cylinder around bolt)**

Formula: $V = \pi \times r^2 \times h$

Diameter of grouting cylinder = 40 mm → radius r = 20 mm = 0.02 m

Height h = 0.15 m

$$V = \pi \times (0.02)^2 \times 0.15$$

Volume per bolt = 0.0001885 m^3

Total for 8 bolts: 0.0001885 × 8 ≈ **0.00151 m^3** (~1.5 liters)

Note: Since, it's very small amount and hence, minor grouting does not require much concrete/epoxy.

Step 3: Approximate Load Check per Bolt

Assume the following:

- Wind, panel and frame load = 20 kg per bolt

- Concrete compressive strength (grouting) = M20 → 20 N/mm^2
- Bolt and epoxy strength > 2000 N, which is safe for small rooftop panels

Step 4: Spacing

- For two base plates for 4 panels:
- The distance between the base plates is equal to the length of the 4 panels (~6.4 m)
- The Bolt spacing within the base plate is around ~300 mm to ensure the stability

Parameter	Value
Number of bolts	8 (4 per base plate × 2 plates)
Bolt spacing	300 mm within plate, 6.4 m between plates
Grouting volume per bolt	0.0001885 m^3 (~0.19 liters)
Total grouting volume	0.00151 m^3 (~1.5 liters)
Concrete grade	M20
Load per bolt	20 kg (simplified)

This calculation helps students understand exactly how much material and spacing they need for roof anchor bolts, including the amount of grout required.

2.3.2 Clamp-Based / Roof Anchor Foundation (Metal Roofs)

In this foundation, special metal clamps are fixed directly onto the folds or ridges of the metal roof sheet as shown in Figure 2.5. These clamps hold the mounting rails of the solar panels firmly without drilling holes into the roof. The clamps are designed to distribute the load evenly on the roof sheet and prevent damage to the roofing material.

a. Materials Required

Material	Specification	Purpose
Aluminium / Stainless Steel Roof Clamp	Compatible with standing seam or trapezoidal roof	To attach mounting structure
Mounting Rail	Aluminium rail (typically 40–50 mm height)	Supports solar panels
Stainless Steel Bolts	M8 or M10 SS bolts with nuts and washers	Fastening components
EPDM Rubber Pad / Gasket	3–5 mm thick	Prevents water leakage and protects sheet

Rail Connector	Aluminium connector plate	Joining two rails
End Clamp / Mid Clamp	Aluminium clamp	Fixing solar panels
Anti-corrosion coating	Zinc / galvanised	Prevents rust

b. Typical Design Specifications

Parameter	Typical Value
Clamp spacing	1 – 1.5 m
Rail spacing	1.2 – 1.5 m
Bolt size	M8 or M10
Minimum roof thickness	0.45 – 0.6 mm metal sheet
Clamp tightening torque	15 – 20 Nm
Material of clamps	Aluminium / SS304

c. Step-by-Step Construction Procedure

Step 1: Roof Survey and Marking

The installer first inspects the metal roof sheet and supporting purlins.

- Identify roof type (standing seam / trapezoidal).
- Check sheet thickness and structural condition.
- Measure the available installation area.
- Mark positions where clamps will be installed.

Typical marking spacing:

Clamp spacing = 1.2 m

Example: If mounting rail length = 6 m

Number of clamps required

$$Number\ of\ clamps = \frac{Rail\ Length}{Clamp\ Spcaing} = \frac{6}{1.2} = 5$$

Therefore 5 clamps are required per rail.

Step 2: Placement of Roof Clamps

Roof clamps are placed on the raised seam or rib of the metal sheet.

Installation procedure:

1. Position clamp on the seam.

2. Ensure clamp base sits properly on metal rib.
3. Insert EPDM rubber pad between clamp and roof sheet.
4. Insert tightening bolts.

Specification:
Clamp material: Aluminium / SS304
Bolt size: M8 stainless steel bolt

The rubber pad prevents from water leakage; sheet damage and galvanic corrosion.

Step 3: Tightening of Clamp Bolts

The installer tightens the clamp bolts using a torque wrench.

Recommended tightening torque: **15 – 20 Nm**

This ensures clamp grips the seam firmly and roof sheet is not deformed

Inspection checklist

- Clamp should not move.
- No deformation of metal sheet.
- Rubber pad should remain intact.

Step 4: Installation of Mounting Rails

Once clamps are installed, **aluminium mounting rails** are attached to the clamps.

Procedure:
1. Place rail on top of clamps.
2. Align rail along the panel row direction.
3. Fix rail using M8 bolt and washer.
4. Tighten bolts properly.

Rail specification:

Height: 40 – 50 mm aluminium rail
Material: Anodized aluminium

Rail alignment is checked using measuring tape and spirit level

Step 5: Joining Rails

For large installations, rails are connected using rail connectors.

Procedure:
- Insert connector inside two rail sections.

- Align both rails.
- Fix with M8 bolts.
- Tighten evenly.

Specification:
Connector overlap length ≈ **200 mm**
This ensures structural continuity of rails.

Step 6: Final Structural Inspection

After rail installation, the installer performs inspection.

Inspection points:

- Clamp spacing maintained
- Rails are straight and level
- Bolts are properly tightened
- No damage to roof sheet

Example:

Let us go through an example of Clamp-Based / Roof Anchor Foundation

Material Calculation

For a 6 m rail supporting 4 solar panels

Clamp spacing = 1.2 m

Number of clamps required: $\frac{6}{1.2} = 5\ clamps$

If system has 4 rails:

Total clamps required: $5 \times 4 = 20\ clamps$

Bolts required:

Each clamp uses **2 bolts:** $20 \times 2 = 40\ bolts$

Summary of Installation

Component	***Quantity Example***
Mounting rails	4
Roof clamps	20

Stainless steel bolts	40
Rail connectors	2
Rubber pads	20

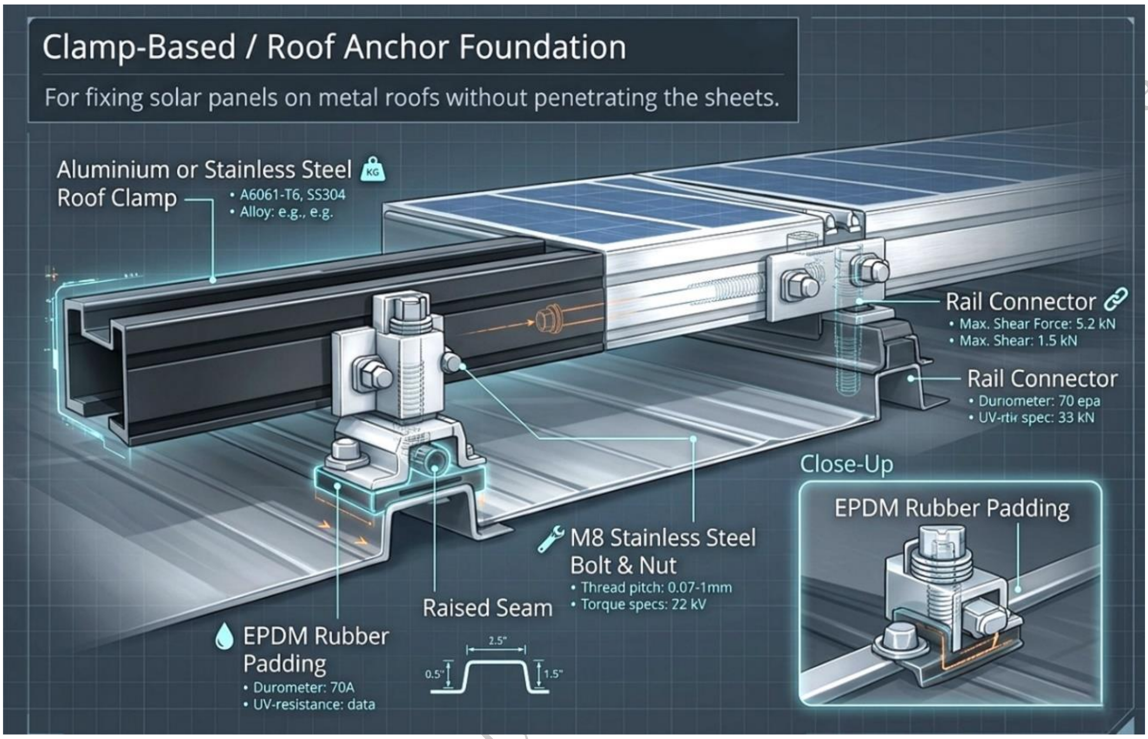


Figure 2.5: Fixing Solar panels on metal roofs without penetrating the sheets (Clamp based/ Roof Anchor Foundation)

2.3.3 Pile Foundation in Solar Panel Installation

Pile foundations are used in ground-mounted solar PV plants where the soil near the surface is weak or loose. Steel piles are driven deep into the ground to transfer the load of the solar structure to stronger soil layers below. This provides high stability against wind loads and structural movement.

Materials Required

Material	Specification	Purpose
Steel Piles	Galvanized steel, 100-150 mm diameter	Main structural support
Mounting Posts	Galvanized steel C-channel or I-section	Supports solar mounting frame
Bolts and Nuts	M12 / M16 galvanized steel	Fastening components

Hydraulic Pile Driver	Machine equipment	Driving piles into ground
Levelling Tools	Spirit level, measuring tape	Alignment of piles
Anti-corrosion coating	Galvanized coating (≥80 micron)	Protection against rust

Typical Design Specifications

Parameter	**Typical Value**
Pile depth	1.5 – 3 m
Pile diameter	100 – 150 mm
Spacing between piles	2 – 3 m
Material	Hot-dip galvanized steel
Minimum embedment depth	1.5 m
Wind load resistance	Designed according to site conditions

Step-by-Step Construction Procedure

Step 1: Site Survey and Soil Inspection

Before installation, the installer inspects the ground condition.

Activities performed:

- Measure installation area.
- Check soil type (sand, clay, gravel).
- Mark the locations where piles will be installed.
- Ensure correct spacing between piles.

Example spacing:

Pile spacing = **2.5 m**

If row length = **25 m**

$$Number\ of\ pile = \frac{Row\ length}{Pile\ Spacing}$$

$$N = \frac{25}{2.5} = 10$$

Therefore, 10 piles are required in one row.

Step 2: Marking Pile Locations

The installer marks the ground using measuring tape and chalk or paint.

Tasks performed:

- Maintain straight alignment of piles.
- Maintain equal spacing between piles.
- Check layout using a string line.

This ensures the solar mounting structure will remain perfectly aligned.

Step 3: Driving Steel Piles into the Ground

Steel piles are inserted into the soil using a hydraulic pile driving machine.

Procedure:

1. Place pile vertically at marked location.
2. Position the pile driver machine.
3. Drive the pile slowly into the ground.
4. Continue driving until required depth is achieved.

Specification:

Pile depth = 1.5 – 3 m

Depth depends on soil strength; wind load and structure height.

Step 4: Checking Vertical Alignment

After driving the pile, its vertical position is checked.

Tools used:

- Spirit level
- Laser level
- Measuring rod

If the pile is tilted, it must be corrected before continuing installation.

Step 5: Cutting and Levelling Piles

After installation, piles may extend unevenly above ground.

Procedure:

1. Measure required pile height above ground.
2. Cut excess portion using cutting machine.
3. Ensure all piles are at the same level.

Typical exposed height: 0.8 – 1.2 m above ground

Step 6: Installing Mounting Posts

Mounting posts or brackets are attached to the top of the piles.

Procedure:

1. Place mounting bracket on pile top.
2. Insert M12 or M16 bolts.
3. Tighten bolts securely.
4. Attach mounting rails.

This structure will support solar panels and maintain tilt angle.

Example Material Calculation

For a **solar row length = 30 m**

Pile spacing = **3 m**

$Number\ of\ piles = \frac{30}{3}$ = 10 piles

If there are **8 rows**

Total piles required:

$$10 \times 8 = 80\ piles$$

2.4 Understanding the basics of Single Line Diagram

Imagine a solar installer reaching a building where a 10-kW rooftop solar plant is to be installed. The installer needs to know, *Where the solar panels will be placed? How the wires will connect? Where the inverter will be installed? How electricity will reach the main distribution board?*

Without a proper plan, installation can become unsafe and confusing. Therefore, the engineers and installers use two important diagrams:

1. ***Single Line Diagram (SLD)*** – shows how electrical components are connected.
2. ***Layout Diagram*** – shows where the equipment is placed on the roof or ground.

SLD and layout diagrams enables the installers to understand the PV system before commencement of the actual installation process (Figure 2.6).

By looking at this diagram, the installer knows exactly where to put the solar panels, stands, walkways, and inverters. It helps them prepare the site, mark the right spots, and leave enough space between rows to avoid shadows and keep enough room for repairs.

Understanding Single Line Diagrams (SLD)

SLD is a simplified electrical drawing that represents an entire electrical system using single lines and standard symbols.

Instead of drawing every wire separately, the diagram uses one line to represent a group of conductors. This makes the electrical system easy to understand and analyse.

Components Shown in a Solar PV SLD

A typical solar PV SLD includes the following components.

1. Solar PV Modules: These are the panels that convert sunlight into DC electricity. In SLD they are usually shown as a PV array block.

Example:
A school rooftop installation may contain **20 panels of 550 W each** to produce about **11 kW power**.

2. DC Combiner Box: When several panel strings are connected, their DC output is combined in a DC combiner box.

It also contains DC fuses and Surge protection devices. The main purpose is to protect the system and combine power from multiple strings.

3. Solar Inverter: The inverter converts DC electricity from panels into AC electricity used in homes and buildings.

Example:
Rooftop solar plant → 5 kW inverter
School building plant → 10–20 kW inverter

4. AC Distribution Board (ACDB): After conversion, electricity passes through the AC Distribution Board.

5. Net Meter / Utility Grid: In grid-connected systems, excess electricity is sent to the electricity grid through a net meter.

Example: A house consumes 6 units of electricity but solar produces 8 units.
The extra 2 units are exported to the grid.

Importance of Single Line Diagrams

SLDs are important because they help:

1. Engineers design the electrical system

2. Installers understand wiring connections
3. Technicians troubleshoot faults
4. Inspectors check safety compliance

Hence, Without SLD, it becomes difficult to install or maintain solar systems correctly.

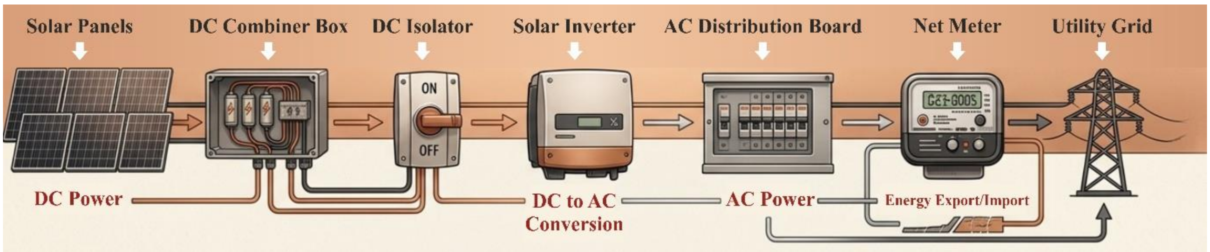


Figure 2.6: Single Line Diagram (Solar PV System)

2.5 Quality Control and Inspection in Solar PV Civil Installation

2.5.1 Quality Control and Inspection in Foundation

Quality control begins even before the construction of the foundation. The solar PV installer (civil) first studies the site layout diagram and structural design prepared during the planning stage.

The solar installer checks the soil, how much the roof or ground slopes, and where the water flows. For ground-mounted plants, the soil must be strong enough to hold the concrete base. If the soil is loose or weak, the foundation needs to be deeper or made stronger with extra support.

Once the site is checked, the next step is to mark the exact spots where the foundations will be built. These marks follow the layout diagram to make sure the stands are spaced correctly. Good spacing is important so that the panels don't cast shadows on each other and workers have enough room to move around for maintenance and repairs (Refer Table 2.2).

> ***For example***, Solar foundations usually use M20 grade concrete to make them strong. After pouring the concrete into the pits, the installer must pack it down well and water it (curing) regularly. If curing is not done right, the concrete can get cracks and become weak.

Once the concrete is hard, the installer checks that the anchor bolts are straight and at the right level. These bolts must be perfect so the metal frame doesn't tilt. Finally, the surface is checked to make sure it is smooth and solid. This process ensures that the structure will stays strong for the entire 20 to 25-year life of the solar PV system.

Table 2.2: *Foundation Quality Control Checklist*

Inspection Item	What to Check	Inspection Method	Expected Condition
Site location	Correct marking of foundation points	Layout verification	Matches design layout
Excavation depth	Width and Depth of the pit	Measuring tape	As per design specification
Concrete quality	Cement, sand, and aggregate ratio	Material inspection	Proper mix ratio
Anchor bolt placement	Positioning and alignment	Visual and level check	Correctly spaced and must be straight
Surface finishing	Surface condition of Concrete	Visual inspection	Crack-free and smooth
Concrete curing	Moist curing period	Observation	Maintain minimum curing period

2.5.2 Checklist for inspecting Mounting Structures

Once the foundations are ready, the next step is to set up and check the solar mounting structure. This structure holds the panels at the right angle and keeps them steady against wind, rain, and heat. It is very important to inspect the structure carefully before the solar panels are fixed onto it.

The solar installer first checks if the mounting structures match the layout diagram and design. The stands must be perfectly straight, and the tilt angle must be exactly what was planned. If the angle is wrong or the rows are crooked, the panels won't get enough sunlight, and the system will produce less power.

The installer also checks the materials, which are usually galvanized steel or aluminium. These are used because they are strong and do not rust easily. The special coating (galvanization) protects the metal from rain and moisture.

Another important step is checking that all bolts and fasteners are tight. Loose bolts can make the frame shake (vibrate) or become unstable when it is windy. The installer makes sure every nut, bolt, and clamp are fixed tightly.

Finally, the structure must be checked for proper grounding and safety. Grounding protects the system from lightning and electrical problems. The installer also doublechecks that there is enough space between rows so that one row doesn't cast a shadow on the other behind it (Table 2.3).

Table 2.3: *Mounting Structure Inspection Checklist*

Inspection Item	What to Check	Inspection Method	Expected Condition
Structural alignment	Straightness of the mounting frames	Visual	Frames properly aligned
Tilt angle	Angle of the panel support structure	Angle measuring tool	As per design specifications
Bolt tightening	Fasteners and Nuts	Manual tightening check	Securely fastened
Material condition	Surface coating and galvanisation	Visual	No damage or corrosion
Structural stability	Rigidity of the frame	Physical stability test	No vibration or play
Spacing between rows	Distance between mounting frames	Measuring tape	As per design and layout

2.5.3 Mounting Structure Field Evaluation Checklist

In solar PV installation projects, the mounting structures are checked on-site after they are set up but before the solar panels are attached. This inspection makes sure that the structure is steady and in the right position to hold the panels. It also confirms that the work follows all standards pertaining to engineering design and safety.

During this check, the inspectors look at whether the stands are straight, if the bolts are tight, and if the tilt angle is correct. They also measure the distance between rows and check if the grounding and safety parts are properly installed. Doing this evaluation carefully ensures that the installed solar system works efficiently safely for many years (Table 2.4).

Table 2.4: *Mounting Structure Field Evaluation Inspection Checklist*

Inspection Item	Observation	Inspection Method Used	Desired Outcome
Structure alignment	Position of mounting frame rows	Visual	Straight and uniform
Bolt security	Tightness of the clamps and bolts	Tool identification and inspection	Properly tightened

Tilt orientation	Panel inclination angle	Measurement of angle	As per design
Row spacing	Distance between structures	Measuring tape	Adequate spacing
Grounding connection	Earthing of structure	Electrical continuity test	Proper grounding

2.6 Cost Analysis and Economic Models in Solar PV Installation

2.6.1 Installation of a Solar PV System for a Particular Load

Before setting up a solar PV system, it is important to calculate the total cost of setting up the system. This cost analysis helps to decide if solar power is economically beneficial or not. For a solar PV installer (civil), it helps to figure out the budget for foundations, metal stands, labour, and cleaning up the site.

The total cost of the solar PV system depends on the size of the system, whether it is on a roof or the ground, and the quality of the materials. Larger systems need more panels and bigger frames, which makes them more expensive. Along with the equipment, there are costs for civil work like building the concrete base, setting up the frames, and paying the workers.

For a civil installer, these tasks are a big contributor in the budget plan. Even though the panels and inverters are expensive, the civil work is what keeps the system safe and strong for many years.

A good cost analysis also looks at maintenance. Since solar systems last for 20 to 25 years, you must also plan for the cost of regular cleaning and checking the parts to make sure that they keep on working well during their life span (Table 2.5).

Table 2.5: *Mounting Structure Field Evaluation Inspection Checklist*

Component	Description	Contribution to Total Cost
Solar Panels	Convert sunlight into electricity	35-40%
Inverter	Converts Direct current to Alternating Current for household use	15-20%
Mounting Structure	Metal frames that hold solar panels at the required tilt	10-15%
Civil Works	Foundations, structural supports, roof preparation	8-12%
Electrical Wiring & Protection	Cables, DC/AC distribution boxes, earthing	8-10%
Installation Labour	Skilled and unskilled labour for installation	5-8%
Miscellaneous Costs	Transportation, permits, inspection	3-5%

Note: *From the above distribution, it is clear that civil works and mounting structure installation form an important part of the project cost. For the solar PV installer (civil), careful planning of material usage, efficient labour management, and proper structural design can significantly reduce the overall project cost while maintaining safety and durability.*

Case Study

A 3-kW solar power plant is a very popular choice for residential homes in India. It can produce about 12 to 15 units of electricity every day, depending on the availability of the sun light. This amount of power is usually enough to run most of the lights and fans in an average house.

The total cost for a 3-kW plant includes the price of the panels, the inverter, the metal stands, wiring, and the money paid for civil work and labour. The price can change based on where you live, the brand of materials you choose, and how difficult it is to install the system on your roof.

Let us estimate the cost for a 3 kW Rooftop Solar powered System

Component	Approximate Cost (₹)
Solar Panels (3 kW capacity)	75,000 - 90,000

Solar Inverter	30,000 - 40,000
Mounting Structure	15,000 - 20,000
Civil Installation Work	10,000 - 15,000
Electrical Wiring and Accessories	10,000 - 15,000
Installation Labour	8,000 - 12,000
Miscellaneous Costs	5,000 - 8,000

Estimated Total Cost:
Approximately **₹1,50,000 – ₹2,00,000**

Government of India provide subsidies to the residential installations, which may further reduce the cost for residential users.

Civil Activity	Description	Estimated Cost Range
Roof inspection and marking	Checking roof strength and layout marking	₹1,000 - ₹2,000
Mounting structure installation	Fixing frames and alignment	₹5,000 - ₹8,000
Anchor bolt fixing	Securing structures to roof	₹2,000 - ₹3,000
Structural levelling and alignment	Ensuring proper tilt angle	₹2,000 - ₹3,000

Note: For civil engineering works, these activities are crucial as inappropriate structural installations may reduce the efficiency of the solar powered systems.

Economic Benefits: A typical 3 kW solar powered system produces around 4,500 to 5,000 units of electricity annually.

If the electricity cost is approximately **₹7 per unit**, the annual savings can be estimated as:

$$\text{Annual savings } (\textbf{₹}) = 5000 \times 7 \approx \textbf{₹35,000}$$

The payback period for this system is about 4 to 5 years. After this time, the electricity it produces is basically free for the rest of the system's life. This financial benefit makes solar power a great choice for homes, schools, and small commercial shops and buildings.

2.7 New Business Models in Solar PV Installation (CAPEX/OPEX, RESCO)

The rise of solar energy in India has brought about new ways to pay for and run solar PV systems. These business models help lower the starting cost for customers, making it much easier for more people to switch to solar power.

2.7.1 CAPEX Model (Capital Expenditure Model)

In the CAPEX model, the consumer pays the entire cost of the solar PV installation. The solar plant becomes the property of the consumer, who is responsible for its maintenance and operation.

Key characteristics:

Feature	Description
Ownership	System owned by the consumer
Initial Investment	Paid by consumer
Electricity Cost	Free after installation
Maintenance	Consumer responsibility

***Note**: This model is common for **residential rooftop solar systems**.*

2.7.2 OPEX Model (Operational Expenditure Model)

In the OPEX model, the consumer does not pay the full installation cost. Instead, a developer installs the solar plant and the consumer pays only for the electricity generated.

Key characteristics:

Feature	Description
Ownership	System owned by developer
Initial Investment	Paid by developer
Payment	Consumer pays per unit of electricity
Maintenance	Developer responsibility

Note:** This model is common for **commercial and industrial buildings where large solar plants are installed.

2.7.3 RESCO Model (Renewable Energy Service Company)

Under the RESCO model, a third-party company installs, owns, and operates the solar power plant on the consumer's rooftop or land. The consumer simply purchases electricity generated by the system at a predetermined rate.

Feature	**Description**
Investment	Made by RESCO developer
Ownership	Developer owns the plant
Consumer Role	Pays only for electricity used
Maintenance	Managed by developer

*Note: This model is widely used for **large rooftop solar installations in schools, hospitals, and industries.***

Activity: Estimating Energy Generation of the Solar Plant

The school installed a 3-kW rooftop solar PV system. Assume that the system receives 5 hours of effective sunlight per day. Students should calculate the approximate electricity generation of the system.

Parameter	Value
Solar system capacity	3 kW
Average sunlight hours	5 hours/day

Tasks:

1. Calculate the daily electricity generation of the system.
2. Estimate the electricity generated in one year.
3. Compare this generation with the electricity consumption of a typical classroom building.

Activity: Cost Distribution Analysis

The total installation cost of the solar system is approximately ₹1.7 lakh. You should estimate the cost distribution of different components of the solar PV system.

Component	Estimated Percentage of Cost
Solar panels	35-40%
Inverter	15-20%
Mounting structures	10-15%
Civil installation work	8-12%
Electrical accessories and wiring	10-12%
Labour and miscellaneous expenses	Remaining cost

You should calculate the approximate cost of each component based on the total project cost. Also, discuss which component contributes the highest cost in the solar installation.

Activity: Identifying the Role of Solar PV Installer (Civil)

Students should carefully analyse the installation process and identify the responsibilities of the Solar PV Installer (Civil) involved in this project.

Identify and enlist:

1. Observe the installation stages of a rooftop solar PV system.
2. Identify the activities that are related to civil work.
3. Explain why proper mounting structure installation and alignment are important for solar energy generation.

Activity: To perform a practical rooftop survey and basic civil installation planning for a 3-kW solar PV system as a Solar PV Installer (Civil).

Materials required:

Tool/Material	Use
Measuring tape	Measure roof
Chalk / Marker	Mark layout
Smartphone compass	Find direction
Scale drawing sheet	Layout planning
Wooden blocks	Model mounting

bolts	Represent anchor bolts

Procedure:

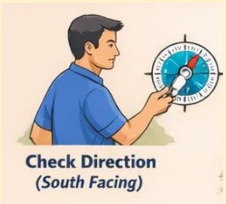
Step 1: Measure the Roof and write the value in your notebook.

- Measure length and width of rooftop.
- Calculate area:
- Area = Length × Width

Step 2: Identify Usable Area

- Identify and Mark all the obstacles such as Water tank, Staircase, AC units etc.
- Subtract unusable area from the total area.

Note: Kindly ensure that the Final usable area should be ~30 m^2 for 3 kW.



Step 3: Direction Check

- Use mobile compass or any normal compass.
- Identify South direction.
- Kindly mark direction arrow on roof using chalk.

Step 4: Marking of the Layout

- Using chalk, draw the panel positions on the roof.
- Assume each panel to be equal to 2 m^2
- Arrange 6 such panels.

Kindly Note: There should be the Gap between panels and Walking path (~0.5 m)

Step 5: Mark Foundation points

- Mark points at equal distance (~2.5 m).
- Place sticks/pegs at these points.

Note: These represent the Concrete footing or the piles.

Step 6: Simulate Foundation

Option A (if digging allowed):

- Dig small demo pits

Option B:

- Draw pit shape on ground

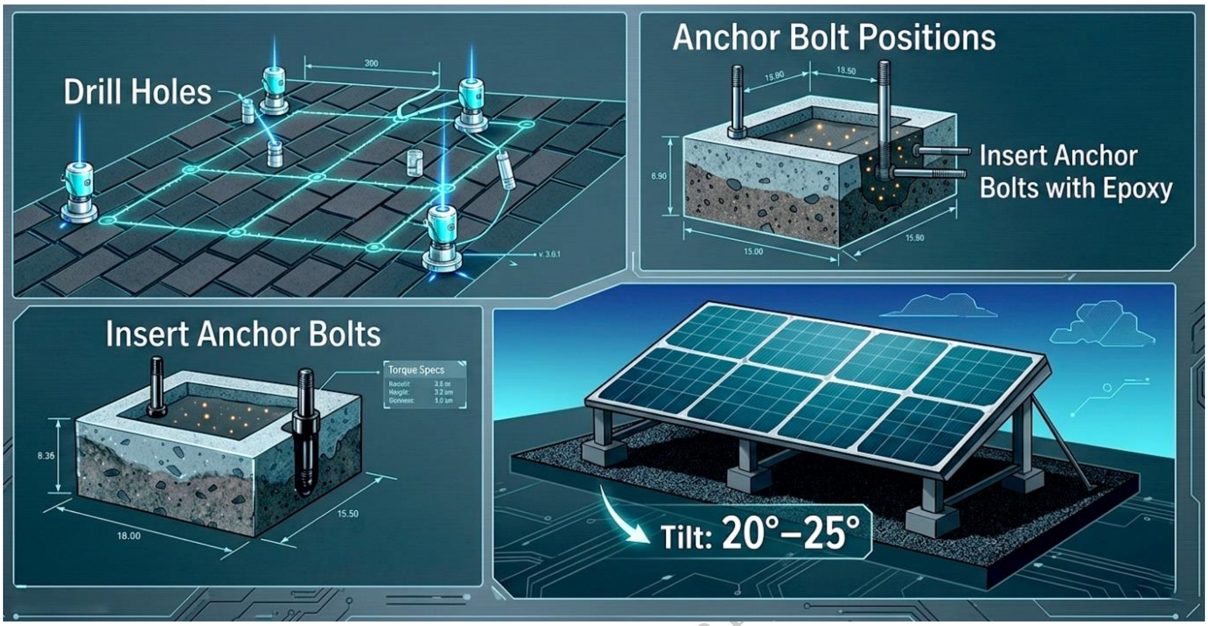
Step 6: Structure Alignment

- Connect pegs using rope.
- Check straight alignment.

This will ensure Proper panel placement and Stability

Step 7: Panel Direction & Tilt

- Mark South direction.
- Show tilt using stick model.



Activity: To study the role of a Solar PV Installer (Civil) in installing a 10-kW ground-mounted solar system, including land survey, foundation construction, and mounting structure.

Materials Required

S. No.	Material / Tool	Purpose
1	Measuring tape	Land measurement
2	Soil testing tools	Checking soil condition
3	Marking tools	Layout marking
4	Concrete (M20)	Foundation construction
5	Steel reinforcement	Strength of footing
6	Anchor bolts	Fixing structure
7	Mounting structure	Panel support
8	Excavation tools	Digging pits
9	Water level / spirit level	Alignment checking

Procedure

Step 1: Site Survey
- Visit open land.
- Precisely Check the availibility of Sunlight, No shading zone, Flat etc
- Ensure the accurate measurement of the area.

Step 2: Soil Inspection
Check soil type:
- Hard soil → suitable
- Loose soil → need deeper foundation
- Ensure stability.

Step 3: Layout Planning
- Mark rows of panels.
- Maintain the proper spacing (to avoid shadow).
- Plan the pathways for future maintenance.

Step 4: Foundation Construction (Concrete Footing)
a) Excavation
Dig pits (e.g., 600 mm × 600 mm × 600 mm).

b) Concrete Filling
- Pour M20 concrete.
- Insert anchor bolts in wet concrete.

c) Curing
Allow curing for 7–10 days.

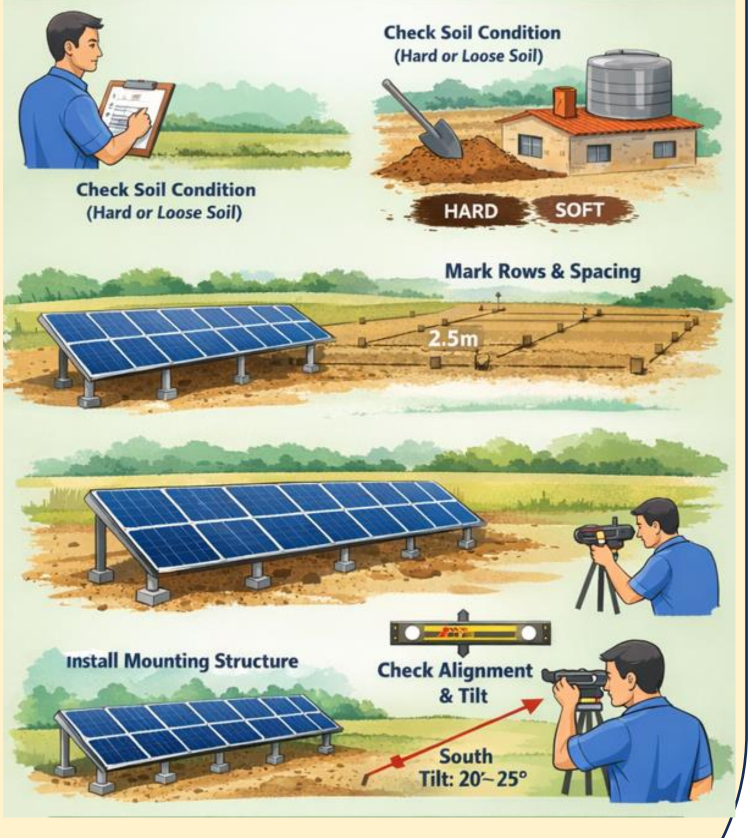
Step 5: Mounting Structure Installation
- Fix the structure on foundation using bolts.
- Maintain proper alignment.

Step 6: Structure Alignment
Kindly ensure
- Proper tilt (~20°–25°)
- Use level instruments.

Step 7: Final Arrangement
- Arrange panels in rows.
- Maintain spacing between rows.
- Provide walking space.

Observation Table

Fill the table below after carrying out the activity:



PARAMETER	OBSERVATION
LAND CONDITION	
SOIL TYPE	
SUNLIGHT AVAILABILITY	
AREA AVAILABLE	
SUITABILITY	

CHECK YOUR PROGRESS

A. Multiple Choice Questions

1. A solar installer needs to fix mounting structures on an RCC rooftop. The installer must apply a suitable foundation method that provides a strong mechanical connection with the concrete slab. Which method should the installer apply?

a) Isolated concrete footing
b) Pile foundation
c) Anchor bolt foundation
d) Wooden block support

2. A solar project is being installed on land where the soil near the surface is loose and cannot support heavy loads. Which foundation method should the installer use to ensure that the structure transfers the load to deeper strong soil layers?

a) Clamp-based roof mounting
b) Anchor bolt foundation
c) Pile foundation
d) Isolated concrete block placed on soil

3. During installation on a metal sheet roof, the installer wants to avoid drilling holes in the roofing sheet. Which mounting method should the installer apply to safely fix the solar panels?

a) Anchor bolt foundation
b) Clamp-based roof mounting system
c) Concrete pedestal foundation
d) Pile foundation

4. A mounting rail of 6 m length requires clamps to be installed at 1.2 m spacing. How many clamps should the installer calculate for one rail?

a) 3
b) 4
c) 5
d) 6

5. A solar installer is fixing 4 mounting rails, and each rail requires 5 clamps. Each clamp uses 2 bolts. How many bolts should the installer determine for the installation?

a) 20
b) 30
c) 40
d) 50

B. Short Answer Questions

1. A residential building has an RCC rooftop where solar panels are to be installed. Demonstrate how an installer would apply the anchor bolt foundation method to securely fix the mounting structure on the roof.

2. A ground-mounted solar plant is planned in an area with weak soil. Explain how the installer would apply pile foundation techniques to ensure the stability of the solar mounting structure.

3. A solar installer studies the layout diagram before installation. Illustrate how the installer can use the layout diagram to determine the correct placement of solar panels and mounting structures.

4. During inspection, an installer finds that the mounting structures are not aligned properly. Explain how the installer should apply inspection procedures to correct the alignment before installing panels.

5. A school installs a 3-kW solar PV system that receives 5 hours of effective sunlight daily. Calculate the approximate daily electricity generation of the system.

C. Long Answer Questions

1. A solar installer is planning to install a rooftop solar PV system on a school building. Apply your understanding of civil installation procedures to describe how the installer would plan and implement the anchor bolt foundation method from site inspection to final mounting structure installation.

2. A solar company is constructing a ground-mounted solar plant in an agricultural area. Demonstrate how the installer would apply appropriate foundation construction

methods, including site survey, marking of locations, installation of foundations, and alignment of mounting structures.

D. Case Study

A solar installation company is assigned to install solar panels at two different locations.

- **Location A:** A school building with a reinforced concrete rooftop (RCC).
- **Location B:** A large open land area where the surface soil is loose and sandy.

The installer must choose the right foundation method to make sure the panels stay steady for over 20 years. This ensures the structure can handle tough weather like strong winds and heavy rain without moving.

Now, attempt the following questions:

1. At Location A, analyse the site conditions (such as soil type, load requirements, and environmental factors) and determine the most appropriate type of foundation. Justify your choice with valid reasons.
2. Based on the given soil conditions at Location B, identify the most suitable foundation type and explain how it meets the structural and stability requirements.
3. Describe the step-by-step process an installer would follow to implement the selected foundation method, ensuring long-term stability and durability of the solar mounting structures.

Module 3	HEALTH AND SAFETY

Module Overview
This module covers the importance of safety rules while performing civil engineering work for solar PV installations. it explains why following safety norms is a mandatory requirement at solar PV installation sites. The module also describes the common hazards that may occur during solar PV civil installation and explains the use of Personal Protective Equipment (PPE) to reduce risks. Safe handling methods for tool and material handling and important safety aspects during foundation construction work is covered in detail. The students will also understand the appropriate use of ladders and scaffolds while working at heights. The contents covered in the module will help to prepare the students to deal with emergency situations by explaining basic response actions and safety procedures at the worksite.

Learning Outcomes

After completing this module, the students will be able to:

- Explain the importance of safety in solar PV civil works.
- Identify the benefits of proper safety management at installation sites.
- Describe common hazards in solar PV civil installation work.
- Use appropriate tools and safety kits related with solar PV installation work.
- Apply safe material handling practices during solar PV installation.
- Apply correct ladder and scaffold safety practices while working at heights.
- Apply appropriate actions during emergency situations at the worksite.

Module Structure

3.1 Importance of Safety in Solar PV Civil Works
3.2 Benefits of Proper Safety Management in Solar PV Installation
3.3 Common Hazards in Solar PV Civil Installation
3.4 Personal Protective Equipment (PPE)
3.5 Safe Material Handling for Solar PV Installers (Civil Work)
3.6 Safety Aspects during Foundation Construction in Solar Panel Work
3.7 Ladder and Scaffold Safety
3.8 Tool and Equipment Safety
3.9 Emergency Situations

Imagine a team installing solar panels on the roof of a school building during a windy day. The panels are large and heavy. The roof is sloped. Electrical cables run nearby. *What will happen if the workers do not follow safety rules?*

The solar PV installer may slip from the roof; A panel may fall and injure someone; the installer may encounter electrical shock; Improper lifting may cause back injury etc. These are some common hazards that can occur at a solar PV installation site at any time.

Solar PV installation is not only a technical job. But also, a safety-sensitive activity. Every installer must understand the health and safety practices before starting the work. Civil works in solar installation involve activities such as: Site preparation; Foundation construction; Structural mounting installation; Material handling; Working at heights; Drilling and cutting operations etc.

All these activities have possible hazards if not done with utmost precautions. Safety procedures help prevent accidents and ensure smooth project execution.

Health and safety practices help to:

- Protect workers and technicians from hazards
- Prevent damage to equipment
- Improve work efficiency
- Reduce project delays
- Ensure compliance with national safety standards

A professional solar PV installer must therefore develop safe working habits, awareness, and responsibility at the worksite.

3.1 Importance of Safety in Solar PV Civil Works

Civil works for solar PV installations involves several physical activities such as digging, lifting heavy structures, drilling concrete surfaces, and installing mounting systems at heights. Each activity presents different types of hazards *(discussed in section 3.3).* The possible hazards in civil work during solar PV installation process is detailed in Table 3.1.

Table 3.1: *Possible Hazards in Civil Works during Solar PV Installation*

Civil Activity	**Possible Hazard**
Excavation for foundation	Collapse of soil
Lifting solar modules	Muscle injury

Roof installation	Falling from height
Cutting metal structures	Sharp edge injury
Drilling concrete	Dust inhalation
Note: *If safety rules are ignored, even a small mistake can lead to serious accidents.*	

3.2 Benefits of Proper Safety Management in Solar PV Installation

Safety management plays a very important role in solar PV installation work. Solar installation sites involve working at heights, handling electrical equipment, lifting heavy solar panels, and using various tools and machines. If proper safety practices are not followed, accidents may occur that can harm workers and delay the project. Therefore, proper safety planning and management must always be followed at every solar installation site.

Proper observance of safety rules by all the parties involved will make the project and the workers successful. The key advantages of safety management include:

1. Prevent injuries

Safety management is primarily aimed at ensuring that workers are not involved in accidents. Placing solar panels can require standing on roofs, installing on high metal ladders and coming into contact with electrical wires. Unless the workers wear safety equipment such as helmets, safety belts (harnesses), gloves, and special tools, they will be exposed to the risk of being severely injured.

For example, when a solar panel installer is installing a panel on a roof, he/she may fall down. Using safety belts (harnesses) and shoes with a good grip can greatly reduce this risk. Similarly, insulated gloves can be used to shield workers against electric shocks when they are working with electrical wires.

2. Improves Work Efficiency

Employees will be able to perform their tasks significantly more efficiently and quickly when they feel safe and secure in the workplace. Proper safety management is to see that the tools are put in the correct usage, the materials are transported in a manner that is safe and also to have a clear and organized plan which is followed by everyone. This decreases the confusion and eliminates the errors, and the entire process of installation goes on smoothly.

As an example, when lifting solar panels, the workers are also trained to employ the correct techniques or special lifting devices. This will avoid physical stress and body damage and the installation will be able to move quicker without any unjustified delays.

Moreover, the solar PV installers do not necessarily have to spend time correcting mistakes and addressing the consequences of accidents when the rules are properly explained. Due to this, the general pace of work and its quality are enhanced.

3. Ensures Project Completion on Time

The accidents in one of the installation sites may lead to the whole project falling behind the schedule. When the solar PV installer is injured, the work is usually terminated as the incident is dealt with. In a similar manner, when equipment is broken or electrical faults arise then time is wasted on repair rather than improvements.

These interruptions are avoided by proper safety management. There is less likelihood of accidents when workers adhere to safe procedures and when the site is checked regularly by the supervisors. This makes sure that the project is on schedule and it is completed within the planned schedule.

4. Reduces Equipment Damage

Solar PV systems such as panels, inverters, and mounting systems are costly and delicate. They can be broken or cracked easily in case they are mishandled during transportation, when lifting them, or when installing them.

Safety management gives proper guidelines on how to handle such equipment. The employees are taught to handle solar panels with care, carry them to safe places, and never to load heavy materials on them. Properly used tools and installation methods also make sure that mounting frames and electrical connections are not damaged, safeguarding the investment in the whole.

5. Improves Overall Project Quality

Safety management doesn't just prevent accidents—it also leads to a higher-quality project. When workers follow the correct procedures and engineering standards, the installation is much more accurate and reliable.

To illustrate, it is necessary to provide safety at the working site to make sure that the installers and technicians are able to fit the solar panels, to install the mounting bolts correctly and to connect the electrical wires correctly. This subsequently enhances the operations of the solar PV system and its longevity.

An installed system works better and generates more electricity, with fewer repairs, and will work efficiently over a few years. Thus safety management enhances the quality and reliability of the solar power project indirectly.

Why Safety is Important?

Consider this practical example: A solar company was installing a 5-kW roof-mounted system in a School. The supervisor conducted a safety briefing to go over protocols before any tools were lifted. Each member of the crew had the necessary equipment, such as helmets, safety harness, gloves, and special non-slip shoes.

In the process, one of the workers lost his footing at the edge of the roof. But since his harness was securely attached to a stable anchor, a fatal fall was avoided. With these measures, a potentially life-threatening accident was averted altogether. The installation took the team only two days, and there were no injuries or damage to the solar hardware. This case clearly demonstrates that rigorous safety management isn't just a rule it's the key to keeping workers safe and keeping projects on track.

Activity: Identify Safety Measures at a Solar Installation Site

Procedure:

1. Imagine a team of solar PV installer is installing solar panels on the rooftop of a building.
2. Carefully observe or think about the activities happening at the site such as lifting panels, drilling holes, connecting wires, and working at heights.
3. Identify at least five possible hazards that may occur during installation.
4. For each hazard, suggest a safety measure that can prevent the accident.

Fill the Table below:

S. No.	Possible Hazard	Safety Measure
1.		
2.		
3.		
4.		
5.		

Discussion Question

How does following safety rules help both the workers and the solar company during installation projects

3.3 Common Hazards in Solar PV Civil Installation

Solar PV civil installation involves several site activities such as roof preparation, mounting structure installation, handling solar panels, drilling, lifting materials, and working at heights. During these activities, different types of hazards may occur.

A *hazard* is any situation or condition that has the potential to cause injury to workers or damage to equipment and materials. Identifying hazards in advance helps workers take preventive measures and perform their tasks safely.

Solar PV installation sites may contain different hazards depending on the type of installation such as rooftop systems, ground-mounted solar plants, or solar installations on commercial buildings. Understanding these hazards is an important responsibility of every solar PV installer.

Following are different types of the hazard that can probably occur at the installation site:

1. **Physical Hazards:** Physical hazards are the most common risks during solar PV installation work. These hazards are related to the working environment, tools, materials, and physical activities performed by workers.

Solar PV civil installers frequently handle metal mounting structures, solar panels, drilling machines, and construction tools. If these materials are handled improperly, they may cause injuries.

Common Physical Hazards

a) **Slippery Roof Surfaces:** Many rooftops have smooth surfaces made of tiles, metal sheets, or concrete. Dust, water, or algae can make the surface slippery. While moving across these surfaces or carrying bulky panels, it is easy for workers to lose their footing and slip. To minimize this risk, the crew must wear specialized non-slip safety footwear. Additionally, it is vital to check that the roof is clear of debris and completely dry before any work begins to ensure a stable walking surface.
b) **Uneven Ground Conditions:** On ground-mounted solar sites, the terrain is often rough, featuring loose gravel, hidden pits, or uneven ground. These hazards make it easy for solar PV installers to trip while transporting heavy equipment or

materials. To prevent such accidents, the site must be professionally levelled and cleared of all debris and obstacles before the installation phase begins.

c) **Falling Objects:** During solar PV installation, tools, bolts, or even panels may accidentally fall from the roof or mounting structures. These objects can seriously injure workers standing below. Workers should wear safety helmets, and work areas should be clearly marked to prevent people from standing under active installation zones.

d) **Sharp Metal Edges:** The frames for solar panels are typically built from steel channels, aluminium rails, and various brackets, all of which can have very sharp edges. When solar PV installers are moving or assembling these long metal pieces, it is incredibly easy to sustain deep cuts on the hands or fingers. To stay safe, workers must always wear heavy-duty protective gloves whenever they are handling these metal parts.

e) **Heavy Lifting:** With solar panels weighing between 18 kg to 25 kg, handling them incorrectly or repeatedly can lead to severe muscle fatigue and chronic back problems. To avoid physical injury, it is essential for the solar PV installers to practice smart lifting habits, such as bending at the knees rather than the waist to utilize leg strength. By keeping the panel tucked close to the body, workers can maintain better equilibrium and take the pressure off their spine. Furthermore, utilizing a two-person lift whenever possible ensures the weight is distributed evenly, making the process safer and more efficient for everyone involved.

Think & Answer

Imagine you are installing panels on a rooftop. The roof surface is dusty and slightly wet after light rain.

What safety measures should you take

2. Electrical Hazards

Although solar PV installers handling civil work mainly focus on structural installation, they often work close to electrical components such as solar panels, cables, and junction boxes. Solar panels produce electricity whenever they are exposed to sunlight. Even if the system is not connected to the grid, the panels may still generate voltage. Because of this, workers must remain careful while handling panels and cables.

Common Electrical Risks

a) **Contact with Live Electrical Wires**: During installation, some wires may already be connected to panels or electrical components. Accidentally touching bare or exposed wires may cause an electrical shock. The installers should avoid touching electrical terminals and must allow trained electrical technicians to perform wiring tasks.

b) **Improper Cable Handling**: Solar cables must be handled carefully during installation. Pulling cables roughly or bending them sharply can damage the internal conductor. This may later cause short circuits or system failures.

c) **Damaged Insulation**: If the insulation of a cable is damaged, the internal conductor may be exposed. This increases the risk of electrical shock. The installers should inspect cables before installation and replace any damaged wires immediately.

Real-Life Example

During a rooftop solar installation project, a worker accidentally placed a metal tool across the connectors of two solar panels exposed to sunlight. The panels generated voltage and created a small spark.

Although no one was injured, What the incident is

3. Working at Height Hazards

Many solar PV systems are installed on rooftops of houses, schools, offices, and industrial buildings. Working at heights is one of the most dangerous tasks in solar installation. Even a small ignorance or mistake, while working at certain height, may lead to serious injuries.

Causes of Height-Related Hazards

a) **Slippery Roof Surface:** The natural accumulation such as dust, moisture or moss on a roof can cause the surface to be extremely slick and greatly decreases traction. These places are particularly dangerous when installers attempt to move through them particularly when they are dragging heavy solar panels along with them. To ensure a safe rooftop environment, it is necessary to keep the workspace clean and pay attention to these environmental hazards.

b) **Strong Wind:** The solar panels due to their large surface area can practically become the sails in a strong wind. Powerful winds can blow the panels, and it becomes extremely hard to control and may push workers out of balance. The weather conditions should be observed to avoid accidents and when working with panels during a time of strong wind or unpredictable weather, it is important to avoid handling them.

c) **Poor Ladder Support:** The ladders can easily slip or fall over when not properly placed or stable. This instability poses a great danger to any person who is climbing as one can easily lose his or her footing and fall due to the abrupt change in position. In order to avoid this, the ladders must be put on a flat, stable surface at all times and tied or grasped at the top of the ladder to keep it stable throughout the process.

d) **Lack of Guardrails:** Fall hazard: Due to the absence of protective railings or barriers on the perimeter, many rooftops are susceptible to falls. When a worker is on the edge and the task at hand is hot, he or she may easily lose his or her location and step back or fall. Even a minor slip will cause a dangerous or fatal fall without a safety guardrail in place, and it is important to implement other safety measures such as using personal fall arrest systems.

Important Safety Measures

To prevent falls, workers must use:

- Safety harness and lifeline
- Strong ladders placed at proper angles
- Guardrails or temporary barriers

Let us imagine that you are inspecting a rooftop solar PV installation. One of the installers is carrying a solar panel near the roof edge without wearing a safety harness.

What instructions would you give the installer so that he/she ensures safe working condition?

4. Environmental Hazards

Solar installation teams are exposed to the elements when working outdoors and this can make a simple task to be a high-risk environment. Such conditions as changing weather, extreme temperatures, and accumulation of debris impose risks that do not exist in indoor construction. The workers should be vigilant enough and be ready to change their methods with reference to the following environmental hazards in order to stay safe:

Common Environmental Risks

S. No.	Environmental Condition	Possible Safety Risk
1.	High temperature	Heat exhaustion or dehydration
2.	Strong winds	Solar panels becoming unstable
3.	Rain	Slippery surfaces
4.	Dust	Breathing problems

a) **High Temperature:** Solar installation is basically an outdoor job and the installers are exposed to dozens of hours of direct sunlight. This continuous exposure to heat may cause physical exhaustion, dehydration or dangerous heat stroke in no time unless handled with care. To prevent such dangers, it is essential that workers consume a constant amount of water and have regular pauses in the shade to control the level of body heat. It is also possible to use proper protective clothing, including breathable, long-sleeved shirts and broad-brimmed hats to cover the skin against UV rays, as well as to avoid inadvertent burn of metal components that are hot to touch.

b) **Strong Winds:** Solar panels are also very vulnerable to wind since they have a larger surface area and it is like having a big sail in the process of installation. These panels may also become very hard to handle or install in high wind speeds, and may blow a solar PV installer off balance or the panel may be snared by a sudden gust. Due to this instability, it is of paramount importance to keep a watch on wind speeds at all times; when the conditions prove to be unsafe or unpredictable, then the installation work is to be stopped at any moment in order to avoid equipment damage or severe personal injury.

c) **Rain:** Rainfall presents various risks to a solar facility, and the main ones include making the rooftops, ladders, and surfaces highly dangerous due to slipping. In addition to physical risk of falling, moisture also plays a significant role in the possibility of electrical shorts or electrical shocks and it is highly dangerous to work with wiring and connectors. The wet conditions weaken both structural and electrical safety, so the installation should be abandoned immediately in heavy rain, and then, only in the case when all the surfaces and parts are dry.

d) Dust: Dust is one of the environmental hazards that may pose serious respiratory complications in large-scale solar plants or active construction sites. The sustained contact with such particles can lead to short-term discomfort in the breathing of the installation team or permanent irritation of the lungs in the long-term. To save their breathing health, workers should always use the right dust masks or respirators when they are working in dusty conditions so that they can freely breathe and still have the concentration to do the job at hand.

Activity: To identify the dangers and hazards at a solar PV installation site.

Instructions

1. Consider a team who is installing solar panels on a hostel rooftop.
2. Observe the following situations:
   - The installation team is carrying solar panels over the roof using a ladder.
   - The roof surface has loose dust.
   - Electrical cables are lying on the floor.
   - Strong wind is blowing.

Tasks:

1. Identify at least four hazards present in this situation.
2. Suggest one safety measure for each hazard.

S. No.	Hazard	Safety Measure
1.	***Example***: Dusty roof surface	Clean roof and use non-slip shoes
2.		
3.		
4.		

Note: Discuss your answers with classmates and compare the safety measures suggested.

The first step towards a professional and secure solar PV installation site is to be able to recognize and understand the possible hazards. Once the workers are trained to understand the risks at an early stage, they can become proactive rather than reactive and take preventive action to protect not only the installation crew but also the valuable equipment. Finally, a safety culture not only will prevent injuries, but also will improve the quality of work and make sure that solar projects are completed successfully and on time.

3.4 Personal Protective Equipment (PPE)

Personal Protective Equipment (PPE) can be defined as Special safety gear which workers wear to prevent injuries and accidents at the workplace at a site. In solar PV civil installation, workers perform activities such as lifting heavy panels, drilling, working on rooftops, and handling metal structures. These activities may expose them to various hazards.

PPE acts as the last line of defence as can be seen from Figure 3.1. This means that even if a hazard cannot be completely removed from the worksite, PPE helps reduce the chances of injury and protects the worker from serious harm.

For example, even if tools may accidentally fall from above, wearing a safety helmet can protect the worker's head from injury. Similarly, when handling sharp metal mounting structures, gloves protect the hands from cuts (Refer Table 3.2 for detailed purpose of PPE).

Figure 3.1: PPE Kit for Solar PV Installer (Civil)

Following are the various Personal Protective Equipment listed with its details:

1. **Safety Helmet:** A safety helmet, also known as a hard hat, protects the head from injuries caused by falling objects or accidental impact (Figure 3.2). Solar PV installation sites involve activities such as drilling, lifting metal mounting structures, and installing panels above ground level. During these activities, tools, bolts, or metal parts may accidentally fall.

   When Helmets Must Be Worn?

   Helmets should always be worn when:

   - Working on construction or installation sites
   - Installing mounting structures
   - Working below elevated work areas
   - Handling heavy equipment

Figure 3.2: Safety Helmet

2. **Safety Harness:** A safety harness, as shown in Figure 3.3, is a critical protective device specifically engineered for working at heights, designed to catch a worker before they can fall from a rooftop or elevated structure. The system consists of a harness worn securely around the body, which is then connected to a certified anchor point via a safety rope or lifeline. In the event of a slip or loss of balance, the harness arrests the fall, holding the solar PV installer safely in mid-air.

   Given that solar PV installations, especially rooftop systems, frequently require working at significant elevations, the risk is constant. Even a minor slip on a surface made slick by dust or moisture can escalate into a life-threatening accident without this equipment. Therefore, the consistent and correct use of a safety harness is not just a precaution; it is a fundamental requirement for ensuring every worker returns home safely at the end of the day.

   Importance of Safety Harness

   - Prevents fatal falls from rooftops
   - Provides support when working near roof edges
   - Increases worker confidence and stability

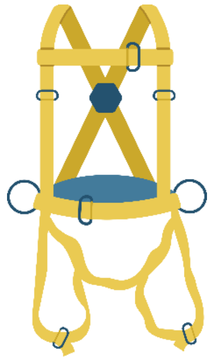


Figure 3.3: Safety Harness

3. **Safety Gloves:** Safety gloves are an indispensable piece of protective gear, shielding hands from the sharp metal edges, hot surfaces, and potential chemical exposure common on job sites (Figure 3.4). Because solar mounting structures are typically constructed from galvanized steel, their edges can be razor-sharp and prone to causing deep lacerations during handling. By wearing durable, high-grip gloves, workers significantly reduce the risk of cuts and punctures while also gaining a layer of insulation against components that have been heated by the sun.

Figure 3.4: Safety Gloves

Types of Gloves

- Cotton gloves for light work
- Rubber gloves for electrical safety
- Leather gloves for heavy-duty work

When to Use Safety Gloves?

While lifting panels or metal structures

- During drilling and cutting work
- While handling tools.

4. **Safety Shoes:** These are specially designed shoes or footwear that protects the feet from injuries caused by heavy materials, sharp objects, or slippery surfaces (Figure 3.5). The solar PV installation generally involves handling heavy panels and metal structures. If a panel falls on the foot, it may cause severe injury. Safety shoes prevent such accidents.

When to Use Safety Shoes?

- During material handling
- While working on rooftops
- During foundation and excavation work

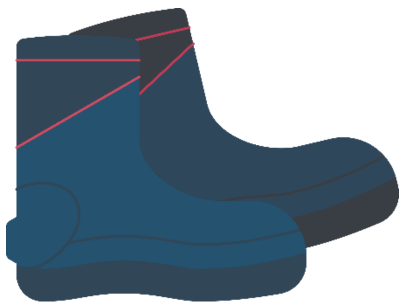


Figure 3.5: Safety Shoes

5. **Safety Goggles:** The safety goggles (Figure 3.6) protect the eyes from dust, debris, and small particles generated while working on solar PV installation site. Activities such as drilling, cutting, and grinding produce dust and flying particles that can enter the eyes and cause irritation or injury. It helps in protection of eyes from dust and debris; Prevent injury from flying particles and reduce exposure to harmful substances.

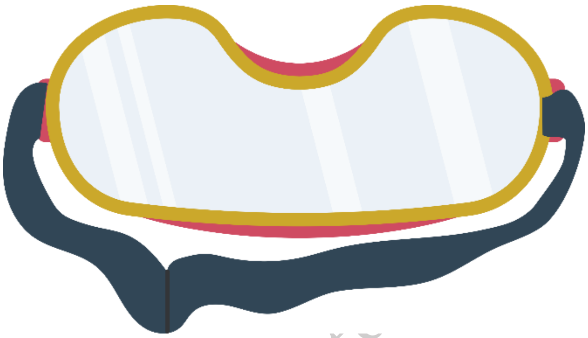


Figure 3.6: Safety Goggles

When to Use Safety Goggles?

- During drilling and cutting operations
- While working in dusty environments
- During grinding or polishing work

6. **Reflective Jacket (High Visibility Vest):** A reflective jacket (Figure 3.7) improves the visibility of workers at the site, especially in low-light conditions or large installation areas. Solar installation sites may have moving vehicles, machinery, or multiple teams working simultaneously. A reflective jacket ensures that workers are easily visible to others. It improves visibility of workers, prevents accidents involving vehicles or machinery and enhances safety in low-light conditions.

Figure 3.7: Reflective Jacket

When to Use reflective jacket?

- At large solar farms
- During early morning or evening work
- Near moving vehicles or machinery

Table 3.2: *Purpose of Personal Protective Equipment (PPE)*

S. No.	PPE	Purpose
1	Safety helmet	Protects head from falling objects
2	Safety shoes	Protects feet from heavy materials
3	Safety gloves	Protects hands from cuts

4	Safety harness	Prevents falls from height
5	Safety goggles	Protects eyes from dust and debris
6	Reflective jacket	Improves worker visibility

3.5 Safe Material Handling for Solar PV Installers (Civil Work)

Safe material handling is an essential part of solar PV installation, especially in civil work such as foundation preparation, mounting structure installation, and rooftop activities. Workers regularly deal with heavy and delicate materials like solar panels, steel or aluminium structures, cement, and aggregates. If these materials are not handled properly, it can lead to injuries such as back strain, cuts, and falls, and may also damage costly equipment like PV panels. Figure 3.8 illustrates the flow of handling of the materials in the solar civil work.

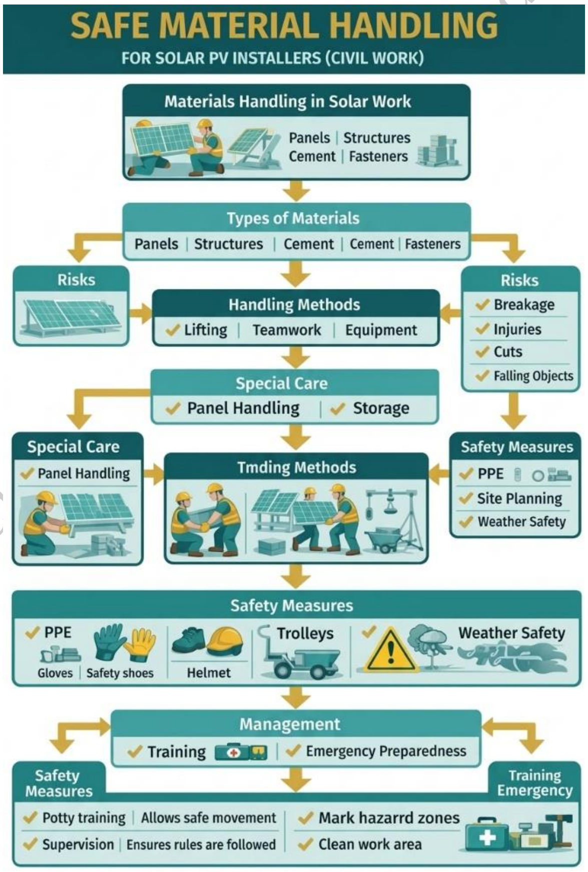


Figure 3.8: Process Flow Diagram of Safe Material Handling Practices

Let us discuss each of the above in detail:

1. Materials Handled -

- *Solar panels* – These are fragile and costly components that need careful handling.
- *Mounting structures* – This metal frames that are heavy and bulky.
- *Cement and aggregates* – Used in civil work and require proper transport.
- *Fasteners* – These are the small parts that must be stored safely to avoid loss.

2. Common Risks -

- *Panel breakage* – Improper handling can damage panels easily.

- *Back injuries* – Wrong lifting posture cause strain.
- *Cuts and slips* – Sharp edges and loose surfaces create hazards.
- *Falling objects* – Materials may fall from height and cause injury.

3. Lifting Techniques

- *Bend knees* – It reduces pressure on the back.
- *Keep back straight* – This maintains correct posture while lifting.
- *Lift with legs* – It uses strong muscles and prevents injury.
- *Avoid twisting* – This prevents muscle strain and imbalance.

4. Team Lifting

- *Lift together* – It makes handling heavy loads easier.
- *Coordinate movements* – It ensures balance and control.
- *Clear communication* – This prevents confusion during lifting.

5. Handling Equipment

- *Trolleys* – Trolleys helps in moving materials easily.
- *Hoists and pulleys* – These are used for lifting materials to height.
- *Wheelbarrows* – These are useful for transporting civil materials.

6. Safe Panel Handling

- *Carry vertically* – It reduces stress on panel surface.
- *Hold from frame* –This protects glass from damage.
- Avoid pressure – It prevents cracks and efficiency loss.

7. Storage Practices

- *Store on level ground* – It prevents shifting and falling.
- *Keep materials dry* – It protects from damage due to moisture.
- **Proper stacking** – This avoids collapse and saves space.

8. PPE Required

- *Gloves* – Gloves protects hands from cuts and improve grip.
- *Safety shoes* – It prevents foot injuries from heavy objects.
- *Helmet* – Helmet protects head from falling materials.

9. Site Planning

- *Clear pathways* – It allows safe movement of workers.
- *Mark hazard zones* – These warns workers about danger areas.

- *Clean work area* – It reduces chances of accidents.

10. Weather Safety

- *Avoid strong winds* – These prevents loss of control while handling panels.
- *Be careful in rain* – It may cause slippery surfaces increase risk.

11. Training & Supervision

- *Safety training* – The training ensures to teach correct handling methods.
- *Supervision* – It is required to ensure rules are followed properly.
- *Follow guidelines* – It maintains discipline at site.

12. Emergency Readiness

- *First aid kit* – Must needed which seems to be helpful in immediate treatment.
- *Medical access* – This ensures quick response in emergencies.

Refer Figure 3.9 for the proper handling of the materials while working in a Solar PV installer lab.

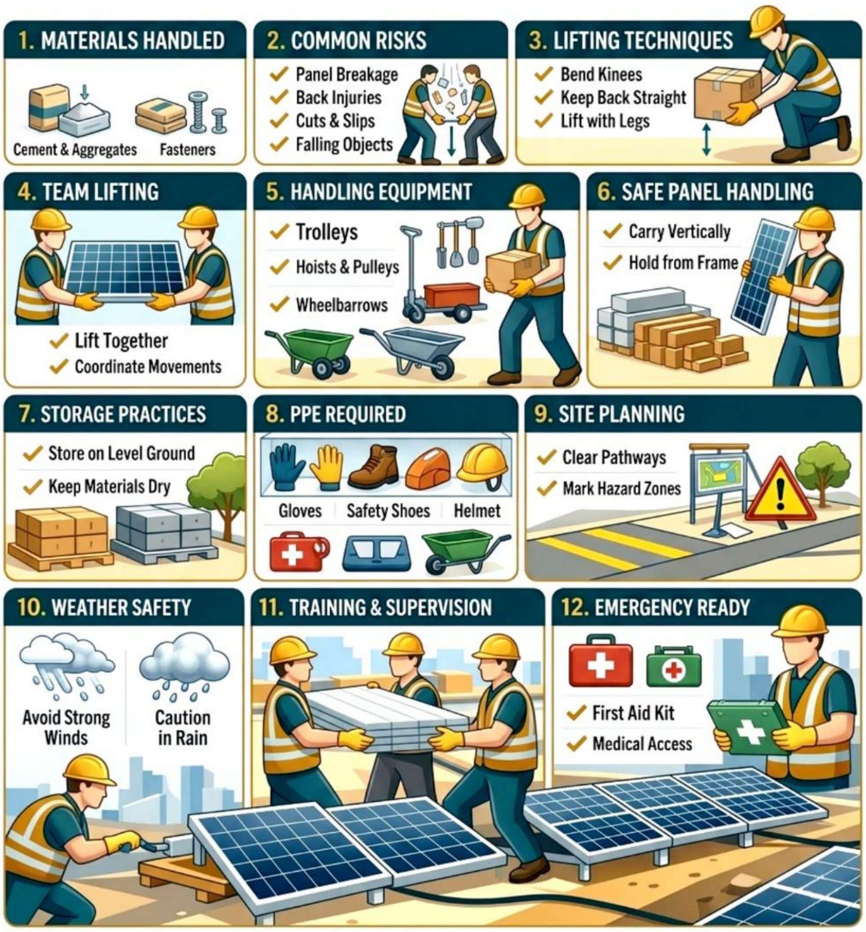


Figure 3.9: Proper and safe handling of material for a Solar (Civil Work)

Activity: Safe Lifting Demonstration

Students understand correct lifting techniques through practice.

Procedure:

1. Divide students into groups of two
2. Provide a dummy object (box or panel frame)
3. Ask one student to lift incorrectly and another correctly
4. Observe and compare posture.

Figure 3.10: Safely lifting of Solar Panels

3.6 Safety Aspects during Foundation Construction in Solar Panel Work

Foundation construction is a key part of ground-mounted solar systems. It includes excavation, reinforcement placement, and concrete pouring. Each stage involves risks and requires careful safety management.

1. **Excavation Safety (Detailed) -** Excavation creates pits in the ground which may collapse if not properly managed (Figure 3.11).

Risks

- Collapse of soil walls
- Workers falling into open pits
- Water accumulation in pits

Safety Measures

- Provide proper slope or support to pit walls
- Install barricades around excavation areas
- Place warning signs near pits
- Avoid working alone near deep excavations

Figure 3.11: Excavation Safety

2. **Concrete Work Safety –** Handling of cement and concrete involves chemical and mechanical risks (Figure 3.12).

Risks

- Skin irritation from wet cement
- Injuries from machinery
- Slipping on wet surfaces

Safety Practices

- Wear gloves and protective clothing
- Use proper tools for mixing and pouring
- Keep the work area clean and dry
- Operate mixers carefully

Figure 3.12: Concrete Work Safety

3.7 Ladder and Scaffold Safety

Working at height is a very important part of rooftop solar installation. Workers use ladders to reach roofs and scaffolds to stand and work comfortably.

In the high-stakes environment of solar installation, even a minor oversight can quickly escalate into a life-threatening accident, such as a severe fall or a debilitating injury. This reality makes it imperative for every professional and student to not only understand safety protocols but to follow them with absolute discipline. Since ladders and scaffolds are the primary means of reaching rooftop systems, they represent a significant point of vulnerability; any failure to secure them properly or use them according to safety standards can result in catastrophic falls. Prioritizing these foundational safety skills is what separates a successful installation from a tragic workplace incident.

3.7.1 Ladder Safety Guidelines

1. Place the Ladder on Firm and Level Ground - Before using a ladder, always check the ground. It should be hard, flat, and even. If the ground is soft, muddy, or uneven, the ladder can tilt or sink, which may cause it to fall. If needed, use a wooden plank or base plate to make the surface stable.

Important: Never place a ladder on loose bricks, stones, or slippery surfaces.

2. Maintain a 75° Angle (Safe Climbing Angle) - The ladder should be placed at a proper angle. If the ladder is too straight, it may fall backward. If it is too flat, it may slip forward. The safest angle is about 75 degrees.

Simple Rule (1:4 rule): For every 4 meters of height, keep the ladder base 1 meter away from the wall.

3. Ladder Should Extend Above Roof Level - The ladder must extend at least 1 meter above the roof edge. This gives proper support to hold while stepping on or off the roof. If the ladder is too short, the worker may lose balance while climbing.

4. Secure the Ladder Properly - Always fix or tie the ladder at the top or bottom to prevent movement. Wind, sudden movement, or uneven load can cause the ladder to slip.

5. Always Face the Ladder While Climbing - While going up or down, always face the ladder. Keep both hands on the side rails and climb step by step. Never turn your back to the ladder, skip steps or rush while climbing

6. Do Not Carry Heavy Loads While Climbing - Carrying heavy tools or materials while climbing can disturb your balance. This increases the risk of falling. Instead use a rope to lift tools or use tool belts or ask another worker to pass materials.

7.Maintain Three-Point Contact - At all times, keep two hands and one foot or two feet and one hand on the ladder. This gives better balance and reduces the chances of slipping (Figure3.13).

Figure 3.13: Factors to consider when putting a ladder on sloping roof

3.7.2 Scaffold Safety

Scaffolds are temporary platforms used when workers need to stay at height for a longer time. They provide more space and comfort than ladders. But if not used properly, they can collapse or cause falls. Following are to be considered for the safety measures for scaffolding:

1. Proper Assembly of Scaffolding - Scaffolds must be assembled by trained persons. All parts like pipes, joints, and platforms should be properly fixed. Following are the important components:

1. Base plates
2. Vertical supports
3. Cross bracing
4. Working platform
5. Cross Bracing

2. Check Stability Before Use - Before climbing, always inspect the scaffold. It is to be checked for loose joints, uneven bases, damaged parts and proper alignment also. If anyone of the above looks unsafe, do not use the scaffold.

3. Use Guardrails and Toe Boards - Guardrails are safety barriers placed on the edges of scaffolds. They prevent workers from falling. Toe boards prevent tools or materials from falling down. Make sure to Never work on a scaffold without guardrails.

4. Avoid Overloading the Scaffold - Do not place too much weight on the scaffold. Excess load can cause bending or collapse. Always follow the load limit.

5. Keep Platform Clean and Dry - Wet or cluttered surfaces can cause slipping. Always keep the working area clean. Remove water, cement spills or if tools lying around.

6. Use Safety Equipment - Workers should wear Helmet, Safety shoes, Safety harness, if required. Safety equipment adds extra protection.

Activity: To learn the correct ladder angle and identify safe and unsafe positions.

Materials Required

1. Ladder
2. Wall
3. Measuring tape
4. Chalk or marker
5. Protractor or mobile angle app

Procedure:

Step 1: Place the ladder against a wall. Keep the ladder straight and stable.
Step 2: Measure the height. Measure how high the ladder touches the wall.
Step 3: Measure the base distance. Measure the distance between the ladder base and the wall.
Step 4: Apply the 1:4 rule. Check if the distance follows the safe ratio.
Step 5: Measure the angle. Use a protractor or mobile app to check if the angle is around 75°.

Correct Position	Incorrect Position
• Proper angle (75°) • Stable base • Safe climbing	• Too steep (may fall backward) • Too flat (may slip forward)

3.8 Tool and Equipment Safety

The regular use of drilling machines, spanners, cutting tools, and measuring devices is central to solar PV installation, allowing for precision and speed. However, these tools pose significant risks if handled carelessly, with many worksite accidents stemming from improper use, a lack of regular tool inspection, or general negligence. Developing safe habits is therefore essential; workers must remain focused and avoid rushing or succumbing to distractions while operating machinery. Beyond basic alertness, comprehensive training on each specific tool is a prerequisite for safety, and the use of personal protective equipment such as gloves, goggles, and helmets provides a vital secondary line of defence. Ultimately, disciplined tool management does more than just prevent physical injury it directly enhances the overall quality and efficiency of the installation (Refer Table 3.3).

Table 3.3: *Safety measures adopted during installation of Solar PV Civil Work*

S. No.	Name of Equipment	Safety Measures to be Taken
1	Drilling Machine	When operating power tools like drilling machines, safety begins with a thorough pre-use inspection of the wires and plugs to ensure there is no fraying or damage. To protect against physical hazards, always wear safety gloves and goggles, and maintain a firm, two-handed grip to ensure the tool remains under your control at all times. For your personal safety, never attempt to touch any rotating parts while the machine is in motion. Once the task is complete, always switch off the power and unplug the device to prevent accidental activation.
2	Wrenches and Spanners	When using spanners or wrenches, it is essential to select the correct size for the bolt to prevent slipping and stripping the hardware. You should avoid over-tightening, which can snap the bolt or damage the tool, and always check for cracks or signs of metal fatigue before starting. For maximum control, maintain a proper grip and pull the tool toward you rather than pushing it away; finally, never use a spanner as a hammer, as this

		compromises the structural integrity of the tool and can cause unpredictable injuries.
3	Cutting Tools	To ensure safety when using cutting tools, always use sharp and clean blades, as dull edges require more force and are more likely to slip and cause injury. For maximum protection, you should always cut away from your body and wear cut-resistant gloves to shield your hands from accidental contact. Never use damaged or rusted tools that could break under pressure, and always cover the blade or retract it immediately after use to prevent accidental cuts during storage or handling.
4	Measuring Devices	Handle gently. Do not drop the measuring devices. Keep them clean and dry. Store the devices safely to maintain accuracy.
5	Tool Storage	Keep tools inside the toolbox after use. Arrange properly. Do not leave the tool at the workplace after use. Ensure dry and safe storage.

3.9 Emergency Situations

Even on the most well-managed solar installation sites, emergencies can arise due to equipment malfunctions, human error, or sudden shifts in weather. True safety lies in constant preparedness, which requires every worker to be fluent in emergency procedures and have immediate access to first aid kits, fire extinguishers, and reliable communication systems. In the event of a crisis, the protocol is clear: workers must be trained to recognize the hazard, stop work immediately, notify their supervisor, and provide initial assistance to anyone in need. By conducting regular safety drills and awareness programs, teams can sharpen their response times and significantly reduce the severity of an accident. Ultimately, a proactive approach to emergencies doesn't just protect expensive equipment rather it saves lives (Refer Table 3.4 for details).

Table 3.4: *Emergency Situations and Response Measures*

S. No.	Type of Emergency	Safety Measures / Response Steps
1	Worker Injury	Stop all work immediately. Inform the supervisor. Provide first aid. Do not move the injured person unnecessarily. Call emergency services if needed.

		Keep the person calm and comfortable. Secure the area to prevent further accidents.
2	Electric Shock	Do not touch the victim directly. Switch off the power supply immediately. Use a non-conductive object (like wood) to separate the person. Check breathing and pulse. Provide first aid/CPR if trained. Call emergency services quickly.
3	Fire Outbreak	Raise alarm immediately. Stop all work. Use fire extinguisher if the fire is small and controllable. Do not panic. Evacuate the area safely. Call fire brigade. Keep away from smoke and flammable materials.
4	Structural Failure	Move away from the area immediately. Warn others nearby. Stop all work. Inform the supervisor. Do not re-enter the area. Barricade the site. Wait for inspection and clearance.
5	Fall from Height	Do not move the injured person unless necessary. Call for medical help immediately. Provide first aid. Check for fractures or bleeding. Keep the person still and calm.
6	Tool/Equipment Accident	Switch off the equipment immediately. Move the injured person away from danger. Provide first aid. Inform supervisor. Check equipment before reuse.
7	Heat Stress / Fainting	Move the person to a shaded or cool area. Provide water. Loosen tight clothing. Allow rest. Seek medical help if condition does not improve.
8	Material Collapse	Stay away from fallen materials. Do not attempt rescue without safety. Inform supervisor. Call emergency services if needed. Secure the area to avoid further collapse.

CHECK YOUR PROGRESS

A. Fill in the Blanks

1. To prevent falling into an excavation pit, workers should install _________ around the area.
2. For safe ladder use, the ladder should be placed at an angle of _________ degrees.
3. Before helping a person affected by electric shock, _________ should be switched off.

4. While handling wet concrete, workers should use _________ to protect their hands.

5. Checking tools for damage before use is known as ____________.

B. Answer the following

1. Suggest a safe method for carrying tools while climbing a ladder.
2. Demonstrate the steps to manage water accumulation in an excavation pit.
3. Identify the action to be taken when a scaffold is found unstable before use.
4. Apply the correct steps during a fire emergency at a worksite.
5. Suggest the correct practice when a damaged tool is being used.

ANSWER KEY

Module 1 - Site Survey for Solar PV Installation

A. Multiple Choice Questions

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

Module 2 - Civil Works required for Solar PV Installation

A. Multiple Choice Questions

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

Module 3 – Health and Safety

A. Fill in the blanks

1. Barricades
2. 75
3. Power supply
4. Gloves
5. Inspection