DRAFT STUDY MATERIAL

Solar Panel Installation Technician

(Job Role)

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

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

Grade XII

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

Preface

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

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

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

Deepak Paliwal

(Joint Director)

Date: 25 Aug 2024 PSSCIVE, Bhopal

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Module 1	**Installation and Commissioning of Solar Panel System**

Module Overview

This module covers several key topics essential for designing and installing a Solar PV system. It begins with the process of conducting a thorough site survey and preparing a site feasibility report, which is crucial for assessing the suitability of a location based on factors such as sunlight availability, shading, and structural integrity. Students will then explore the selection and design of a Solar PV system, learning how to choose the appropriate system size and components that meet the energy needs of the site while optimizing efficiency and cost. The module emphasizes the importance of understanding design features and their impact on the system's performance, reliability, and long-term maintenance.

This module provides a comprehensive guide to the essential steps and best practices in designing and installing a Solar PV system. It covers everything from conducting site surveys to the final installation, ensuring that students are well-equipped to handle all aspects of a solar PV project.

Learning Outcomes

After completing this module, you will be able to:

- Describe and perform the site survey and prepare site feasibility report
- Identify and select the design of the Solar PV system
- Describe the importance of design and evaluation features
- List the material handling procedure
- Construct the foundation for the solar PV system unit
- Describe the cable connection used in the solar installation
- Installation of Mounting structure and Solar panel
- Discuss the quality parameters

Module Structure

Session 01: Site Survey and Selection of Site

Session 02: Selection of Solar PV System

Session 03: Design Criteria for Solar PV System

Session 04: Material Requirement and Construction of the Foundation for the Solar Panel System

INTRODUCTION

Solar energy is being used as a sustainable alternative to conventional energy sources in many sectors of our daily lives. Solar technology based on solar energy like solar pump (for irrigation and lifting the underground water), solar cooker, solar streetlight, solar electricity generation, and solar rooftop on farm building and production facilities are rapidly evolving. Solar photovoltaic system is being used for agricultural operations, cooking, and, electricity generation especially in urban and rural areas. It consists of photovoltaic (PV) panels, inverter, DC distribution box, AC distribution box, DC cable, AC cable, energy meter, panel structure, and MC4 connecters.

When properly designed, solar PV systems result in significant long-term cost savings and a smaller environmental footprint compared to conventional power systems. The electricity generated depends on size of solar photovoltaic system. Solar-powered system depends on the total amount of solar energy available at that time, location and size of the PV array. Specifically, the intensity of the solar energy available and the size of the PV array used to convert that solar energy into direct current (DC) electricity determines the electricity generation. The power produced by this system is used for various applications and excess power is been supplied to a grid.

Grid Solar rooftop programme is one of the oldest programmes of the Ministry of New and Renewable Energy (MNRE) aimed at providing solar PV-based applications in areas where grid power is either not available or is unreliable.

NEED FOR DESIGNING AND INSTALLING SOLAR PANEL SYSTEM

Every solar panel system is unique and is been tailored to the needs of each customers. Thus, designing a solar power system depends on individual's consumption load. When designing a solar panel system, the designer must select the individual components of the solar panel system as per the capacity planned for the system. A solar panel system consists of several key components that work together to harness sunlight and convert it into usable electrical energy.

The main components of a typical solar panel system are Solar Panels (Photovoltaic Modules), Inverter, Mounting Structure, DC Disconnect Switch (DC Distribution box), AC Breaker Panel (AC Distribution box), Energy Meter, Monitoring System, and Grounding Equipment.

In some solar systems, the power produced by the solar panels needs to be stored. Batteries are being used to control this stored energy. A Charge Controller is being used to make sure these batteries are safe and operate at their best.

These solar panel system components work together seamlessly to harness solar energy, convert it into electricity, and integrate it into the electrical system of a various application. The design and installation of these components are critical to the overall efficiency and reliability of the solar panel system. The following information is required to design a PV system correctly.

- Energy Consumption (load analysis)
- Need of system type
- Location and Site Information
- Available Roof or Ground Space
- Budget and Financial Considerations
- Incentives and Rebates
- Climate and Weather Data
- System Monitoring and Maintenance Plan

Installing a solar PV system is a systematic task, with various tasks such as selection of system components, size, and type; selection of inverter and battery; selection of type of solar panel; pouring concrete; elements of electrical work; and heavy construction work (often including earthmoving, fastening, etc.)

SESSION 01: SITE SURVEY AND SELECTION OF SITE

A site survey is an important step in the overall solar installation process. It is very necessary to design a correct and profitable solar energy generation system for the owner of the system. The location of solar panels, their direction, orientation, and the potential of sunlight play an important role in determining the amount of energy the system can generate from the sun.

In general, the following parameters are considered during the site survey of a solar power system (solar PV system)-

a. **Climatic condition of the site**
b. **Type land/roof and shadow-free**
c. **Location of solar PV array**
d. **Shade Analysis**
e. **Space availability**
f. **Size and location of existing electrical connection**
g. **Location for mounting solar system components**

a. **Climatic condition of the site:** The solar irradiation level, temperature, and variation in wind speed at the site provide an estimate of the potential for the solar PV installation and the requirements of specific components. For instance, an efficient solar panel is required at low solar irradiation level sites as compared to high solar irradiation sites. Similarly, solar panels work more efficiently in colder regions as compared to hotter regions. Further, the worst wind load on the panels and the structure on which they are mounted should be consider in the installation design of the solar system.
b. **Type of land/roof:** Defining the type of land/roof and their soil type is required in the designing of the solar system. It is important to note if soil is capable for foundation work and site/soil can bear the load of the structure. The type of roof is also important, as there can be various types such as RCC (Reinforced Cement Concrete), Metal sheet, Aluminium sheet, and Asbestos sheets. A roof can be flat or sloping with a specific potential to carry the weight of panels so this helps determine many other factors dependent on this information.
c. **Location of solar PV array:** It is important to determine the ideal solar PV array during the site survey. South, southeast, and southwest are three directions of the property where a solar PV array can be installed.
d. **Shade Analysis:** Ideally, the location where the solar PV array is to be installed should be shadow-free. During the site survey, any obstructions such as adjacent buildings, trees, water tanks, dish antennas, parapet walls, etc. should be noted as any obstacles that can cause shade and can affect electricity generation. Shadow analysis is done to ensure maximum sunlight is captured throughout the year during the period of 9:00 AM to 3:00 PM.

e. **Space Availability:** The space needed for a 1kW solar system is 80 square feet. So, for a 10-kW system, the space needed is 800-1000 square feet During the site survey, the potential area is measured on the roof or the ground, and on this basis, the solar PV system is designed. The structure and type of roof (flat or slope), its direction, nearby obstructions, and its accessibility influence the location where the solar PV array is to be installed.

f. **Size and location of existing electrical connection:** To get the correct information on the size of system and location of the connection it is necessary to answer the few questions. Is it a single-phase or a three-phase electrical connection? What is the standard voltage and frequency of the electricity supplied to the property? Where is the main connection of the property to the electricity grid? These questions will improve the analysis of the site survey.

g. **Location for mounting solar system components:** Once the ideal location of the PV installation is decided, the location and diagram of mounting other components are to be specified in the site survey. Factors such as the distribution box, the inverter, and the wiring route of the whole system should be determined as well. If the installation is off-grid, the placement of the battery is also necessary.

After the site survey, draw a line diagram with appropriate scaling (dimensions).

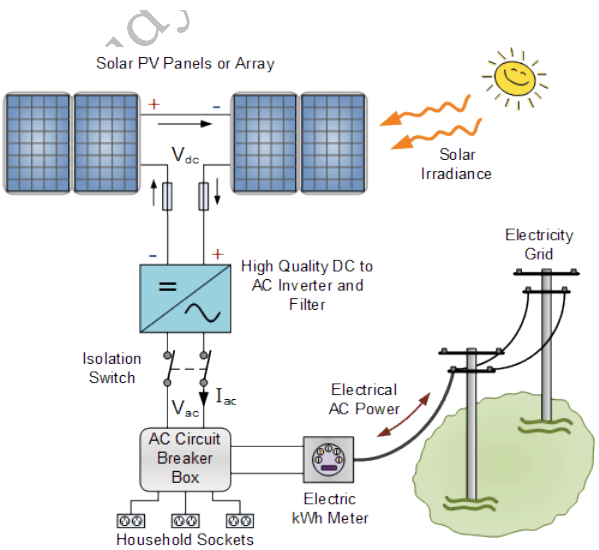


Fig. 1.1: Typical layout of grid connected solar PV System

PERFORMANCE EVALUATION OF SOLAR PANEL SYSTEMS

It is often difficult to predict the solar system performance. Every installation tends to be unique which also makes the system performance difficult to predict accurately. Due to this, there is a range of tools to optimise the performance of our solar panel systems.

The solar photovoltaic-based grid connected system is the best-suited technology for the electricity generation for household consumer. However, the electricity generation may not match with the solar insolation. The performance evaluation of the solar panel system can be carried out based on the solar insolation as input and electricity generation as output.

Performance evaluation of solar panel systems the required data are:

- **Average solar insolation (W/m²):** Solar insolation is the measurement of average daily solar radiation. It is stated as a daily value called insolation hours. The hours of insolation are equal to the average daily kilowatt-hours received per square meter. Average solar insolation is received in India 4-7 kWh per square metre per day.
- **Average sunshine hours on the test day (hour):** Average sunshine hour in India depends on the location, but generally a 5-hour peak of sunshine is counted for the design purpose of the solar PV system.
- **Area of one Solar PV module (m²):** A PV module consists of many PV cells wired in parallel to increase current and in series to produce a higher voltage. 72-cell modules are the industry standard for large power production. As a thumb rule, a 10 square meter area for a 1 kW solar system capacity is required.
- **Number of Solar PV modules:** Number of the solar photovoltaic module depends on the system and panel rating. For example, if we install 7kW Solar system, we would require a capacity solar panel of 330 W x 21 for the electricity generation.

SESSION 01

Practical Exercises

1. Describe the list of parameters for the site survey and selection of the solar PV system.
2. Draw the layout of the solar PV system.
3. List the components of the solar PV system.
4. Explain the advantages of the solar PV system.

Check Your Progress

A. Short Answer Questions

1. Explain the importance of solar insolation.
2. What is the minimum area required for a 1 kw solar photovoltaic module?
3. Why shade analysis is necessary?
4. What are the average sunshine hours in India?

B. Fill in the blank

1. The full form of KW is ....
2. 1KW is equal to ....Watt.
3. .... area is required for a 1 kW solar system capacity.
4. The average solar energy received in India is solar ....

C. Multiple Choice Questions

1. A device used for measuring solar irradiance on a planar surface by measuring the solar radiation flux density (in units of W/m^2), is
   a) Pyranometer
   b) Multimeter
   c) Ammeter
   d) Voltmeter
2. 1 hp equal to?
   a) 800 watts
   b) 750 watts
   c) 746 kW
   d) 746 watts
3. Why is a shading analysis crucial in site selection for a solar project?
   a) determine the latitude of the site
   b) To assess the wind speed
   c) To identify obstacles affecting sunlight exposure
   d) To evaluate soil conditions
4. What is the typical unit of measurement for solar irradiance as recorded by a pyranometer?
   a) Watts per square meter (W/m^2)
   b) Kilowatt-hours (kWh)

c) Joules per second (J/s)
d) Lumens per square meter (lm/m^2)

SESSION 02: SELECTION OF SOLAR PV SYSTEM

A solar PV-based system is an integration of different subsystems that can be grouped into electrical, mechanical, and electronics components. Therefore, the synchronous operation of these components becomes vital in achieving better efficiency. The generalized structure of Solar PV system (Solar Photovoltaic System) comprises of a PV array, an Inverter combined with AC distribution box, DC distribution box, net meter, power electronic interface and some of case transformer. The size of the PV array required for electricity generation is being chosen by considering several factors namely: location, temperature, solar insolation, sanctioned load, required electricity per day, etc.

MAIN COMPONENTS OF THE PV SYSTEM

Solar PV Array: It consists of an array of solar panels connected in series and parallel combinations so to achieve the desired voltage and current necessary to generate electricity. The power rating of the solar array will be suitable for the design of the PV System. There are many types of solar panels and many denominations: monocrystalline, polycrystalline, cadmium telluride (CdTe) and Amorphous Silicon (a-SI). All have advantages and disadvantages, different costs, and performance ratios. The solar panels used in the solar PV systems produce electricity by using the photovoltaic effect. These solar panels absorb the sun's photons and convert them into energy. This is the main component of a solar PV system.

Inverter: An inverter is a crucial component that converts the DC electricity produced by the solar panels into alternating current (AC), which is the type of electricity used in most household and commercial applications. Inverters also optimize the power output and ensure compatibility with the utility grid.

Module Mounting Structure: Mounting structures are the backbone of a solar power plant as they provide support to the modules. These support structures raise solar panels at appropriate angles so to ensure that they receive maximum solar irradiation. Without these, solar panels will not be able to capture the required quantum of solar radiation for generating optimum solar energy.

DC Disconnect Switch: The DC disconnect switch allows for the safe isolation of the DC power generated by the solar panels. It is used during maintenance, repair, or emergencies to disconnect the system from the solar panels.

AC Disconnect Switch: Similar to the DC disconnect switch, the AC disconnect switch is used to isolate the system from the electrical grid. It ensures the safety of maintenance personnel and allows for the disconnection of the PV system from the grid when necessary.

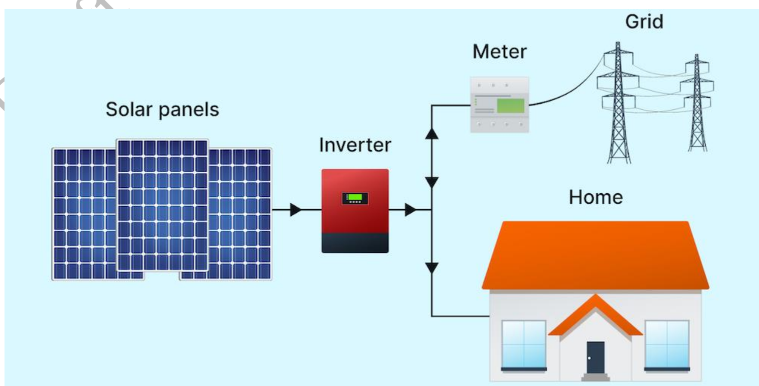
Battery (optional): Off-grid or hybrid setups often integrate batteries to capture excess energy generated during sunny periods, storing it for later use during low-light periods or after sunset. These batteries serve as a reliable backup, ensuring uninterrupted power supply in the event of grid failures.

Charge Controller (for battery systems): A charge controller regulates the charging and discharging of batteries in systems with energy storage. It helps prevent overcharging or deep discharging, thereby extending the life of the batteries.

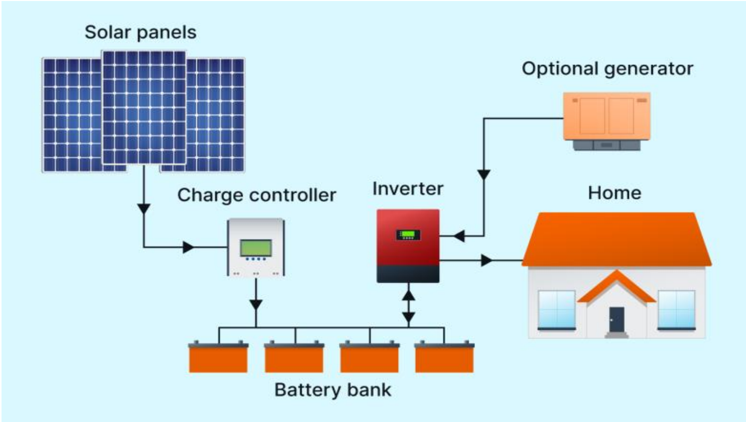
SOLAR PV SYSTEMS

Generally, solar PV systems can be categorized into grid-connected, off-grid systems, and hybrid PV system.

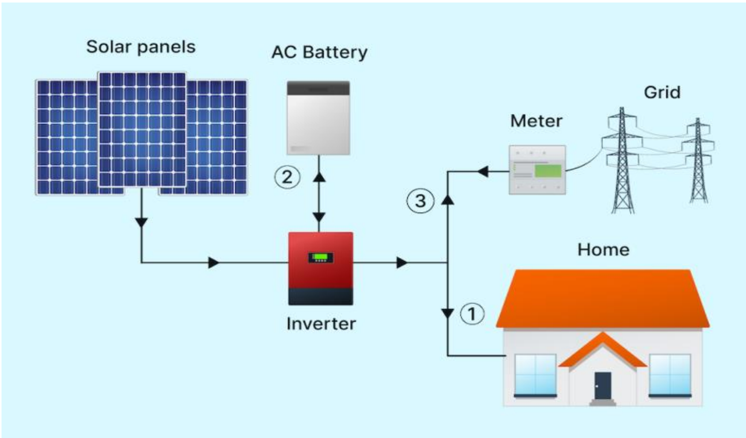
Off-grid systems are further subdivided into battery-driven and direct-driven systems.



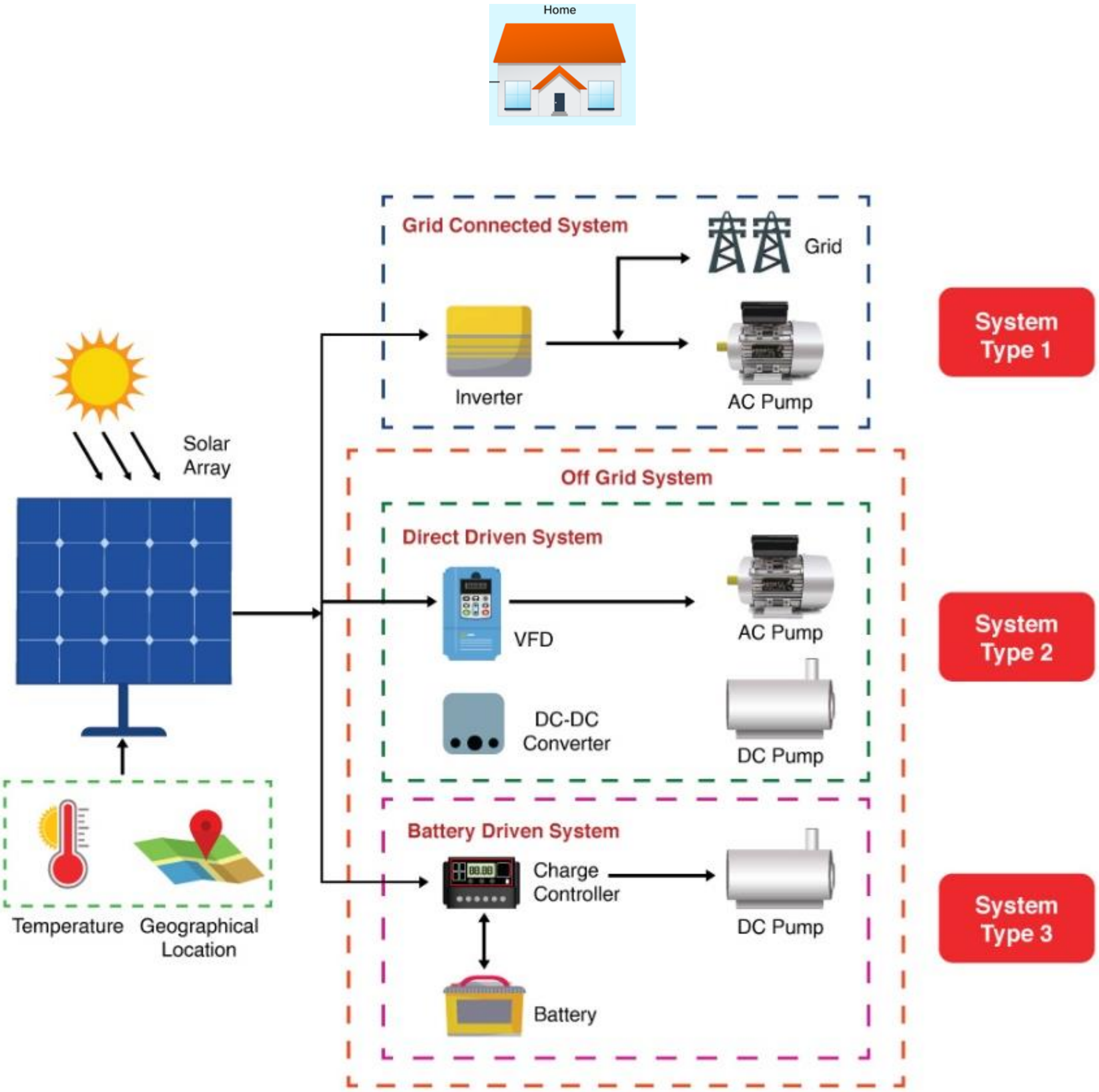
(a)


Solar panels
Optional generator
Charge controller
Inverter
Home
Battery bank

(b)


Solar panels
AC Battery
Grid
Meter
2
3
Home
1
Inverter

(c)



(d)

Fig. 1.2 (a), (b), (c) and (d): *Generalized structure of solar PV system (SPVS)*

SYSTEM TYPE 1: GRID CONNECTED SYSTEM

It is also known as a grid-tie or grid-feed solar system. These systems do not need batteries and use either solar inverters or micro-inverters and are connected to the public electricity grid. In on-grid solar system, if in case the solar panel is generating more power than the domestic consumption, then the excess power will automatically be exported to the grid via net metering and the government will adjust it in your next electricity bill.

Net metering is a billing mechanism that credits solar energy system owners for the electricity they add to the grid. For example, if a solar pump customer has a PV system on their land, it may generate more electricity than the pump uses during daylight hours. If the pump system is net-metered, the electricity meter will run backward to provide a credit against what electricity is consumed at night or other periods when the home's electricity use exceeds the system's output. Customers are only billed for their "net" energy use. On average, only 20-40% of a solar energy system's output ever goes into the grid, and this exported solar electricity serves nearby customers' loads.

SYSTEM TYPE 2: OFF-GRID SYSTEM

An off-grid system is not connected to the electricity grid. The off-grid Solar PV Applications Programme is one of the oldest programmes of the Ministry of New and Renewable Energy aimed at providing solar PV-based applications in areas where grid power is either not available or is unreliable. The solar off-grid system provides reliable electricity facility in rural/remote areas of the country.

SYSTEM TYPE 3: BATTERY-DRIVEN SYSTEM

In this type of system, a battery is being added to store the power for the night application. This solar PV system consists of four main components: Solar PV module, Electronic controller, Battery and DC loads.

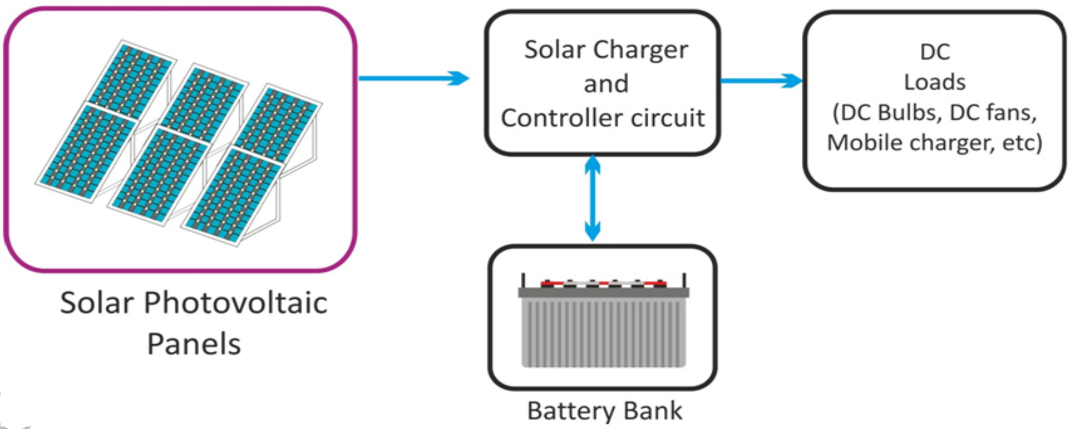


Fig. 1.3: (off-grid system with battery)

SYSTEM TYPE 4: HYBRID SYSTEM

The hybrid solar system is connected to the grid via net metering and has a battery backup to store the power. The energy that solar panels collect goes through a hybrid solar inverter to generate electricity. The most important benefit of a hybrid solar system is the power backup facility. It means you can continue using electricity without disruptions even during power outages. A battery backup helps store the extra power generated by the solar system during peak hours.

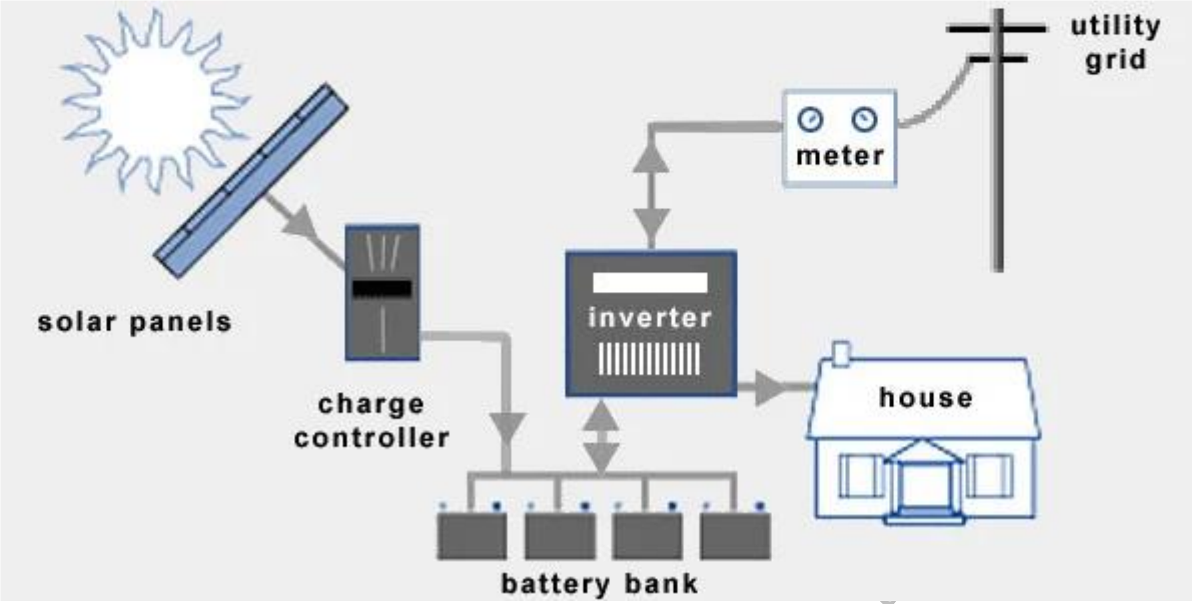


Fig. 1.4: Hybrid System

The steps in selecting a solar PV system are summarised as follows:

1. **During the site visit:**
    - **a.** Determine the load capacity and energy consumption based on the solar PV system by selecting the appropriate size and type of solar PV system to be installed.
    - **b.** Determine where the solar array will be located.
    - **c.** Determine where the inverter will be located.
    - **d.** Determine the length of cables required between the solar array to inverter (DC cable) and inverter to meter (AC cable).
    - **e.** Determine the solar irradiation for the selected site on an annual and monthly basis.
2. Choose a type of PV system consistent with the electricity generation and the overall characteristics of the site.
3. With the final selection of PV system, finalise the selection of inverter and battery size (if needed) of the system from the manufacturer's tables or data sheet. Table 1.1 shows technical specifications of the solar PV system.
4. After the selection of the solar PV system configuration, the installation of system takes place.

SOLAR PV SYSTEM:

In a solar PV system, the major aspect is the right selection of solar PV system. Nowadays various types of solar PV systems are available in the market but it is very difficult to select the feasible and desired solar PV system. Therefore, the solar technician should follow Table 1.1, 1.2 and 1.3 before buying the solar PV system.

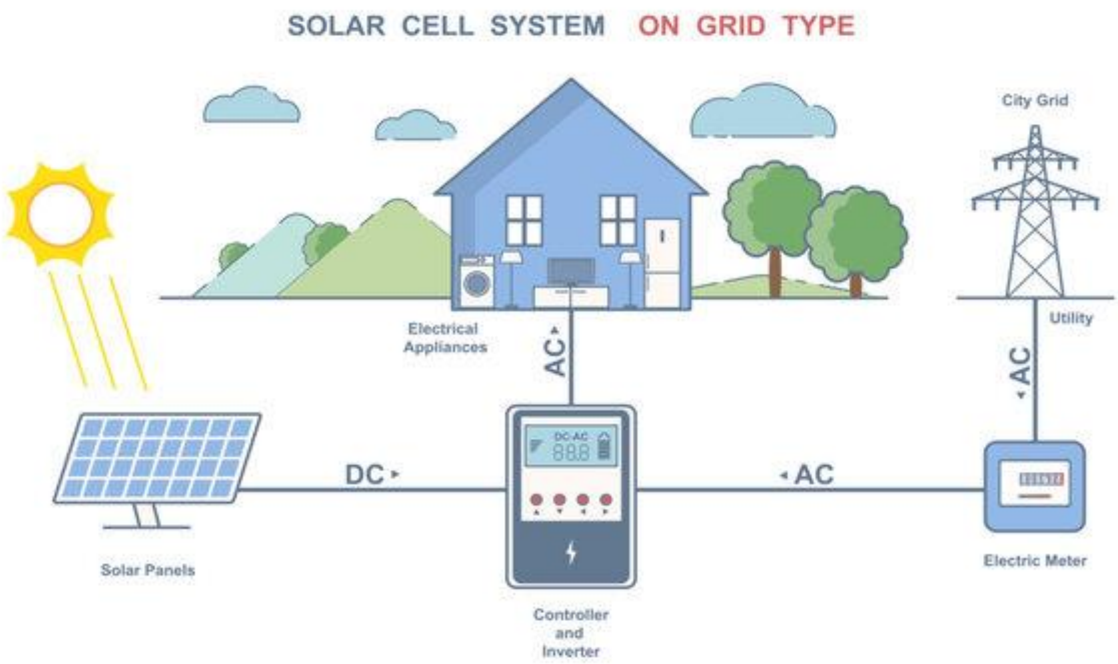


Fig. 1.5: Single-line diagram of the solar PV system

In solar market, on grid, off grid, hybrid and battery-driven solar system are available but, in most cases, on grid solar PV system are installed by the consumer. Solar PV system design depends on consumption of electricity and sanction load. The technician selects the solar PV system as per the requirements of the customer from the table given below.

Table 1.1. Solar PV System

SYSTEM COMPONENTS	ONS2 GRID	OFF GRID	HYBRID
Solar panel	Yes	Yes	Yes
Inverter	Grid tie inverter	Off grid inverter	Hybrid inverter
Battery	Not required	Yes	Yes
Meter	Net meter	Not special required	Net meter
Cost	Low	Moderate	High
Power backup when grid goes down	No	Yes	Yes

SESSION 02

Practical Exercises

1. Draw the layout of the Off-Grid system.
2. Make a table of different types of solar PV systems.
3. Construct a line diagram of the Direct Driven System (off-grid system without battery).

Check Your Progress

A. Short Answer Questions

1. Why Hybrid system is used?
2. Write the difference between on grid and off grid system.
3. Short note on shade analysis?
4. Write a short note on net metering.
5. Explain the Grid-connected solar PV system.

B. Fill in the blank

1. The full form of SPV is ....
2. If we install the 3kw Solar PV systems, solar inverter capacity is required ....
3. A solar charge controller is an electronic device used for................. in battery.

4. Inverter convert DC to ……………

C. Multiple Choice Questions

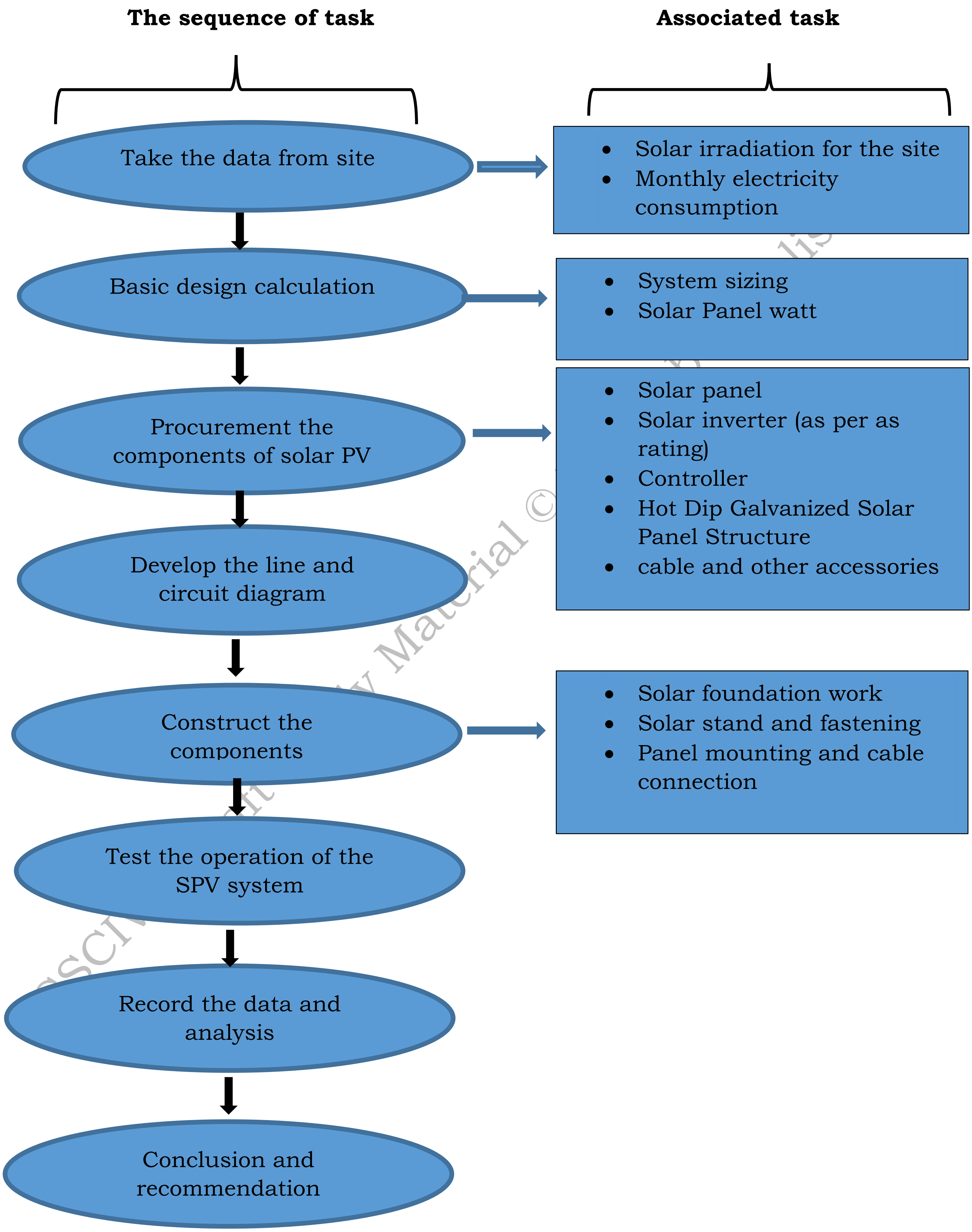
1. Which type of Solar System not required battery.
    a) On Grid System
    b) Off Grid System
    c) Hybrid System
    d) b & c
2. Which type of solar system needs to be installed where grid power is not available?
    a) On Grid System
    b) Off-Grid System
    c) Hybrid System
    d) None of the above
3. If Grid is not available & we want to operate the Solar System at night, which type of solar system will require?
    a) Hybrid System
    b) On-grid System
    c) Off-grid System
    d) a & c
4. Invertor used in which type of Solar system
    a) On Grid system
    b) Hybrid System
    c) Off-Grid System
    d) All of the above

SESSION 03: DESIGN CRITERIA FOR SOLAR PV SYSTEM

A solar PV (photovoltaic) system is a renewable energy technology that converts sunlight into electricity. It consists of several key components working together to harness solar energy and generate power. Solar PV systems are fundamental for electricity generation, transmission and storage purposes whether it has been used in irrigation, residential applications. The use of photovoltaic panels to support the electrical requirements of these systems has been executed globally for a long time. However, introducing the best sizing techniques to such systems can benefit the end-user by saving money, energy, and time. The design and evaluation have been carried out through intuitive and mathematical methods.

The following steps will be used in the design process for a solar PV system. These steps will help you ensure that the system functions properly and generate electricity.

Fig. 1.6: Flow chart of Design and Installation process of the solar PV system



The important parameters for solar panel installation and commissioning

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

Design consideration:

Step 1. Determination of the solar irradiation for the site

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

A typical application of silicon-cell pyranometer includes incoming shortwave radiation measurement in agricultural, ecological and hydrological weather networks and solar panel arrays.

Fig. 1.7: Pyranometer

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

The average solar radiation in India is 5 kWh/m^2/Day and we count average hours of radiation as 5 Hours/Day. India has a high potential for solar power generation of about 300 direct sunshine days per year. The regular solar incident in India varies with annual sunlight of 4 to 7 kWh/m^2. The Solar Radiation Map of India is shown in Fig.1.9.

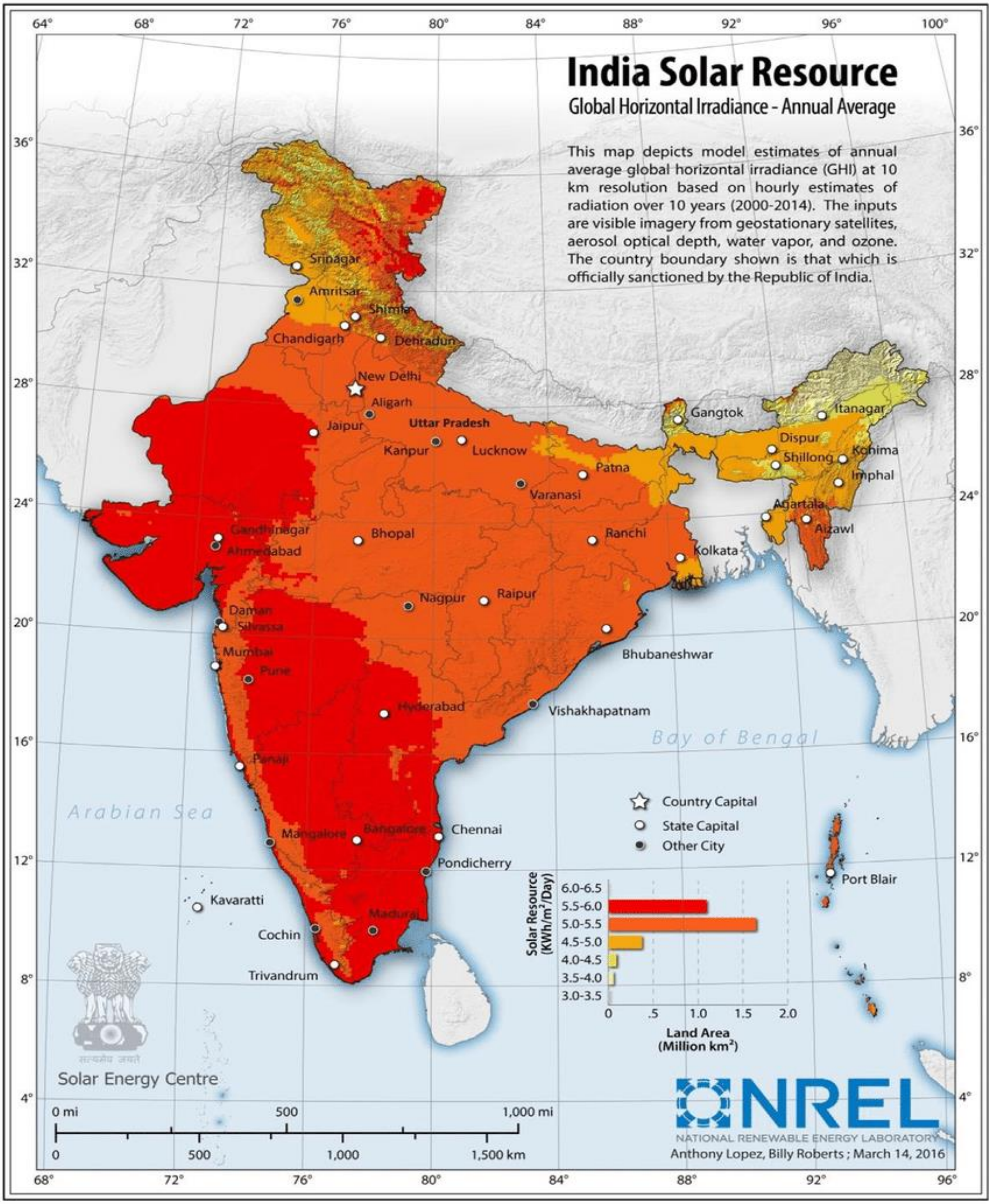


Fig. 1.8: Solar Radiation Map of India

Source: National Renewable Energy Laboratory (NREL)

Step 2. Basic design calculation

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

a. **Energy Consumption Analysis**: Determine your average daily energy consumption in kilowatt-hours (kWh) by reviewing your utility bills or using energy monitoring devices.
b. **Roof Assessment:** Evaluate your rooftop's suitability for solar installation, considering factors like orientation, tilt angle, shading, and available space.
c. **Energy/ Power requirement**: To determine the daily and monthly power requirements for domestic or industrial use, we rely on electricity bills, particularly the section load information. The initial step involves estimating the energy demand per day in kilowatt-hours (kWh). A good estimate can be found in "Basic Energy Requirements for Domestic Activities”.

Step 3. Selection of the inverter

After energy calculation, the inverter rating in kilovolt ampere (KVA) will be calculated on the basis of system sizing. Let us calculate the required capacity of the inverter, i.e., the Volt-Ampere rating. In an ideal condition, an inverter would operate with 100% efficiency. Most inverters have an efficiency of between 60% and 80%. This efficiency can also be referred to as the power factor of an inverter. For our calculations, we would use a power factor of 0.8. Hence,

Power supplied (or VA rating of the inverter) $= \frac{\textbf{Power consumed by equipment in watts}}{\textbf{Power factor}}$

The total power consumed by consumer home (total wattage) is 1200W and Power factor = 0.8

Therefore, required VA rating of inverter $= \frac{1200}{0.8}$ = 1500 VA = 1.5KVA

Therefore, using a 1.5 kVA inverter will be inappropriate for the solar PV system.

Step 4. Procurement the components of solar PV system

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

Step 5. Develop the line and circuit diagram

Developing a line and circuit diagram for a solar PV system involves illustrating how to connect the components so to form a complete electrical system. A line diagram provides a visual representation of the electrical connections between the main components of the solar PV system. It shows the flow of electricity from the solar panels to the grid or load.

Step 6. Construct the components

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

Solar Panels: Solar panels can be represented as rectangular shapes with a grid pattern to symbolize solar cells.

Mounting Structure: The mounting structure will be depicted as a frame or support system around the solar panels.

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

Charge Controller (for Off-Grid Systems): If the system is off-grid and includes a charge controller, we can represent it as a device between the solar panels and battery bank.

Battery Bank (for Off-Grid Systems): The battery bank can be shown as a collection of rectangular shapes connected in series or parallel to store energy.

DC Disconnect Switch: The DC disconnect switch will be represented as a switch symbol along the DC wiring between the solar panels and the inverter.

AC Disconnect Switch: Similarly, the AC disconnect switch will be depicted as a switch symbol along the AC wiring between the inverter and the main electrical panel.

Wiring and Cables: Wiring and cables will be shown as lines connecting the various components, with labels indicating DC or AC, and possibly cable types or sizes.

Meter Installation: The vendor will arrive to install the net meter at the agreed-upon location. They will disconnect the existing meter (if applicable) and install the new bidirectional net meter capable of measuring electricity flow in both directions. The installation may involve wiring connections to the electrical panel or meter socket, depending on the meter type and configuration.

Monitoring and Control System: The monitoring and control system can be represented as a separate box or panel with displays and indicators for system monitoring and data logging.

Step 7. Test the operation of the SPV system:

Testing the operation of a solar PV (photovoltaic) system involves verifying that all components are functioning correctly and efficiently generating electricity. Here is a basic procedure for testing the operation of an SPV system:

Visual Inspection: Conduct a visual inspection of the entire system, including solar panels, mounting structures, inverters, wiring, and electrical connections. Look for any signs of physical damage, loose connections, or debris that may affect performance.

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

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

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

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

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

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

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

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

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

SESSION 03

Practical Exercises

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

Check Your Progress

A. Short Answer Questions

1. What is the average daily and monthly energy consumption of the site in kilowatt-hours (kWh)?
2. What type of solar panels (e.g., monocrystalline, polycrystalline, thin-film) is most suitable for the site?
3. What are the average sunshine hours in India?
4. Write the main components of the grid-connected solar PV system.

B. Fill in the blank

1. ___________: Understanding the latitude, longitude, and solar irradiance at the installation site is crucial for optimal panel orientation and performance.
2. ___________ Requirements: Determining the energy consumption patterns and peak demand periods helps size the solar PV system appropriately.
3. ___________ Size and Configuration: Selecting the right capacity and configuration, whether grid-tied, off-grid, or hybrid, ensures efficient energy production.
4. Component ___________: Choosing high-quality solar panels, inverters, and mounting structures compatible with the site conditions is essential for system longevity.

C. Multiple Choice Questions

1. The formula of energy required per day is equal to
   a) $\text{Power consumption} * \text{Running hour/day}$
   b) $\text{Discharge(Q)} * \text{Total} \frac{\text{head(H)}}{3960}$
   c) $\text{Voltage(V)} * \text{Current(I)}$
   d) None of the above
2. What is the primary function of an inverter in a solar PV system?
   a) Convert AC electricity to DC
   b) Convert DC electricity to AC
   c) Store excess electricity in batteries
   d) Measure solar irradiance levels

3. Formula Power is most commonly expressed as -
    a) m
    b) kW
    c) m^3/s
    d) m/s
4. In a grid-tied solar PV system, the inverter synchronizes the produced electricity with the
    a) Utility grid
    b) Battery bank
    c) Solar panels
    d) Load center

SESSION 04: MATERIAL REQUIREMENT AND CONSTRUCTION OF THE FOUNDATION FOR SOLAR PANEL SYSTEM

Material procurement is the process of researching, selecting, ordering, and paying for the raw materials required for constructing a building or structure. Procurement of any kind of material involves identifying and selecting vendors or suppliers, negotiating prices and terms, and awarding contracts.

Once the output is required from the system, you need to prepare a list of materials required for installation need to be prepared as per the specifications.

For installing solar arrays and system controllers:

- The manufacturer which provides the whole mechanism, which includes solar modules/arrays, connecting cables, structures to fit in solar panels (mounting structure), standing pole structures, and an instruction manual, will be finalized.
- Always read the manufacturer's instructions to ensure the specificities.
- Check the guarantee period.
- Take into account the maintenance cost of the system you purchase.
- It is important to check the compatibility of all parts, if the items are purchased from a different manufacturer.

- Wiring of the solar panels in the array and with the system controller must be according to Indian standards. Wiring should be done in such a way that it offers minimum electrical losses.
- All safety measures, while handling electrical instruments like earthing, short circuits, etc., must be considered.

Procurement of Raw Materials

For installing a solar panel system, the following materials are need to be arranged /purchased by the technician or vendor:

Table 4.1 List of Raw Materials

S.No.	Parts name	Specification
A.	PV Panel	
B.	Earthing kit	
C.	Controller/Inverter	
D.	Circuit Breakers	
E.	Solar panel	
F.	Wiring Cable	
G.	Solar Panel structure, the main pole, made of metal frames, c - channels	
H.	Concrete material	
I.	Paint to prevent corrosion	
J.	MC4 connector	
K.	Junction box (AC or / DC)	
L.	Fastening and Fittings materials	

Minimum 5 years of warranty for complete solar water pumping system and 25 years for solar panel is needed

Handling of various equipment

While installing the solar water pump or loading and unloading, solar technicians will come across many mechanical instruments. These instruments need to be handled carefully and with precautions.

- Always wear gloves or/and eye masks, if you are working with any rough or sharp knife or object. Eye masks are important while working with chemical substances or soldering.
- Wear steel boots to cover your feet completely, while carrying heavy equipment.
- While maintenance of the pump, inverters, etc., always switch off the main power source. Do not touch the metal turner with your hands or finger in the running pump. It can cause injury.
- Lift any item with a proper technique. Bend in squat at your hips to the ground and keep your back and legs straight while lifting.
- Use a pulley and proper lifting equipment to carry heavy instruments from one place to other or from ground to height.
- Wear lumbar belts while operation. Get help from a co-worker in such cases.
- Wear safety belts while installing solar systems on the roof or at heights**.**

CONSTRUCTION OF THE FOUNDATION FOR THE SOLAR PANEL UNIT:

The following steps will be taken during the Solar Panel System installation:

Step 1. Site Preparation

- Choose a location that receives ample sunlight throughout the day and is relatively free from shading.
- Clear the area of any debris, vegetation, or obstructions.
- Level the ground using a shovel, rake, or a small bulldozer, if necessary.

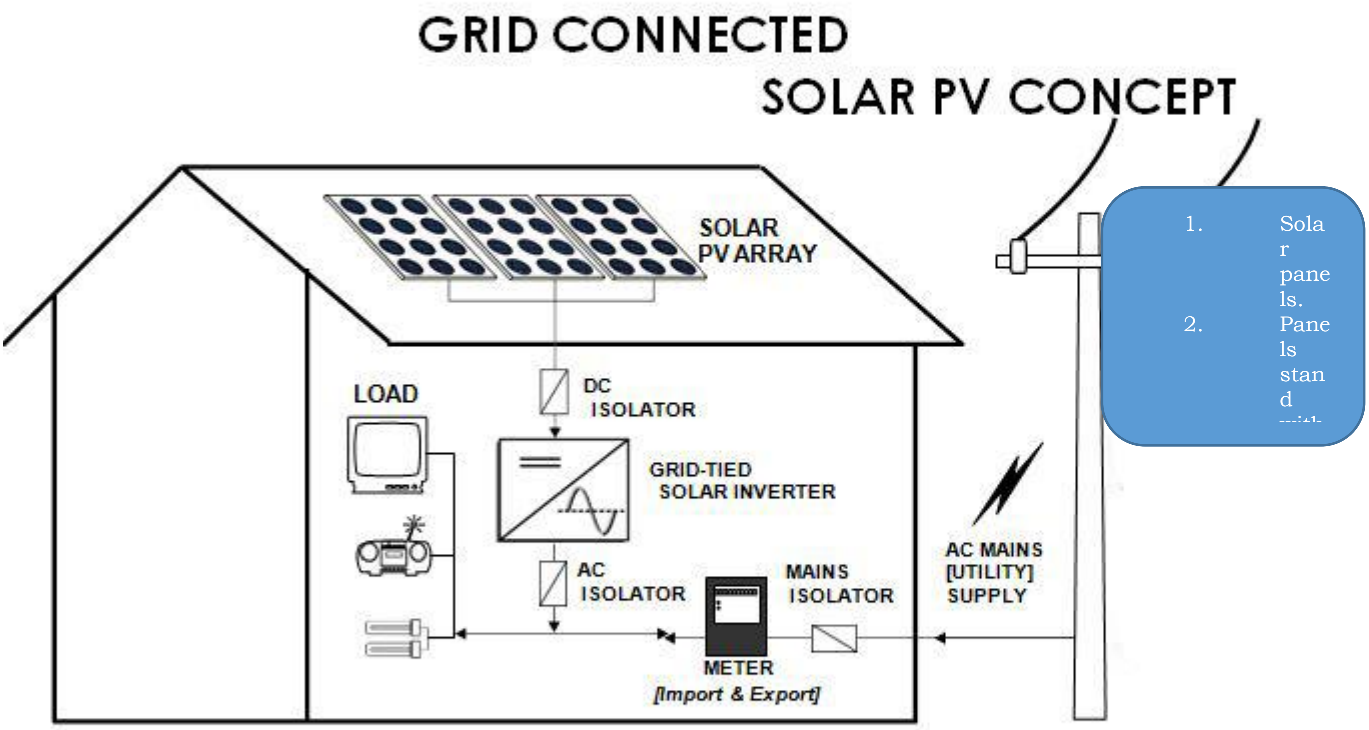


Fig.1.9: Line diagram (layout) of the Solar PV system

Step 2. Foundation Design

- Determine the type of foundation suitable for your soil type and the size of your solar panel array. Common options include concrete pads, ground screws, or ballasted systems.
- Consult with a structural engineer to ensure the foundation design meets local building codes and can support the weight and wind loads of the solar panels.

Step 3. Beam/pole placement & foundation

Pole mounting is the type of mounting where PV arrays are mounted above a certain height on the ground using poles. In areas with a space limit, pole mounting is preferred. Same as ground mounting, this type of mounting also is easy to maintain and adjust the tilt when required and the space below allows the system to cool down by itself.

First, select the module mounting system for beam /pole installation. Mounting refers to the process of installation or setting up of PV modules on pre-prepared mounting structures on the ground or the roof. Each PV array requires a mounting structure to stand on the ground or the roof. Mounting elements involve:

- Poles that need to be installed directly in the ground or embedded in the concrete structure depending on the type of soil
- Mounting structure on which PV modules are fitted
- Steel or concrete base to hold the system

Ground mounting structures can be fixed or can have an adjustable tilt to support the season variants. Technicians have to make decisions and select the type of mounting that are required as per the site conditions.

Step 4. Set up the solar panel stand and solar array rack

The solar array rack is the metal frame on which solar modules will rest. The factory-built mounts have to be assembled as per the company guidelines with bolts so to make one solid structure. This structure will be attached to the pole mounted on the ground. It is important to make sure the structure is attached firmly. Place the array at some height above the ground to avoid shading from any nearby vegetation or unnecessary rodents. Keep in mind that trees and perennial plants will grow taller over the years. If the mounting area is accessible to livestock and other human beings, it is advisable to keep the height much higher.

The Solar panel is a metal framework consisting of I-beams/ circular beams and C-channel that help support the solar panel and keep them inclined at the required angle. Before building the metal stand or framework, one must determine the optimum angle at which one must place solar panels to get the maximum efficiency from the solar system. To get the best out of photovoltaic panels, one need to angle them towards the sun. The optimum angle varies throughout the year depending on the seasons and location and on a month-by-month basis shows the difference in sun’s height.

Fig.1.10: Placing Solar rack

Step 5. Solar Array /Placing the solar modules on the rack/ Adding solar panels

The solar array consists of parallel and series combinations of identical photovoltaic (PV) modules to form the required capacity (kW) to drive the motor and pump. The number of modules in a series generates the required voltage suitable to supply power to the controller and the number of modules in parallel generates the required current. Thus, the series and parallel combination of the modules generate the required voltage and current, respectively, to drive the motor and pump. Figure 1.11 shows a solar array.

Fig.1.11: Solar Panel mounting

First, determine the position where the array needs to be installed. The solar PV array is to be installed carefully at a proper location to avoid shadowing any part of the array or other obstructions throughout the day at any time of the year. The output from the solar array is maximum when solar radiation falls perpendicular to the surface of the module.

The solar angle is the optimum angle at which the panels or pump will receive the maximum sunlight. Angle the panels towards the sun and to find it you can use an online calculator.

Step 6. Tilt angle

A tilted array will receive more light than a vertical array. Any angle between vertical and 15^0 off horizontal can be used. For self-cleansing, a minimum tilt of 15^0 to the horizontal is recommended to allow the rain to wash the dust off the solar panels. For a south-facing panel, the recommended tilt angle is between 15^0 to 60^0. The solar module has to be installed at a tilt angle approximately equal to the latitude of the area. The optimum tilt angle is calculated by adding 15 degrees to your latitude during winter and subtracting 15 degrees from your latitude during summer. For instance, if the latitude is 34°, the optimum tilt angle for solar panels during winter will be 34° + 15° = 49°. The summer optimum tilt angle on the other hand will be 34° – 15° = 19°

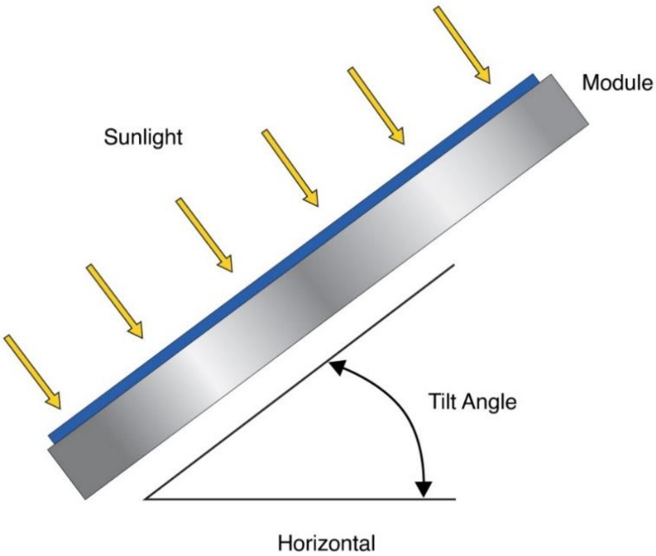


Fig.1.12: Tilt angle

(a) 4-Module-MMS20.

(b)6-Module-MMS

(c) 8-Module-MMS

(d)Side-View

(e) MMS for solar water pumping system

Fig.1.13: (a),(b),(c),(d),(e) Different types of module mounting structures

Standard MMS for 4, 6, and 8 solar modules has been specified. These standard MMS may be used in combinations for different capacities of solar water pumping systems as follows:

1. Standard MMS of 4 Modules for 1 HP
2. Standard MMS of 6 Modules for 2 HP
3. Combination of standard MMS of 4 Modules and 6 Modules for 3 HP
4. Combination of two standard MMS of 8 Modules for 5 HP
5. Combination of three standard MMS of 8 Modules for 7.5 HP and so on

Step 7. Make the electrical connections

Place all PV modules/panels on the rack and do connections of wire with the help of the MC4 PV connector. MC4 connectors are used to connect solar panels. These are universal connectors and can be connected to any type of solar panel. The solar array wiring becomes simpler and faster using MC4 connectors.

Fig.1.14: MC4 connection

Solar panel wiring: PV solar panels can be wired together in series, in parallel, or in a combination of series and parallel to obtain the needed output voltage and current. PV panel wiring generally has two types:

1. **PV panels are wired in series** by connecting the negative terminal of one panel to the positive terminal of the next panel as shown in Figure 1.21. When panels are wired in series, the panel voltages are added.

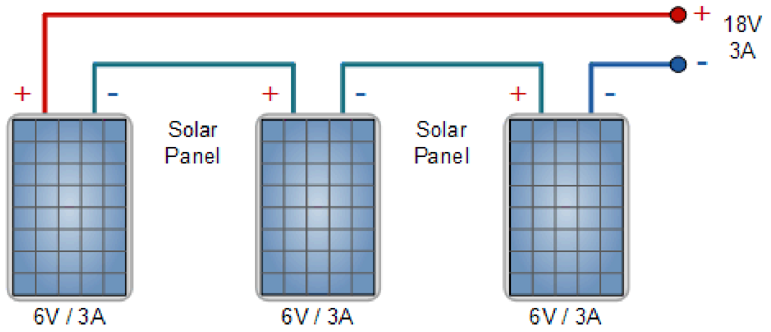


Fig.1.16: PV panels are wired in series

In this method, all the solar panels are of the same type and power rating. The total voltage output becomes the sum of the voltage output of each panel. Using the same three 6 volts, 3.0-amp panels from above, we can see that when these PV panels are connected in series, the array will produce an output voltage of 18 Volts (6 + 6 + 6) at 3.0 Amperes, giving 54 Watts (volts * amps) at full sun.

2. **PV panels are wired in parallel** by connecting all the positive terminals (positive to positive) and all of the negative terminals (negative to negative) until we are left with a single positive and negative connection to attach to the regulator as shown in Fig. 1.22. When panels are wired in parallels, the panel amperes are added.

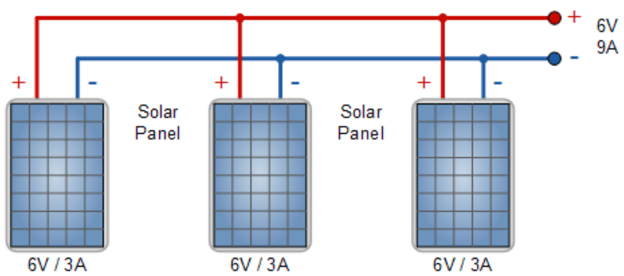


Fig.1.17: PV panels are wired in series

In this method, all the solar panels are of the same type and power rating. Using the same three 6 volt, 3.0 Amp panels as above, the total output of the panels, when connected together in parallel, the output voltage remains at the same value of 6 volts, but the total amperage has now increased to 9.0 Amperes (3 + 3 + 3), producing 54 watts at full sun.

Inverter Installation: The inverter is another major component of the solar PV system. As already explained in the earlier section, an inverter is an essential component in solar photovoltaic (PV) systems. Its primary function is to convert the direct current (DC) electricity generated by solar panels into alternating current (AC) electricity that can be used to power household appliances, commercial equipment, or be fed into the electrical grid. Securely mount the inverter on a sturdy surface using appropriate mounting brackets or hardware. Make sure to follow the manufacturer's guidelines for mounting and ensure that there is proper ventilation around the inverter to prevent overheating.

Connecting DC Input: Connect the DC input cables from the PV array to the input terminals of the inverter. Ensure that the polarity is correct and that the cables are securely connected, using appropriate cable connectors and strain relief devices.

Connecting AC Output: Connect the AC output cables from the inverter to the electrical distribution panel or grid connection point. Again, make sure that the connections are secure and comply with local electrical codes and regulations.

Grounding: Properly ground the inverter according to the manufacturer's instructions and local electrical codes. This typically involves connecting grounding conductors from the inverter to grounding electrodes or the grounding system of the building.

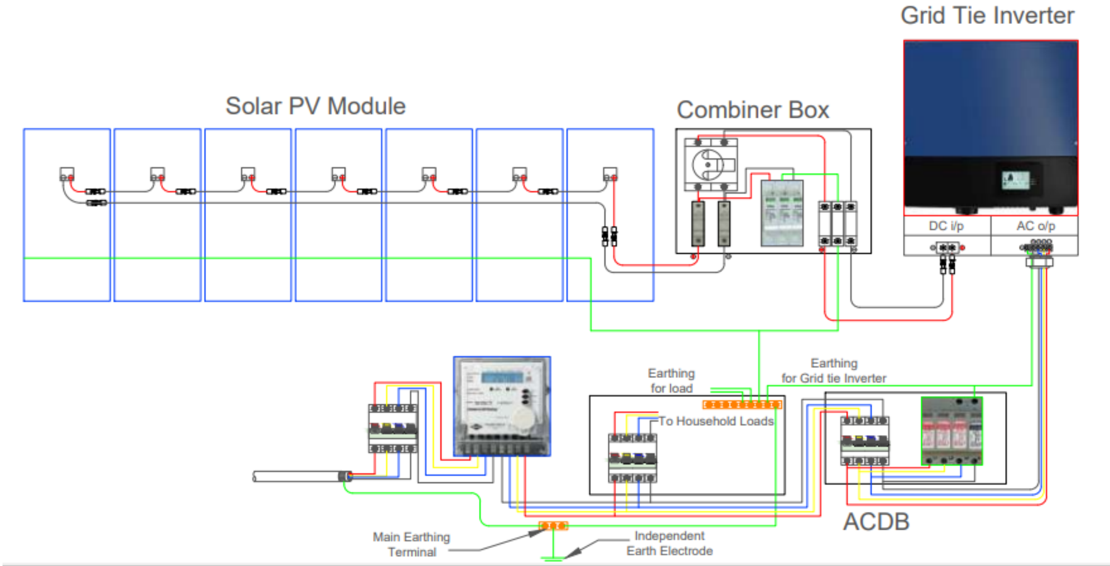


Fig.1.18: Typical circuit diagram of AC/DC Connection

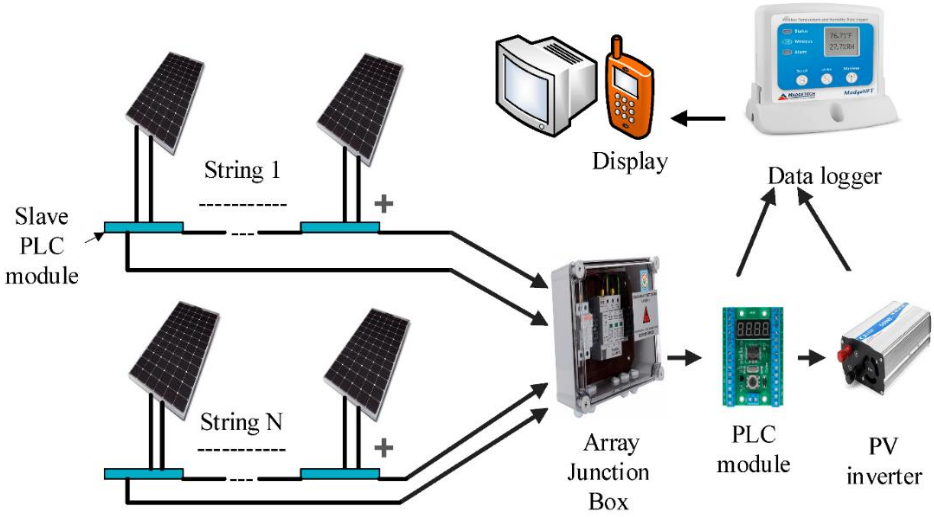


Fig.1.19: Solar PV System with monitoring system

SESSION 04

Practical Exercises

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

Check Your Progress

A. Short Answer Questions

1. Which direction is the face of solar module mount in India?

2. Why do we tilt solar panels?
3. What is parallel wiring?
4. Write all the steps of Solar PV system installation.

B. Fill in the blank

1. …………… are used to connect solar panels.
2. Setting the solar module at the …………………… Increases the power output.
3. The ………………… takes DC inputs from the solar PV array and supplies pulsating DC or variable frequency AC to the motor.

C. Multiple Choice Questions

1. The series connection of PV module is used for
   a) Increasing the voltage
   b) Decreasing voltage
   c) Increasing voltage and current remain same
   d) Increasing current
2. The parallel connection of PV module is used for
   a) Increasing the voltage
   b) Decreasing voltage
   c) Increasing voltage and current
   d) Current increasing and voltage remain same
3. Which direction is best for solar power/ radiation in India?
   a) East
   b) North-west
   c) South east
   d) South

4. Which factors that affect the output of Solar Power System:
   a) Tilt angle
   b) Cleanliness of Solar Panel Surface
   c) Weather Change
   d) all of the above

Module 2	Repair and Maintenance of Solar PV System
Module Overview	
This module provides essential knowledge and skills for maintaining solar PV systems, focusing on the procedures for cleaning, testing, and inspecting solar panels. Students will learn how to ensure the optimal performance and longevity of solar PV installations through regular maintenance and fault detection.	
Learning Outcomes	
• Describe the procedure of cleaning and testing solar panel • Checking of solar panel mounting systems and identifying the different faults in the solar PV system	
Module Structure	
Session 01: Cleaning and Testing of Solar Panel Maintenance	
Session 02: Checking and Identifying the Different Faults in the Solar Panel System	

SESSION 01: CLEANING AND TESTING OF SOLAR PANEL MAINTENANCE

Solar photovoltaic panel cleaning technology can considerably increase the efficiency of electricity generation and also increase the durability of solar panels. The various cleaning methods, such as electrostatic cleaning systems, super hyperbolic coating methods, mechanical methods, microcontroller-based automatic cleaning methods, self-cleaning nanodomes, and various characteristics of dust particles are discussed in this session. This unit throws light on various cleaning methods for solar photovoltaic panels and maintenance of solar water pumping system. Before cleaning the solar panel, follow the instructions given below –

- Never use an abrasive sponge or soap for your solar panel cleaning as may scratch the glass. The best way to clean solar panels is by using a soft rag or biodegradable soap.

- It is important not to use harsh materials when cleaning solar panels as they could cause damage, and solar panels are costly to repair.
- For your safety and the safety of others around you, use a long-handled wiper to clean the panels while you are standing on the ground.
- If you must get on the roof, take proper care as once you begin cleaning, the roof becomes slippery and you could slide off when you get down, so use safety ropes or a harness for support.
- Always watch out for dirt on the solar panels to make sure it does not build up because solar panels can absorb sunlight better when they are free of dirt.

Some methods of cleaning solar panels are as discussed below:

1. Cleaning Solar Panels surfaces with a soft brush or a sponge

In this method, use a foam base brush or a sponge. Generally, using soft brush one can clean 10-20 solar PV panels effectively. It is the simplest way to clean the panel.

Fig. 2.1: Clean Solar Panels surfaces with a Soft Brush or a Sponge

2. Cleaning with Power washing

High-pressure water flushing is the process of cleaning a solar panel by spraying it with water from a nozzle. Power washing with plain water is the best method because it is quick and effective, but it is risky. The glass/metal seal on the front of the modules cannot withstand the potential force from power washing, and forcing water into the module will almost certainly destroy it and void the warranty. However, believe that with caution, power washing can be effective. When the modules are hot, do not spray them with water. The glass may break, and even if it does not, you may cause damage to the metal/glass.

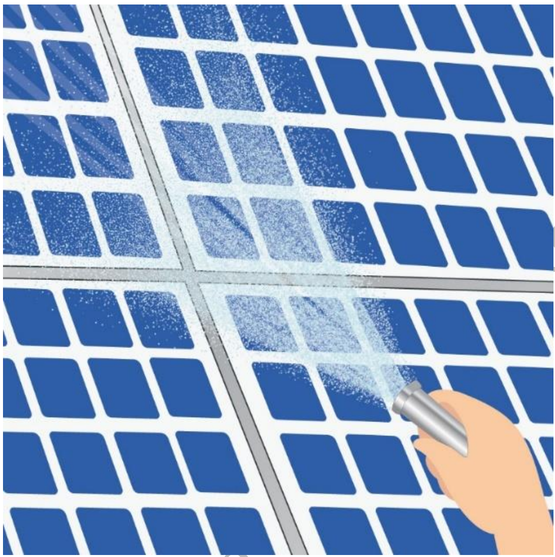


Fig.2.2: Cleaning with Power washing

3. Photovoltaic cleaning machines powered by electricity (semi-automatic)

This technology is used in small and medium-sized solar panel arrays. It is easy operation and has high-cost performance. A typical diagram is shown below in fig. 2.3

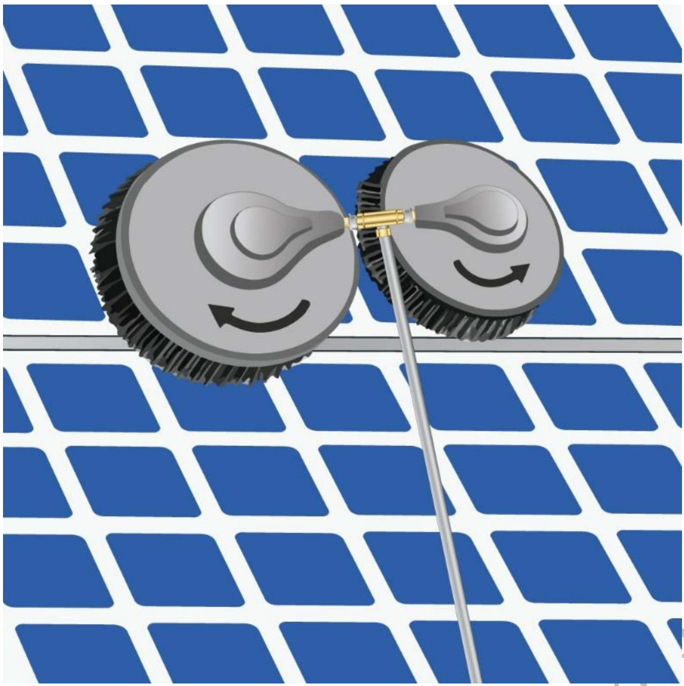


Fig. 2.3: Cleaning machines powered by electricity

4. Automatic cleaning

Technology now allows the automatic cleaning of solar panels without the use of water or labour. The system takes advantage of the fact that most dust particles have an electric charge, which is especially useful in dry environments. The entire panel vibrates to shake dust loose.

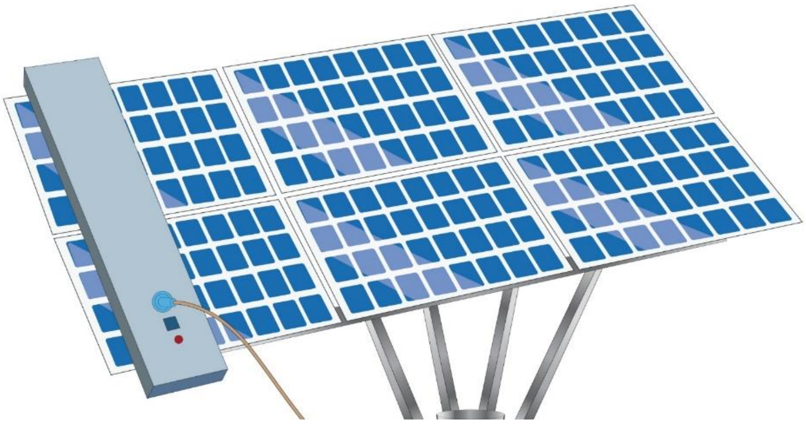


Fig. 2.4: Automatic cleaning

TESTING OF SOLAR PANEL

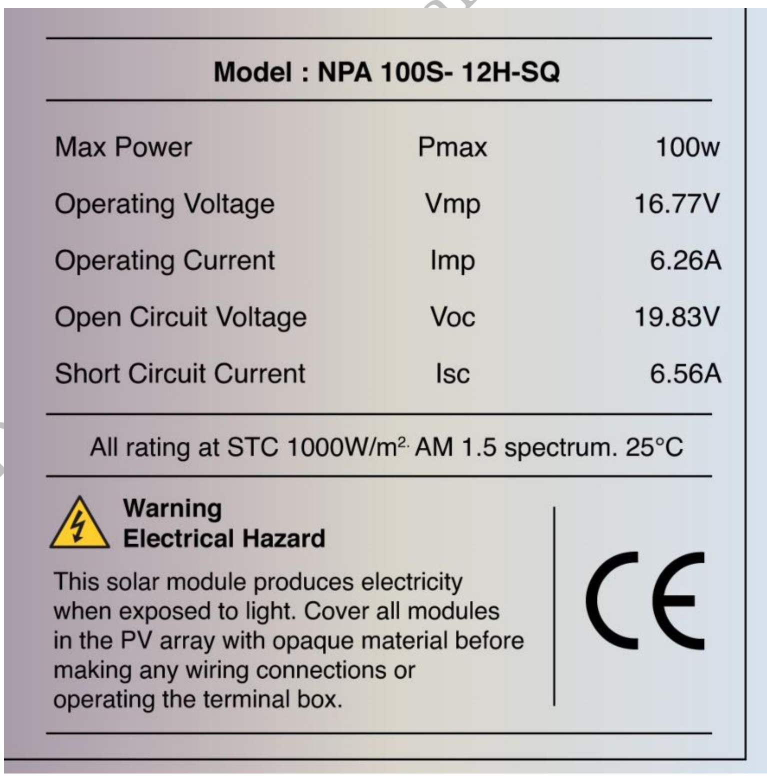
Solar panel testing is key to assuring both the quality and safety of a module. Solar panels have a long lifespan; properly built and installed equipment should generate usable electricity for more than 25 years. Given the longevity of the investment, it is important to make sure that any equipment on the roof will perform well and operate safely on the roof.

The power rating of a solar panel is given by the manufacturer and the number simply represents the amount of power that the solar panel is capable of producing under the most ideal conditions. However, in reality, solar panels are rarely exposed to ideal conditions for more than a few hours per day.

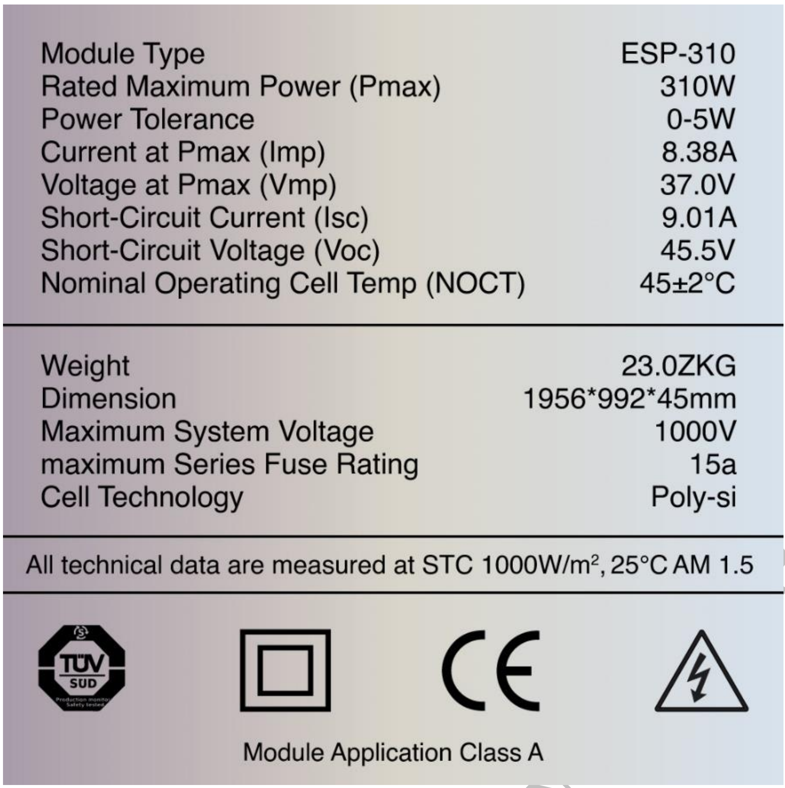
Essentially, testing your solar panels will allow you to make sure that they are generating enough power to meet your needs and let you know if you need to reinstall them so you can optimize their performance and get the highest possible amount of solar electricity out of your system.

One can measure the following term of solar panel with the help of a multimeter-

- Open Circuit Voltage (V_{OC})
- Short circuit Current (I_{SC})
- Operating current



(a)

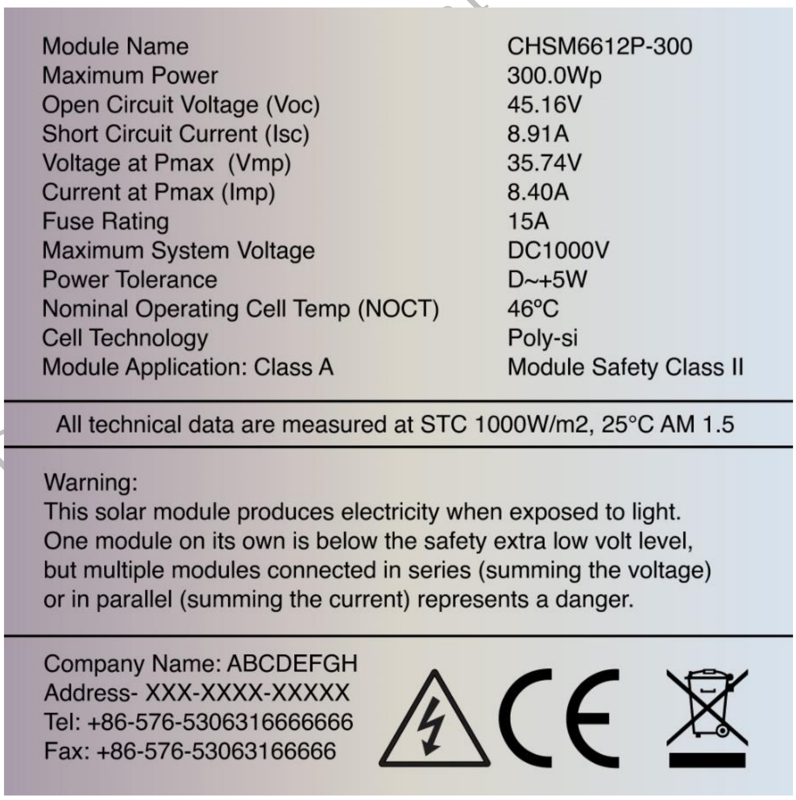


Module Type	ESP-310
Rated Maximum Power (Pmax)	310W
Power Tolerance	0-5W
Current at Pmax (Imp)	8.38A
Voltage at Pmax (Vmp)	37.0V
Short-Circuit Current (Isc)	9.01A
Short-Circuit Voltage (Voc)	45.5V
Nominal Operating Cell Temp (NOCT)	45±2°C
Weight	23.0ZKG
Dimension	1956*992*45mm
Maximum System Voltage	1000V
maximum Series Fuse Rating	15a
Cell Technology	Poly-si

All technical data are measured at STC 1000W/m², 25°C AM 1.5

Module Application Class A

(b)



Module Name	CHSM6612P-300
Maximum Power	300.0Wp
Open Circuit Voltage (Voc)	45.16V
Short Circuit Current (Isc)	8.91A
Voltage at Pmax (Vmp)	35.74V
Current at Pmax (Imp)	8.40A
Fuse Rating	15A
Maximum System Voltage	DC1000V
Power Tolerance	D~+5W
Nominal Operating Cell Temp (NOCT)	46°C
Cell Technology	Poly-si
Module Application: Class A	Module Safety Class II

All technical data are measured at STC 1000W/m2, 25°C AM 1.5

Warning:
This solar module produces electricity when exposed to light.
One module on its own is below the safety extra low volt level,
but multiple modules connected in series (summing the voltage)
or in parallel (summing the current) represents a danger.

Company Name: ABCDEFGH
Address- XXX-XXXX-XXXXX
Tel: +86-576-5306316666666
Fax: +86-576-53063166666

(c)

Fig.2.5: 1,2,3 A typical solar panel specification

- **Open Circuit Voltage (Voc):** When the maximum load is connected to a PV device (resistance = infinite), a PV device produces maximum voltage and zero current. This maximum voltage is referred to as its open-circuit voltage, Voc. Locate the open-circuit voltage (Voc) on the specs label (as per the Fig.2.3) on the back of your solar panel. Remember this number for later. For example, we are now using the Newpowa100W 12V panel. It has a V_{oc} of 19.83V. Now, prep your multimeter to measure DC volts. To do so, plug the black probe into the COM terminal (common terminal) on your multimeter. Plug the red probe into the voltage terminal. Set your multimeter to the DC voltage setting (and the correct voltage range if yours is not auto-ranging). It is indicated by a solid line above a dotted line next to the letter V. Locate the positive and negative solar panel cables. The positive cable is typically the one with the male MC4 connector, which has a red band around it. Touch the red probe of your multimeter to the metal pin inside the positive MC4 connector. Touch the black probe to the metal pin inside the negative MC4 connector. Read the voltage on your multimeter and compare it to the open circuit voltage (V_{oc}) listed on the back of panel. (If voltage reading is negative, reverse the probes and measure again.). We measured a V_{oc} of **19.85V** on panel. The claimed V_{oc} for this panel is 19.83V, so were spot on. The voltage measure with multimeter should be close to the open circuit voltage listed on the back of the panel. It does not have to be identical, though.

- **Short Circuit Current (I_{sc}):** When zero load is connected to a PV device (resistance = zero), the device produces maximum current and zero voltage. This maximum current is referred to as short-circuited current (I_{sc}).
  Locate the short circuit current (Isc) on the specs label on the back of the panel. Remember this number for later. Panel's I_{sc} is **6.56A.**
  Prepare your multimeter to measure amps. To do so, move the red probe to the amperage terminal. Set multimeter to the amp setting (A), choosing the right limit if yours is not auto-ranging. The short circuit current you are measuring should be close to the one listed on the back of the panel. We measure 6.53A. It is similar to the (I_{sc}) listed on the back of the panel, panel is working fine.
- **Operating Current:** When different load connected to a PV device (varying

resistance) to measure the current, can use a multimeter. Again, these devices are affordable and worth investing, if you are running a solar power system. They can also be found at most hardware and automotive stores. If want to make sure are getting an accurate reading; you will also need to use a variable resistor box. These devices allow you to get readings at different levels of resistance.

Once you have the appropriate tools, you can use the multimeter to test your solar panels by following these steps:

- Locate the junction box (protected enclosure for electrical wiring)/converter box, which is usually located at the back of the solar panel. If it has a cover, remove it.
- Locate the positive and negative connectors and make sure are certain you know the difference. Consult the instruction manual for your solar panel if they are not clearly marked, or if you are unsure that you have correctly identified them.
- Make sure solar panel is receiving the same amount of sunlight that it normally would.
- Set the multimeter to read DC power (DC Voltage and DC current respectively). Also set the multimeter to measure a voltage level that is suitable for solar panel, meaning will want to set it higher than the voltage rating the solar panel has. This will make sure can get an accurate rating and the multimeter itself is not interfering.
- Connect the multimeter to the solar panel correctly, meaning the positive and negative clips of the multimeter are connected to the correct connectors.
- Note the voltage reading. Once you have your reading, turn the multimeter off, then you can disconnect the device from your solar panel.
- Following the steps above should give an accurate reading of the solar panel voltage. If are testing a fairly new solar panel in conditions where it is receiving adequate sunlight, the voltage should be fairly similar to the voltage rating the solar panel had when panel is in good working condition.

MAINTENANCE OF SOLAR WATER PUMPING SYSTEM

Routine maintenance: Once the solar pumping scheme has been installed and commissioned, several simple actions are to be followed by the owners of the system to prevent failure of the water supply due to an unexpected system shutdown. Routine maintenance activity is similar to the daily tasks that need to perform while operating the solar water pumping system. Inspection is required day to day or during the week to check if, all components are working and damage-free. Follow the below chart for schedule maintenance.

Table 2.1 Routine Maintenance for SWPS (solar power pumping system)

INSTRUMENTS	ACTIVITY	TIME
Solar panel	Cleaning	Weekly and monthly/when dirty
	Trimming trees	If needed to avoid shadow
MMS	tightening of clamps and nuts and bolts	If needed
Inverter	Reading	Once a month
Piping system for cleaning	Inspect water piping, repair	Fortnightly
Wiring	Fault of wiring	Once a quarter Once a year

Preventive maintenance: A fundamental element of maintenance services, preventive maintenance involves regular visual and physical inspections as well as verification activities to comply with the operating manuals. The preventive maintenance plan details a list of inspections that should be performed at predetermined intervals (typically quarterly, biannually, or annually) by a technician with specialized knowledge. Further, the tracking records of preventive maintenance carried out will optimize activities. The maintenance contract should include this scope of services and each task frequency. Ideally, such a contract will be negotiated together with the installation contract. It is the responsibility of the contractor in charge of maintenance to prepare the preventive maintenance plan for the duration of the contract period.

SESSION 01

Check Your Progress

A. Short Answer Questions

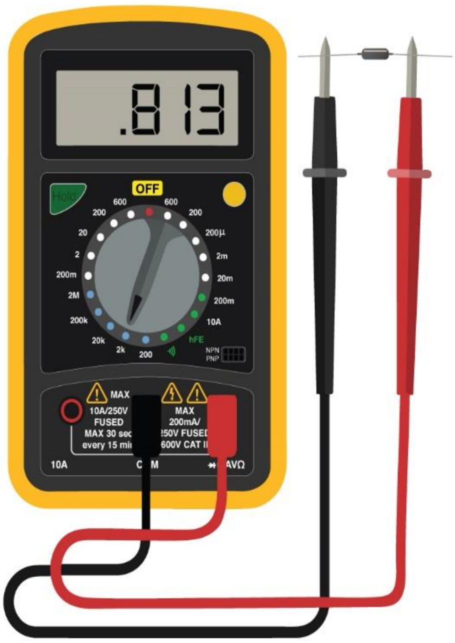
1. Explain the importance of maintenance.
2. What is the Open circuit voltage?
3. Which parameter of the solar panel is measured by a multimeter?
4. Discuss the various cleaning methods of solar panels.
5. What do by short circuit current?

B. Fill in the blank

1. A digital multimeter is used for checking............
2. Unit of current is ....
3. Junction box is ....
4. .... setting should be used to test a fuse.

C. Multiple Choice Questions

1. Identify this equipment



a) Pyranometer
b) Multimeter
c) Ammeter
d) Voltmeter

2. The **"Ω"** symbol is used for

a) Current
b) Ohm
c) Voltage
d) AC Current

3. When zero load is connected to a PV device means
   a) Zero current
   b) Zero resistance
   c) Zero voltage
   d) None of the above
4. Which setting should be used to test a fuse?
   a) Continuity
   b) Voltage
   c) Current
   d) hFE (Hybrid parameter forward current gain, common emitter)
5. What does 1 displayed on the left-hand side of the screen show?
   a) 1 A
   b) 1 V
   c) 1 Ohm
   d) Out of Range

SESSION 02: CHECKING AND IDENTIFYING THE DIFFERENT FAULTS IN THE SOLAR PV SYSTEM

Regular maintenance of the equipment is one of the most important aspects of any electrical or mechanical system. Maintenance of equipment helps in increasing the efficiency and output capacity of the system. When equipment runs efficiently, the project achieves the desired goal. Timely maintenance helps you in avoiding unscheduled delays and issues in the system.

Solar PV systems, like any other system, also require regular monitoring and maintenance to ensure that the consumer has the regular electricity generation and does not suffer an untimely breakdown of the system. However, solar panels require very minimal maintenance as compared to other equipment.

The following points describe the importance of maintenance of solar water pumps:

- It increases the shelf life of your equipment by a significant amount.

- It increases the capacity and efficiency of your system.
- It delays the cost of purchasing your next equipment.
- It saves fuel and other resources due to less loss of energy in the well-maintained equipment.
- Some instruments emit hazardous gases and waste when not maintained properly or when they become old.
- It ensures the safety of equipment and from any dangerous incidence.
- Timely maintenance fixes the issues like leakages, loss of power, part failure etc.

CHECKLIST OF MAINTENANCE

For Modules and Arrays

- Check the conformity of the solar modules/arrays as per the specifications.
- Compare the number of modules in the array with the design specified.
- Check if there are any shade problems due to vegetation or new building. If so, arrange for removing the vegetation or moving the panels to a shade-free place.

Fig 2.6: Shade Problems

- Check the inclination of the panel as per the season and output.
- Ensure that no module is broken, twisted, scratched, or cleaned. If it is broken, repair it (Fig. 2.7).

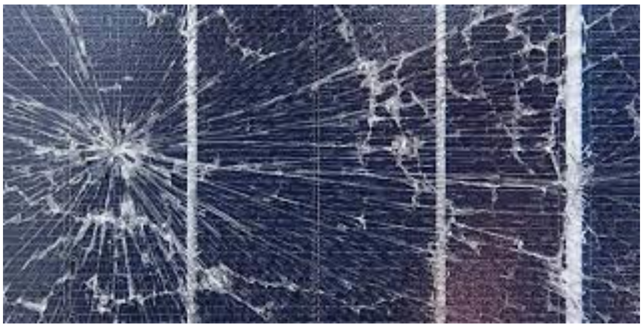


Fig 2.7: Broken glass of solar panel

- Measure the voltage output from each string and ensure it is consistent for all the modules.
- To check the performance of the PV module, check the short circuit current (I_{sc}).
- Check the modules mounted are attached properly and all bolts are intact.
- Ensure the mounting structure is not rusted including bolts.

For Wiring and cables

- Ensure all cables are sealed and installed properly.
- Ensure for no broken cables.
- Check that there is no naked cabling and that all cable connections are inside the junction boxes.
- Ensure all cable structures are sufficiently tight and tied with cable ties to the structures.

Fig 2.8: Cable defect

- Check the grounding rods for earthing and any kind of damage.
- Cables are not within reach of children or human beings and are above the ground.

For Solar support structure

- Ensure that the supporting structure is installed firmly with all bolts.
- Ensure that there is no corroded part in the structure and ensure regular painting of the structure to avoid exposure.
- Check the place around the structure. It should be clean and easily accessible.

For Inverter/Controller/ VFD

- Check the conformity of inverter specifications.
- Check if the inverter is correctly installed and is above the ground.

- Make sure that the inverter is well protected from adverse conditions and is placed in a well-ventilated room. Investors should not have open holes to prevent the entry of any insects and rodents.
- Ensure that all devices are protected that are installed in the solar pumping system whether it is a PV array or inverter. Install proper DC connects, breakers, earthing, short circuits, surge protectors, etc.
- Verify inverter supplies current to the load.

Steps to follow to check invertor:

- Always wear the electrical insulation gloves.
- Turn off the disconnect switches 1 and 2.
- Use a clamp-on ammeter (AC) on the AC side.
- Connect the voltmeter (Not the ammeter) to the battery terminals (remember: Ammeter short circuit's the battery and the fuse blows).
- Turn on the disconnect switches 1 and 2.
- Observe if voltage and current flowing to the load. If yes, the inverter works properly.

For PV system

- Check the conformity of solar panel and inverter specifications.
- Check on the pump setting and connections.
- Check the depth specifications matches with the original.
- Ensure all DC/AC connections are tight on joints.
- Ensure the settings like the voltage, output, etc.
- Check the performance of the inverter in terms of input and output voltage, current and units.
- Check the mounting points are firm and steady.
- Inspect the other electrical and mechanical components for seal, insulation
- Inspect the pump for any leakage.
- Inspect the couplings.
- Inspect and clean filters.

MONITORING THE TECHNICAL ISSUES AND REPAIR OF THE SOLAR PV SYSTEM

Troubleshooting

Troubleshooting provides an overview of the key failures that are often reported in the field. The studies indicate that

- the batteries failed within 2 years due to improper maintenance,
- the inverters failed due to poor design and
- the charge controllers failed the batteries due to improper voltage set points.

One of the case studies clearly recommends purchasing only certified products according to quality standards. It is not only important to train the personnel but also important to retain the trained workforce for the sustainability of the programs.

Inverter Failure

- As per one of the research studies, out of 90 water pumping systems investigated, 22 have hardware failures and 70% of this failure is due to poor inverter design.

Charge Controller Failure

In Solar Home Systems (SHS), most problems were related to charge controller set points.

- Quality Standard: Bad quality SHS components were reduced by World Bank Quality Standard in Western China
- Capacity Sustainability: All the staff present during installation training had been transferred to other health centres at the time of the real system installations
- Disconnect between system usage and system design.
- Lack of understanding about the limitations of the PV system.
- Serious lack of maintenance.
- Lack of attention to maintenance priorities..
- No maintenance policy.
- Lack of local capacity to offer maintenance services recommendations.
- Consult and educate end-users on good operational behaviour.
- Make maintenance a priority.
- Develop, and promote maintenance policies.

- Train local technicians and encourage entrepreneurial activity.
- Train end-user to perform routine maintenance.
- Allocate budgets for maintenance, as well as for training.

Battery terminal corrosion

- Insist on ensuring maintenance in every single installation

Common Failures — PV Modules

- PV module - Low or no power output

Causes

- Wrong orientation (wrong tilt angle)
- Accumulation of dust
- Crack in the glass lamination
- Shadows
- Climate condition
- Short circuit of bypass diode
- Loose connection of wires
- Theft

Check for the following:

- Rectify orientation and tilt angle
- Clean PV with water, detergents are not needed
- Tighten loose connections at the terminal box
- Shadowing at PV module between 9 am—3 pm
- Bypass diode

Table 2.1 Troubleshooting points

S.No	Possible Reason	Check Point	Solution
1.	Loose connection	Terminal	Reconnection/Retightening
2.	The set voltage is shifted	HYD and LYD setting	Rectify setting
3.	Malfunction of C/C	Operation of C/C	If bad, Contact the engineer
4.	Damage to the PV module	Condition of PV module	If bad, replace it

5.	Damage of cable	Condition of cable	Repair/Replacement
6.	Shadow on PV module	Surrounding condition	Removal of the source
7.	Dirt on the PV module	The surface of the PV module	Cleaning

Maintaining Log Books:

Solar pump technicians should maintain the log books of each site installation and maintenance. Following are the checkpoints that need to be maintained in the log book:

- System documentation
- PV system layout and diagram
- Details of the installation date and specifications of each component installed
- Warranty of products
- Record of all the purchases, contracts, and vendor details
- Output parameters of the system
- Connections of the PV system
- Diagram of wiring and earthing being done

Single Line Diagram: This shows the specification of all the electrical flow which is important for maintenance and troubleshooting Regular report of power generation, any issues, and follow-up dates.

Maintenance Documentation

- List of services included in the contract with vendors, installer, and their period of service and rates.
- Monitoring Records: These need to be maintained and monitored regularly to ensure the efficiency of the system.
- Contact information of all stakeholders: Vendors, Installation, Plumber, Electrician, etc.

Component Documentation

- Detailed datasheets of all the components: PV modules, inverters, battery, etc. These will have all the details about your components, their classification, their performance, and their capacity.

- Warranty certificates.
- Other certificates like subsidies by the government, safety, insurance, etc.

SESSION 02
Practical Exercise

Check Your Progress

A. Short Answer Questions

1. Solar panel not generating voltage properly. Write a minimum of three possible reasons.
2. What will happen if the solar panel got damaged?
3. Write the different Troubleshooting points of Solar PV System
4. Write the checkpoints that need to be maintained in the logbook.

B. True and False

1. Grid-connected Solar PV systems are designed to generate electricity for on-site use as well as to feed excess power back into the grid.
2. Always check the voltage between any conductor and any other wires, and to the ground. Do not touch the conductive part by a wet hand.
3. These systems require inverters to convert the DC power generated by the solar panels into AC power suitable for use in homes or to be exported to the grid.
4. Grid-connected solar PV systems typically require batteries to store excess energy generated during the day for use at night.
5. Grid-connected solar PV systems can help reduce greenhouse gas emissions by generating clean, renewable energy and reducing reliance on fossil fuels.

C. Match the Columns:

POSSIBLE REASON	SOLUTION
1) PV module is not working	a) Cleaning
2) Shadow on PV module	b) Repair/Replacement
3) Dirt on the PV module	c) If bad, replace it
4) Cable Damage	d) Removal of the source

Module 3	Cost Economics of Solar PV Systems and Business Opportunities
Module Overview	
This module explores the financial aspects of Solar PV systems, focusing on cost analysis and the economic factors that influence solar energy projects. It also explores into the business strategies and opportunities in the solar industry, including an overview of government schemes and policies that support solar energy adoption.	
Learning Outcomes	
• Calculate the cost of the solar power plant and installation cost. • Describe the business strategies, government scheme, and policy • Explain the different marketing strategies- add on, Solar Panel System spare parts • Describe about work effective and annual maintenance	
Module Structure	
Session 01: Cost Economics	
Session 02: Business Strategies and Government Schemes and Policy	

SESSION 01: COST ECONOMICS

"Solar energy is free, but it's not cheap" is the major hurdle for the solar industry. There are no technical obstacles peruse to developing solar energy systems, even at the utility mega Watt level. However, at such large scales a high initial capital investment is required. Over the past three decades, a significant reduction in the cost of solar products has occurred, without including environmental benefits; yet, solar power is still considered a relatively expensive technology.

Early industrial society and modern agriculture were founded on fossil fuels (coal, oil, and gas). But, now world is making a gradual shift throughout the twenty-first century from burning fuels to technologies that harness clean energy sources such as the sun and wind. As the modernization of developing countries raises the energy demand and constricts the fossil fuel supplies, alternatives will forcibly introduced due to the increased fuel prices.

The cost of technologically driven approaches to clean energy will continue to fall and become more competitive. Eventually, clean energy technologies will be an inexpensive solution. As the full effect and impact of environmental externalities, such as global warming, become apparent; society will demand cleaner energy technologies and government policies that favour the development of a clean-energy industrial base. By the end of the twenty-first century, clean-energy sources will dominate the landscape. This will not be an easy or cheap transition for society, but it is necessary and inevitable.

Solar energy is cost-effective for many urban and rural applications. Solar panel systems are very competitive, with typical paybacks from 3.5–6 years. We can be achieved this through energy conservation than solar energy usage alone for reducing carbon emissions. The decision to use a solar energy system over conventional technologies depends on the economic, energy security, and environmental benefits expected. Solar energy systems have a relatively high initial cost; however, they do not require fuel and often require little maintenance. Due to these characteristics, the long-term life cycle costs of a solar energy system should be understood to determine whether such a system is economically viable. Historically, traditional business entities have always expressed their concerns in terms of economics. An economical analysis should be considered while looking at life cycle costs rather than at just the ordinary way of doing business and low initial costs. Life cycle costs refer to all costs over the lifetime of the system. In addition, all the incentives and penalties for energy entities should be considered. What each entity wants is to earn subsidies for itself and penalties for its competitors. Penalties come in the form of taxes and fines whereas incentives may in the form of tax breaks, unaccounted social and environmental costs, and what the government (society) could pay for research and development.

Life cycle costs: Life cycle cost (LCC) is an approach that assesses the total cost of an asset over its life cycle including initial capital costs, maintenance costs, operating costs, and the asset's residual value at the end of its life.

CALCULATE THE COST OF SOLAR PANEL INSTALLATION

The cost of solar panel installation can vary significantly depending on various factors such as location, size of the system, type of panels, mounting equipment, labour costs, and any additional features or services. Additionally, government incentives, rebates, and tax credits can also influence the overall cost. Here is a general breakdown of the factors affecting the cost:

1. **Size of the system**: The size of the solar panel system is typically measured in kilowatts (kW) or megawatts (MW). Larger systems will generally cost more.
2. **Type of panels**: There are different types of solar panels, such as monocrystalline, polycrystalline, and thin-film. Each type has different costs associated with them.
3. **Mounting equipment**: This includes the racks or frames used to mount the solar panels, as well as any additional equipment required for installation, such as inverters and wiring.
4. **Labour costs**: Labour costs can vary depending on the complexity of the installation, local labour rates, and the experience of the installers.
5. **Permitting and Inspection fees**: There may be fees associated with obtaining permits and inspections from local authorities.
6. **Additional features**: Optional features such as battery storage systems or monitoring systems can add to the overall cost.

Because of this, the economic analysis of solar panel systems is important.

Solar panel system costs depend upon the following factor - like PV array, Inverter, Controller, Panel structure, DCDB/ACDB, Interface electronics, Connecting cables & switches, Location, Support structure & tracking system, etc. Now, we can calculate the 10kW GRID connected solar system's cost. The total cost (before subsidy) for installation and commissioning of the 10kW GRID connected solar system varies by type, brand, and rating. Generally, the installation cost of solar panel system is approx. four lakhs (without subsidy).

Following are the benchmark costs for grid connected solar systems for the year 2023-24 are given in Table 3.1.

Table 3.1 Capacity-wise benchmark cost of Solar panel system

Solar Panel System Capacity	Type of system	Benchmark Cost (Rs.)	
		General Category States/ union territories of India Per KW	North Eastern States/Hill States & union territories of India / Island UTs Per KW
UP TO 1 KW	Grid Connected	47000	52000
2 KW	Grid Connected	43000	47000
3 KW	Grid Connected	42000	46000
4 to 10 KW	Grid Connected	41000	45000
Above 10 KW	Grid Connected	40000	42000

All the above benchmark costs of the system as per MNRE specification inclusive of the total system cost and its installation, commissioning, transportation, insurance, comprehensive maintenance charges for five-year applicable fees and taxes. All the above costs can vary ± 10% to 12% depending on location, availability, and solar brand.

While calculating the cost economics, we may work out the annual cost of operation of a solar water pump and then compare it with the diesel pump set cost and the electric motor-driven pump.

Cost of Solar Photovoltaic (PV) Systems

Solar Photovoltaic (PV) systems convert sunlight directly into electricity. Calculating the economics of a solar PV system is the key to understanding whether an investment in solar is right for your home, business, or farm.

1. Determine if you have a viable site (facing south with little shade).
2. Determine the total installed cost of a system from your local solar installer.
    - Work with the installer to estimate annual production from solar array.
3. Determine your cost of electricity (check your most recent electricity bill).
    - Check state net metering laws.

- Check your local utility's net metering policy (in some cases local utilities have a more generous policy than state law).

4. Calculate simple payback.
5. Determine eligibility for local, state, and federal grants and tax credits.
6. Calculate payback with incentives.
7. Include inflation estimate in your calculations.
8. Calculate internal rate of return and net present value using a spreadsheet or an online calculator.

The price of solar panels has declined in recent years, improving the economics of solar installations. The national institute of solar energy reported that the solar installed costs of ₹50000 per Kilo Watt in year of 2024. The declines have continued with installed costs. Excess electricity also may be sold back to the grid (local power company) or, in the case of net metering, can flow to the grid with the sum used to offset electricity used during other times. Understanding the economics of solar PV systems will be one of the most important considerations when deciding on solar energy.

One should view their solar PV system as an investment. This decision should be made after determining the feasibility of installing a solar system at a specific site. Presently, we focuses on grid-tied PV systems, but the economic calculations will be similar for off-grid or battery-backup systems. Grid-tied systems are connected to the electric grid so that electricity can flow out to the grid when the system is producing more than the load.

To find the total installed cost of a system, consult a solar array installer who can provide the total cost of solar panels, mounting system, inverters, and installation. Make sure you determine total installed costs. All solar systems have many small components beyond the panels that make up the balance of the system and can add to total costs. System components will differ depending on the goals and configuration of the system.

Grid-tied systems are the most common when a load is connected to both the solar PV system and the utility electric grid. Off-grid systems are not connected to the utility electric grid and will need batteries to provide on-demand power. Batteries can be added to a grid-connected system to give backup power during an outage. Note that the addition of batteries is uncommon due to the added cost of batteries and the associated parts. Contact your local utility company first to establish an understanding of its specific policies and protocols for safe installation. You should not assume all utilities follow the same guidelines. Policy and protocol will vary depending whether a company is a cooperative, public utility, or investor-owned utility. Check your electrical provider's cost per kilowatt-hour consumed; this can usually be found on your monthly statement.

After you know all this information, it is best to determine the payback period. A payback period is the length of time required to cover the cost of an investment. Here is an equation that can be used to help determine the payback period for your specific solar system:

Simple Payback Period (In year)

$$\text{Payback Period} = \frac{\textit{Total installed cost of project} - \textit{tax credits, grants, and subsidies}}{(\textit{Estimate of annual produced kilowatt hours}) \times (\textit{grid price per kilowatt hour})}$$

Simple payback period is only a simplistic measure and gives the number of years needed for a system to pay itself off. Consider that modern, high quality solar panels have an expected life of approximately 30 years. However, it is important to refer to the manufacturer's specifications for the exact lifespan. In some cases, the simple payback calculation is not enough because it does not take into account the time value of money and does not measure profitability. Nor does it include price inflation.

For these reasons, it is also important to compute the net present value and internal rate of return for your investment. Net present value compares the difference between present cash outflows and present cash inflows, essentially comparing the value of the rupee's today with that in the future. Internal rate of return is the rate of growth a project is supposed to generate. These can be calculated with Microsoft Excel or with online financial calculators. The mathematical equations are not shown in this document because a key factor in the equations changes based on time and interest rates.

Factors such as the price of electricity per kilowatt-hour and its inflation rate will play a large role in the payback period of a solar PV system. One key example of this is the system size with regard to net metering. When building a system, you should consider sizing it according to how many kilowatt-hours of electricity it can produce. Based on the net metering laws in your location, an undersized system can usually have all electricity produced by the system either used or credited at "retail rate," while an oversized system will likely have some of its production purchased by the utility at an avoided cost rate, which is usually less than half of the retail rate.

Net Metering

MNRE ensures small renewable systems are allowed to connect to the grid. But states and electrical utilities can have different policies on how the excess power is bought and sold. Net metering is a policy in which the "net" electricity usage is used to calculate a bill at the end of the billing period. In the case of net metering, electricity put on the grid offsets electricity used from the grid at other times during the same billing period. For example, the solar electricity will flow to the grid while you are not home (and thus using less power), and the solar electricity will be used first when you return and use electricity. Your bill at the end of the month will represent the "net" amount, referring to how much you used minus how much you produced.

The method of calculation for the net amount will differ with each utility's individual policy. If the renewable system produced more than was used in that month, the excess energy is purchased by the utility at the avoided cost rate (usually much lower than retail).

Other states have net metering laws that allow the excess to roll over each month, only totalling at the end of each year. This annual system allows for balance between a solar PV system's high production in the summer and lower production in winter. Allowing any kind of net metering is a benefit to renewable energy system owners. However, the annual type can be of greater value to the system owner due to the seasonal differences in production and electricity usage, and the ability to bank credits from times of the year when more energy is produced to times when more energy is used.

Solar System Examples:

A 10-kW solar PV system is installed for ₹45000 per Kilowatt. The figures below show an estimated energy output, simple payback period, internal rate of return, and net present value for the 25 years of the project life.

Assumptions:

- Price of electricity: ₹7/kWh
- The electric load exceeds the system-size load (if the load is greater than production, most or all of the electricity produced by solar systems gets used or credited at full retail rate).
- Electricity production is estimated at 15,500 kWh per year. (as per as MNRE Standard)
    - One simple method that works for many Indian sites: (Multiply solar array rating (kW) × 6 hours a day × 365 days a year × 70 percent). The 70 percent takes into account system efficiencies. In this example, this would give 15,330 kWh per year.

Annual Offset Electrical Cost: ₹7/kWh × 15,500 kWh = ₹1,08,500

Total installation cost = ₹45000/kW × 10kW = ₹4,50,000

Simple Payback Period without Incentives:

₹450000/₹108500 = 4.14 years

Payback Including Incentives:

- Ministry of New and Renewable Energy (MNRE) provides subsidy grant (must be farm, ranch, or rural business to qualify; renewable system must be attached to farm, ranch, or rural business)
- The subsidy amounts vary based on system capacity and location. For most regions, solar energy systems up to 3 kW receive a subsidy of up to ₹14,588/kW. Systems ranging from 3 kW to 10 kW get ₹14,588/kW for the initial 3 kW and ₹7,294/kW for the rest. Beyond 10 kW, a fixed amount of ₹94,822 is provided.

Payback Including Incentives:

On 10 kw solar system, one gets a subsidy of ₹94822

Then,

Payback Period=$\frac{\textit{Total installed cost of project} - \textit{tax credits,grants,and subsidies}}{(\textit{Estimate of annual produced kilowatt hours}) \times (\textit{grid price per kilowatt hour})}$

Total installed cost of project = ₹450000

Tax credits, grants, and subsidies = ₹94822

Electricity production is estimated at 15,500 kWh per year.

Grid price per kilowatt hour = ₹7/kWh

Payback Period = 450000 - 94822/(15,500*7)

= 355178/108500

= 3.2 Years.

BUSINESS OPPORTUNITIES:

The global solar water pump market size was USD 2.38 billion in 2020. The market is projected to grow from USD 2.86 billion in 2021 to USD 5.64 billion in 2028 at a CAGR (Compound annual growth rate) of 10.2% in the 2021-2028 period. The global impact of COVID-19 has been unprecedented and staggering, witnessing a negative impact on demand across all regions amid the pandemic. Based on our analysis, the global market exhibited a decline of -18.1% in 2020 as compared to the average year-on-year growth during 2017-2019. The rise in CAGR is attributable to this market's demand and growth, returning to pre-pandemic levels once the pandemic is over. A solar water pump is a system driven by solar energy and pumps water for many purposes, such as irrigation, community water supply, and potable drinking water, and has decreased its reliance on diesel, gas, or coal. These systems are environmentally sustainable and have low fuel-free maintenance requirements. It is one of the most capable applications of solar energy, which can be effective in rural and remote regions in most of the world. With the rise in demand for reliable and clean water supply and agriculture activities, it is anticipated to increase the product demand in the rural area.

India has great potential for solar energy due to geographical advantages. The nearing equator location of the Indian subcontinent ensures all year guarantee for solar radiation. Starting a solar business in India is a lucrative opportunity for budding Indian entrepreneurs. Solar thermal and photovoltaics can effectively harness the capabilities of solar radiation and conversion into heat and electricity.

Few of the recognized and untapped options are opportunities for the solar energy business in India are listed below-

- **Manufacturing Solar products**
- **Solar Panel Installation work**
- **Solar Project Consultants**
- **Solar cleaning and maintenance services**
- **Distribution of Solar products**
- **Solar energy auditing**

Market trend, strategy, and typically available brands of Solar Pump in India

The solar water pump market is now well-established and mature. There are many manufacturers in the market and below is a list of the top ten solar pump brands in India. All of these brands' solar pumps are of high quality and efficiency.

- Tata Power Solar Pump
- Shakti Solar Pump
- Falcon Solar Pump
- Amrut Solar Pump
- Crompton Solar Pump
- Lubi Solar Pump
- Waaree Solar Pump
- Texmo Solar Pump
- Oswal Solar Pump
- KBL Solar Pump

The market is fully dependent on the government's policies. Under the PM Kusum scheme, there are many opportunities for the manufacturers, EPC (Engineering, Procurement, and Construction) players, and service providers as well. The business opportunities include selling the equipment, consultancy, marketing for the reputed brands, installation and commissioning, post-installation service, training and skill development, etc.

METERING PROCESS: An electric meter, or energy meter, is a device that measures the amount of electrical energy consumed by a building, tenant space, or electrically powered appliance. Thus, the process of taking and giving power is called metering.

Electric utilities use electric meters installed at customers' premises to measure electric energy delivered to their customers for billing purposes. They are typically calibrated in billing units, the most common one being the kilowatt hour [kWh]. They are usually read once each billing period.

In the case of a solar system, the metering of electricity is done by two methods:

(i) Gross Metering Method

(ii) Net Metering Method

(i) Gross Metering Method: In gross metering, the fixed price of electricity produced from a solar system is announced by the distribution companies (DISCOMs), and accordingly, the calculation for the payment is done and the producer is compensated.

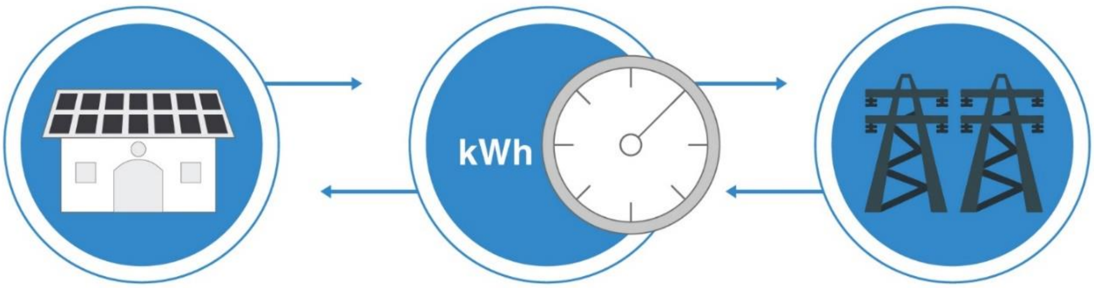


Fig 3.1: Gross Metering Method

(ii) Net Metering Method: In the net metering method, the units of electricity produced by a solar system are taken into account and are adjusted in the electricity bill at the same tariff as that of the electricity being charged in the bill. This net metering is method is being followed in the grid-connected solar rooftop system by most of the states in the country.

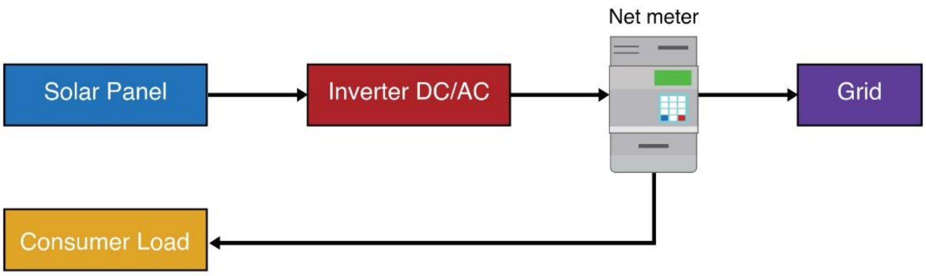


Fig 3.2: Net Metering Method

On a cloudy or rainy day when your panels are not producing enough energy, the utility grid will feed home energy, and count that energy against the credits that have been banked over time. As a solar customer, you will only be billed for your "net" energy usage. Also known as net energy metering or NEM, net metering is the solar industry's foundational policy.

SESSION 01

Check Your Progress

A. Short Answer Questions

1. What do you mean by life cycle cost?
2. What is gross metering
3. Explain the net metering concept.
4. Write the list of five solar water pumping system manufacturers

B. Multiple Choices Questions

1. In……….method, the entire energy generated by your solar system is exported to the grid at a certain rate.
   a) Net metering
   b) Gross metering
   c) a and b
   d) None of the above
2. In……….method, the units of electricity produced by the solar system are taken into account and adjusted in the electricity bill at the same tariff at which the electricity is charged in the bill.
   a) Net metering
   b) Gross metering
   c) Volt meter

d) None of the above

3. The concept of Net Metering is related to
   a) Sewage dumping in the ocean and sea
   b) Electricity lost during distribution
   c) Solar energy generation
   d) Amount of natural gas wasted during transportation
4. The full form LCC …………
   a) Life Cycle Cost
   b) Life Cost Cycle
   c) Life Circle Cost
   d) None of the above

SESSION 02: BUSINESS STRATEGIES AND GOVERNMENT SCHEMES AND POLICY

Business Strategy: A business strategy is the combination of all the decisions taken and actions performed by the business to accomplish business goals and to secure a competitive position in the market.

It is the business's backbone since it serves as a road map for achieving the intended results. Any fault in this roadmap can result in the business getting lost in the crowd of overwhelming competitors.

Importance of Business Strategy: A business objective without a strategy is just a dream. It is no less than a gamble if you enter the market without a well-planned strategy.

With the increase in the competition, the importance of business strategy is becoming apparent and there is a huge increase in the types of business strategies used by the businesses. Following are the five reasons that indicate the importance of strategy in the business.

- **Planning**: Business strategy is a part of a business plan. While the business plan sets the goals and objectives, the strategy gives you a way to fulfil those goals. It is a plan for getting to your desired destination.
- **Strengths and Weaknesses**: For most of the time, we get to know about our real strengths and weaknesses while formulating a strategy. Moreover,

it also helps us capitalise on what we are good at and use that to overshadow our weaknesses (or eliminate them).

- **Efficiency and Effectiveness**: When every step is planned, every resource is allocated, and everyone knows what is to be done, then business activities become more efficient and effective automatically.
- **Competitive Advantage**: A business strategy focuses on capitalising on the strengths of the business and using it as a competitive advantage to position the brand in a unique way. This gives an identity to a business and makes it unique in the eyes of the customer.
- **Control**: A business strategy decides the path to be followed and interim goals to be achieved. This makes it easy to control the activities and see if they are going as planned.

The business strategy is a part of the business plan, which is a part of the big conceptual structure called the business model.

The business model is a conceptual structure that explains how the company operates, makes money, and how it intends to achieve its goals. The business plan defines those goals, and business strategies outline the roadmap of how to achieve them.

Main Components of a Business Strategy:

While an objective is defined clearly in the business plan, the strategy answers all the what-why-who-where-when-and-how questions of fulfilling that objective. Here are the key components of a business strategy:

- Mission
- Vision
- Business Objectives

The main focus of a business strategy is to fulfil the business objective. It gives the vision and direction to the business with clear instructions of what needs to be done, how it needs to be done, and who all are responsible for it. Following are the ways to identify business opportunities within the business:

1. SWOT Analysis

An excellent way to identify opportunities inside your business is by creating a SWOT analysis. The acronym SWOT stands for strengths, weaknesses, opportunities, and threats. SWOT analysis framework:

Fig 3.3: SWOT Analysis

By looking at self and your competitors using the SWOT framework, can uncover opportunities that can exploit, as well as manage and eliminate threats that could derail your success.

2. Establishing Your USP (Unique Selling Proposition)

Establish your USP and position yourself as different from your competitors. Identify why customers should buy from you and promote that reason.

Marketing Strategy: Renewable energy is blowing up in the consumer, commercial, and industrial sectors right now. And the core of that explosion is solar energy. Marketing is a dynamic and ever-changing field. The top digital marketing strategies change with the consumer and technology trends of the day. This is why every company needs a good marketing strategy that is well planned and has well-defined milestones and objectives. Once you have the right map, the chances you will reach the goals you have set for your business, are much higher.

Market research is the process of gathering, analysing, and interpreting market information on a product or service that is being sold in that market. It also includes information on:

- Past present, and prospective customers
- Customer characteristics and spending habits

- The location and needs of the target market
- The overall industry
- Relevant competitors

Market research involves two types of data:

1. **Primary information**: Research data is collected by yourself or by someone hired by you.
2. **Secondary information**: Research data already exists out there for you to find and use.

Fig 3.4: Marketing plan

Primary research can be of two types:

- **Exploratory Research**: This is open-ended and usually involves detailed and unstructured interviews.
- **Specific Research**: This is precise and involves structured, formal interviews. Conducting specific research is more expensive than conducting exploratory research.

Secondary Research: Secondary research uses outside information. Some common secondary sources are:

- **Public sources**: These are usually free and have a lot of good information. Examples are government departments, business departments of public libraries, etc.
- **Commercial sources**: These offer valuable information but usually require a fee to be paid. Examples are research and trade associations, banks and other financial institutions, etc.
- **Educational institutions**: These offer a wealth of information. Examples are colleges, universities, technical institutes, etc.

THE 4 Ps OF MARKETING:

The 4 Ps of marketing is marketing is a concept that summarizes the four basic pillars of any marketing strategy.

The four Ps of marketing are:

Product: What you sell. Could be physical goods, services, consulting, etc.

Price: How much do you charge and how does that impact how your customers view your brand?

Place: Where do you promote your product or service? Where do your ideal customers go to find information about your industry?

Promotion: How do your customers find out about you? What strategies do you use and are they effective?

Marketing Strategies to Fuel Your Business Growth

- Content Marketing
- Use Videos as Marketing Tools
- Social Media Marketing
- Email Marketing
- Search Engine Optimization
- Referral Programs
- Industry Events
- Conversational Marketing

GOVERNMENT POLICIES AND SCHEMES:

The current energy requirement in India is heavily dependent on conventional energy sources. The Indian government acknowledges the increasing concern related to climate change and global warming and has recognised the urgent need to address these issues. The promotion of renewable energy and solar industrial growth is one of the key measures taken by the government in this direction. Today, renewable energy is increasingly becoming an integral part of energy security initiatives in India. The Indian government has been promoting the setting up of Renewable Energy based power plants through various policy initiatives and incentives for investors, developers, and consumers. The government had earlier issued the Incentive Policy for Encouraging the generation of power in India through Non-Conventional Energy Sources. The Ministry of New and Renewable

Energy (MNRE) is the nodal Ministry of the Government of India for all matters relating to new and renewable energy. The broad aim of the ministry is to develop and deploy new and renewable energy for supplementing the energy requirements of the country. They provide direct and indirect tax benefits such as sales tax, excise duty exemptions, and custom duty exemptions. A few important policy names are given below-

- Electricity Act, 2003
- National Electricity Policy, 2005
- Tariff Policy, 2006
- Jawaharlal Nehru National Solar Mission (JNNSM), 2010
- The National Tariff Policy, 2016

India is blessed with abundant solar energy potential with 300 days of sunlight. About 5,000 trillion kWh per year of energy is experienced over India's land area with most parts receiving 4-7 kWh per sq. m per day. The government henceforth aims to create solar schemes to use this renewable source of energy efficiently. Below is a list of some of the most successful and known solar schemes in India –

1. ***PM Kusum Scheme***
2. ***Surya Mitra Skill Development Programme***
3. ***Grid-connected Rooftop Scheme***
4. ***Development of Solar Park Scheme***

PM KUSUM Scheme:

(Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan)

The Government of India launched KUSUM Scheme or Pradhan Mantri Kisan Urja Surakshaevam Utthaan Mahabhiyan Yojana in March 2019. This scheme was announced by the Ministry of New and Renewable Energy (MNRE), aiming for growth in income for Indian farmers.

Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan Yojana is a scheme to subsidise farmers to install solar irrigation pumps for cultivation. Each farmer will receive a 60% subsidy to set up tube wells and pump sets. They will also get 30% of the total cost as a loan from the Government.

Objectives of the PM-KUSUM Scheme

The primary objective of the PM KUSUM scheme is to make cutting-edge technology available to our farmers and provide sources for de-dieselised irrigation to the agricultural sector. The main objectives of this scheme are:

1. The solar pumps assist our farmers in much more effective and eco-friendly irrigation as these are capable of generating safer energy.
2. In addition, the pump sets comprise an energy power grid that generates more energy than diesel-driven pumps. Farmers will be able to sell the extra power to our government directly to enhance their income.

Components of the KUSUM Scheme

The KUSUM scheme comprises three components that have different features:

Component A: Install a total of 10 GW grid-connected stilt-mounted decentralised solar plants and other renewable energy-based power plants. Each plant is sized up to 500 kW to 2MW.

Component B: Installation of 17.50 lakh standalone Solar powered agriculture pumps of individual pump capacity up to 7.5 HP.

Component C: Installation of 10 Lakh grid-connected agriculture pumps of individual pump capacity up to 7.5 HP.

Who is eligible for the KUSUM Scheme?

The eligible categories for KUSUM Scheme are:

- An individual farmer.
- A group of farmers.
- Farmer producer organization.
- Panchayat.
- Co-operatives.
- Water User Associations.

Benefits of the KUSUM Scheme:

This scheme provides the following benefits:

- The Indian government initiated the construction of solar plants that can generate an aggregate of 28,250 MW of power.

- The Government will subsidise 60% and provide a loan of 30% of the total cost. This leads our farmers to bear only 10% of the total cost to install solar plants and solar pumps.
- As per the KUSUM Scheme details, our government will provide subsidies to install state-of-the-art solar pumps. They improve irrigation as they hold 720 MW of capacity.
- This scheme offers our farmers an opportunity of selling the extra power generated by the plants directly to our government. This ensures the scope of increase in the income of our farmers.
- A landholder in a rural area can get a stable source of income by utilising barren and uncultivated land for solar plant implementation for 25 years.
- The solar plants will be set up above a minimum height in cultivable lands. This way, our farmers will be able to continue with cultivation after installing the plants.
- KUSUM Scheme ensures increasing the use of renewable energy helps to mitigate pollution in farms and opens a gateway to eco-friendly cultivation.

Documents required for the KUSUM Scheme

- Aadhar card
- A land document including Khasra Khatauni
- A bank account passbook
- A declaration forms
- Mobile number
- Passport size photo

After a successful online application for KUSUM Scheme, farmers must deposit 10% of the total cost to set up a solar pump to the supplier sent by the department. The solar pump set will be empowered after the subsidy amount gets sanctioned, which generally takes 90 to 100 days.

The PM KUSUM Scheme aims to promote the use of renewable energy in the agricultural sector and offer the benefits of solar farming to Indian farmers and farmers can sell the extra energy generated from the solar plants directly to the Government of India. This is one of the greatest benefits of the KUSUM Scheme that will allow our farmers to increase their earnings.

2. Surya Mitra Skill Development Programme

The National Institute of Solar Energy (NISE), an autonomous institution of the Ministry of New and Renewable Energy (MNRE), is the apex National R&D institution in the field of Solar Energy. NISE is organizing “Surya Mitra” skill development programmes in collaboration with State Nodal Agencies, at various locations across the country.

The programme aims to develop the skills of youth, considering the opportunities for employment in the growing Solar Energy Power project’s installation, operation & maintenance in India and abroad. The Surya Mitra Programme is also designed to prepare the candidates to become new entrepreneurs in the Solar Energy sector. The surya mitra skill development programmes are sponsored by the Ministry of New & Renewable Energy, Government of India.

WORK EFFECTIVE AND ANNUAL MAINTENANCE

After the system has been installed and commissioned, the focus shifts to O&M (operation and maintenance) throughout its lifetime. System operation can be optimized by closely monitoring and recording key system parameters (data logging), enabling operators to assess system performance or demand changes.

The supplier provides an annual maintenance contract to the beneficiary after an initial guarantee period of 5 years. The solar panel is expected to provide about 20 years of satisfactory service under normal conditions, even though the cell itself may last much longer. The only maintenance required is occasional washing of the surface to maintain maximum optical transmission through the glass. The panel has to be protected from breakage by external agencies. Some manufacturers cover the cell/array with unbreakable glass. The motor and the pump require the usual periodic maintenance like cleaning, lubrication, and replacement of worn parts.

The contractor will have full responsibility for the repair and maintenance of the solar pumping system already installed at various locations in India. This will include all the minor wear and tear of equipment, regular service of the Pump, and replacement of spares (excluding the items/spares).

The contractor will have to do the periodic check by visiting at least once in a quarter to each pump location and doing the routine check-up and maintenance of the pumps. Other than the periodic visits, contractor has to visit the pump location for repair & maintenance purposes as and when required.

To ensure 100% working status, during the annual maintenance cyclic period, the vender will have to arrange all required instruments, tools, spares, manpower, and other necessary facilities at the local service centre.

The maintenance service provided shall ensure the proper functioning of the SPV water pumping system as a whole. All preventive/routine maintenance required for ensuring maximum uptime shall have to be provided for a specified period.

SESSION 02

Check Your Progress

A. Short Answer Questions

1. Explain the 4Ps
2. Write down a short note on marketing
3. Write a short note on the PM-KUSUM scheme.
4. Create a list of solar schemes
5. Write a short note on Surya Mitra Skill Development Programme

B. Fill in the blank

1. The full form of JNNSM is ....
2. Full form of SWOT ....
3. In Kusum scheme Component "A" Install a total of 10 GW grid-connected stilt-mounted decentralized solar plants and other renewable energy-based power plants. Each plant is a capacity up to...........
4. The Government of India launched KUSUM Scheme or Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan Yojana in the year of **...........**

C. Multiple Choice Questions

1. Under KUSUM Scheme, which component provide the installation of 17.50 lakh standalone Solar Powered Agriculture Pumps of individual pump capacity up to 7.5 HP?
   a) Component A
   b) Component B
   c) Component C
   d) Component D

2. Under KUSUM Scheme, which component provide the installation of 10 Lakh Grid-connected Agriculture Pumps of individual pump capacity up to 7.5 HP.
   a) Component A
   b) Component B
   c) Component C
   d) None of the above

3. What is a skill development programme that aims to develop the skills of youth, considering the opportunities for employment in the growing solar energy power projects?
   a) Surya Mitra Skill Development Programme
   b) Skill India Mission
   c) Make in India
   d) All of the above

4. In SWOT analysis "T" stands ....
   a) True
   b) Threat
   c) Trainer
   d) Team

Module 4	Innovation and Development in Solar Energy
Module Overview	
This module focuses on the latest advancements and innovations in solar energy, highlighting the cutting-edge developments that are shaping the future of the industry. It covers both product innovations and new solar technologies that are driving increased efficiency and expanding the applications of solar power.	
Learning Outcomes	
• Describe the innovations in different solar products • Explain new solar technology	
Module Structure	
Session 01: Innovations in the Field of Solar Energy Products	
Session 02: New Solar Technologies	

India had aimed to achieve 100GW of solar power production by 2022. At first, such an ambitious project may seem like a herculean task. But, it may not be too difficult for the country to achieve its long-term energy goals. India aims to achieve 450 GW of renewable energy capacities by 2030, of which about 280 GW is expected to be solar energy. There is a huge potential in the country for solar power due to the geographical location and terrain of the country.

SESSION 01: INNOVATIONS IN THE FIELD OF SOLAR ENERGY PRODUCTS

The field of solar energy is continuously undergoing innovation and discoveries. In the last few years, various products developed in solar industries like home lighting systems, lanterns, solar water heaters, cooling, space heating, solar cookers, solar power banks, solar street lights, solar balloons, solar water RO, solar e-rickshaw, solar charging stations, etc. Few of them are discussed below-

1. **Solar charging station**

Solar charging station provides clean energy to power up batteries, ensuring vehicles are fully charged while minimizing environmental impact. This technique transforms solar power into electricity and stores it in a battery bank. Road transport is undoubtedly the most common and affordable form of commute for people around the world. However, recently, it has faced much criticism due to its dependence on fossil fuels and its relatively low operational efficiency. This has opened the doors for the electric mobility industry, and the world has witnessed a drastic surge in the acceptability of EVs. India's first solar-powered EV charging station was installed in Mumbai. Its name is “ATUM Charge”, India's first 100 percent self-sustaining solar-powered EV charging station.

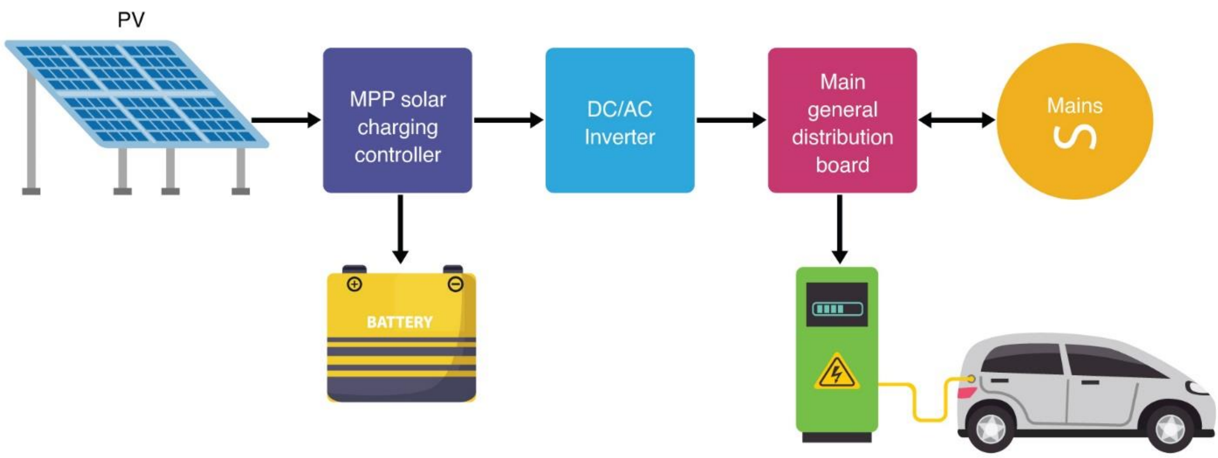


Fig. 4.1: Solar charging station

Benefits of Solar Electric Battery Charging

- Clean and easy to use
- Solar power maximizes battery life
- Safe and reliable
- Zero carbon footprint
- Government incentives and tax credits

2. **Solar Street Light**

A standalone solar photovoltaic street lighting system is an outdoor lighting unit used for illuminating a street or an open area. Recent advances in LED lighting have brought very promising opportunities for application in street lighting.

Combining LED's low power, and high illumination characteristics with current photovoltaic (PV) technology, PV-powered street light utilizing LED has become a norm in many places. In today's application, most of the common High-Intensity Discharge (HID) lamps, often High-Pressure Sodium (HPS) lamps are being replaced by more low powered Light Emitting Diode (LED) lamps.

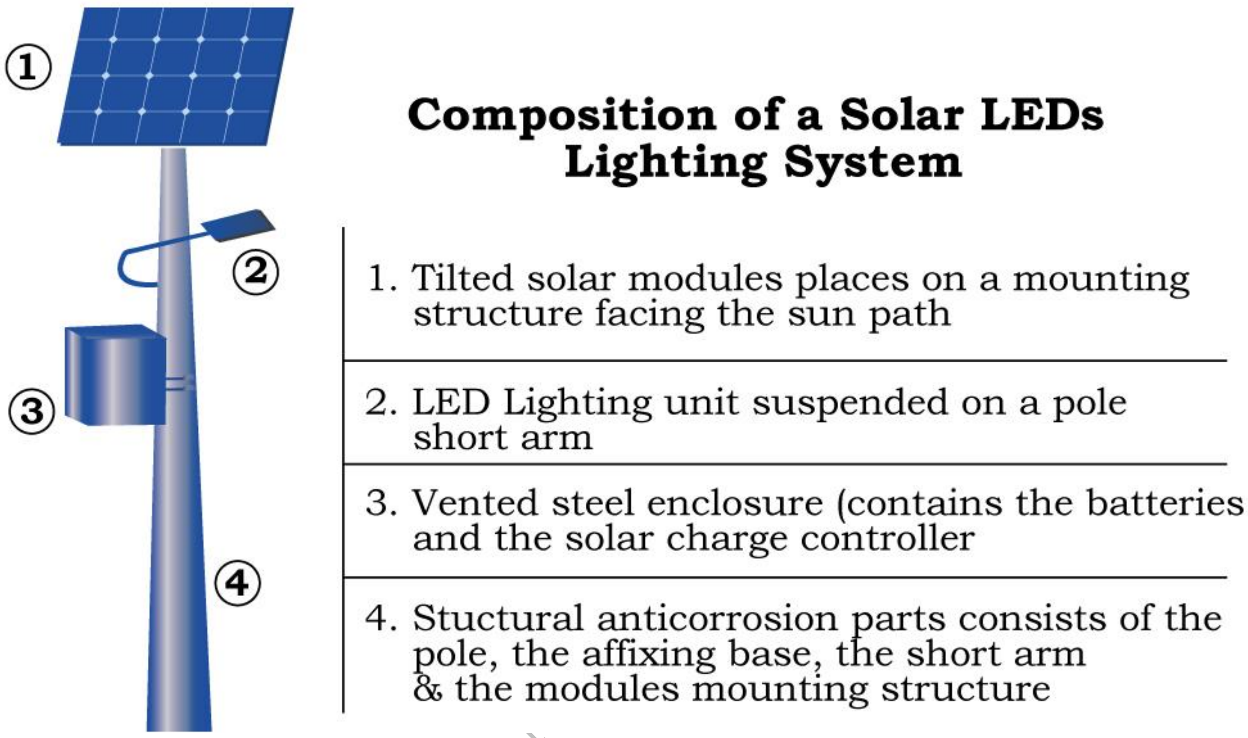


Fig. 4.2: Solar Street Light

A basic solar-powered LED street light system components are:

1. Solar panel or photovoltaic module
2. Lighting fixture – LED lamp set
3. Rechargeable deep cycle battery
4. Solar charge controller
5. Light pole

The solar panel will provide electricity to charge the battery during the daytime. The battery's charging is controlled by a charge controller. The operation of the led bulb is controlled by a control circuit either by using sensors such as light dependent resistor (LDR) or a voltage or current sensor. All these components will be fixed on a pole as shown in figure 4.2. The solar panel is mounted at the top of the pole to minimize the possibility of any shading on the panels.

Lead-acid was the popular choice of batteries for solar streetlights earlier as they were relatively inexpensive and were available for a variety of applications. They demand bigger solar panels for charging and the panels are required to produce 12V to charge the batteries, hence their effectiveness is not at its best during cloudy and rainy days. Modern solar streetlights consist of 3.2 to 3.7-volt lithium-ion or LiFePO4 batteries. Because this advancement, solar panels no longer require generating high currents to effectively charge these batteries. They are now compact, have a longer lifespan and demand hardly any maintenance.

3. **Solar Lantern**

A solar lantern is a simple application of solar photovoltaic technology, which has found good acceptance in rural regions where the power supply is irregular and scarce. Even in urban areas, people prefer a solar lantern as an alternative during power cuts because of its simple mechanism. A solar lantern is made of three main components - the solar PV panel, the storage battery and the lamp. The operation is very simple. The solar energy is converted to electrical energy by the SPV panel and stored in a sealed maintenance-free battery for later use during the night hours. A single charge can operate the lamp for about 4-5 hours.

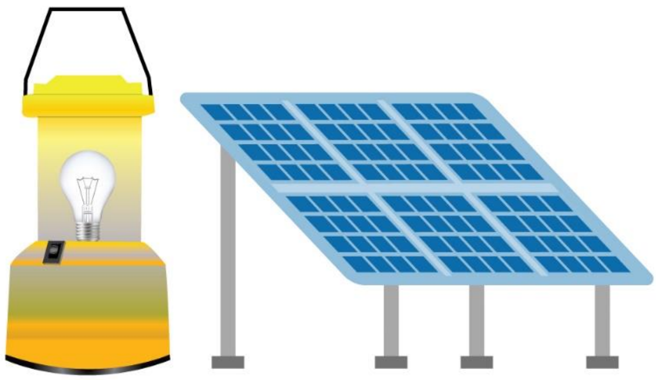


Fig. 4.3: Solar Lantern

4. **Solar Rickshaw**

A solar rickshaw is a vehicle, usually three-wheeled, driven by an electric motor and powered either by solar panels or by a battery charged by solar panels. E-rickshaws, since works on solar energy, do not emit smoke and hence they are non-polluting. Economically compared to other types of vehicles, e-rickshaws are quite cheap and can easily be afforded by a common person. E-rickshaw is the most commonly used vehicle for short distances throughout the world. These rickshaws generate no pollution, no sound, and are easy to operate.

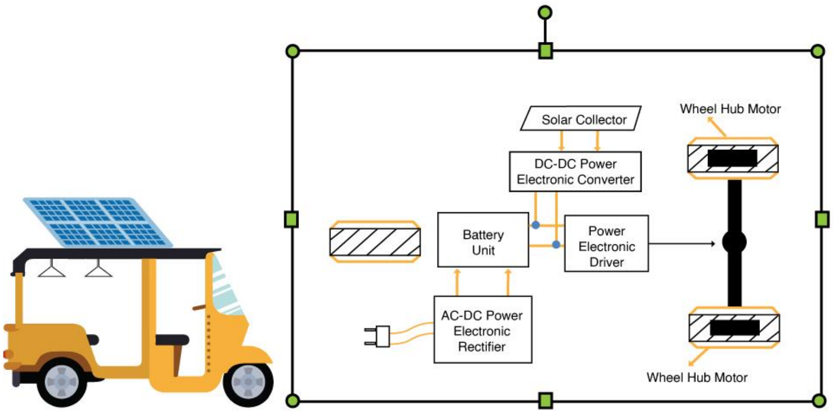


Fig. 4.4: E-rickshaws

5. **Solar Powered Cold Storage System**

In a solar-powered cold storage system, cooling takes place by solar energy. During the daytime, the electricity produced from solar photovoltaic panels runs the cold room. During the day, the excess energy stored in the panels is stored in the form of latent heat energy of thermal energy storage to be utilized in night.

In the daytime, two operations take place simultaneously- one for the charging process of the Thermal Energy Storage (TES) and the second for the direct cooling in the cold storage by running the compressor.

In the night, the energy stored in the TES, in the form of solidified ice, is utilized by circulating the Refrigerant R-134a and delivering the cold air through the evaporator of the cold storage. The schematic functioning of the solar cold storage is shown in Fig 4.5. The cost of a 5-ton capacity solar-powered cold storage system is about ₹8-10 lakh.

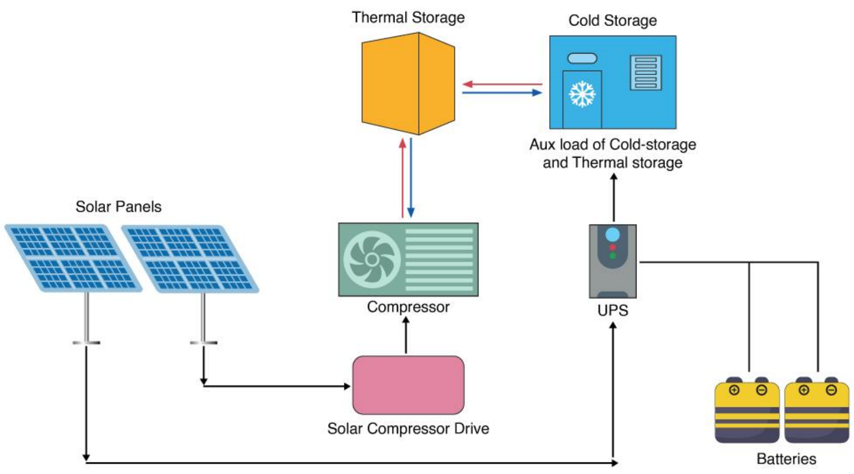


Fig.4.5: A solar-powered cold storage system

6. **Dish Type Solar Cooker**

Dish-type cookers produce the highest temperature and can be used to fry or grill food; pot lids and cooking bags are not necessary. It uses a dish of parabolic shape to concentrate a large amount of sunlight into a single focal point, where the temperature can reach up to 450^{0}C. It can cook food in lesser time than a box solar cooker. It costs about between ₹8000- ₹10000.

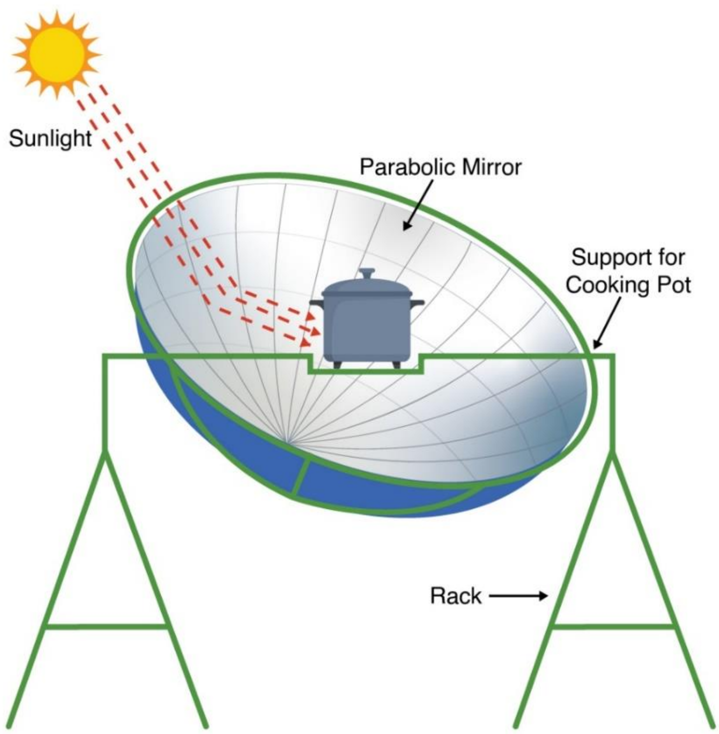


Fig.4.6: Dish Type Solar Cooker

7. **Solar Powered Water ATM**

A solar-powered water ATM is a clean water-dispensing machine in which RO quality drinking water is supplied. The water is purified using the solar electricity produced from solar photovoltaic panels to run an RO system. The card is used to dispense the water of any desired quantity i.e. 10, 20, 30, 50-liter bottles.

Fig.4.7: Solar-Powered Water ATM

8. **Solar Powered Bulk Milk Chiller**

The solar-powered bulk milk chiller is suitable for preserving the milk collected in village-level cooperatives before transferring it to the main dairies. It works on a similar principle to solar cold storage. During the daytime, the milk tank is connected by the electricity which is been produced from solar photovoltaic panels. During the day, the excess energy is stored in the thermal battery in the form of latent heat energy of thermal energy storage to be utilized in night. The cost of a 500-liter capacity is about ₹8.00 lakh.

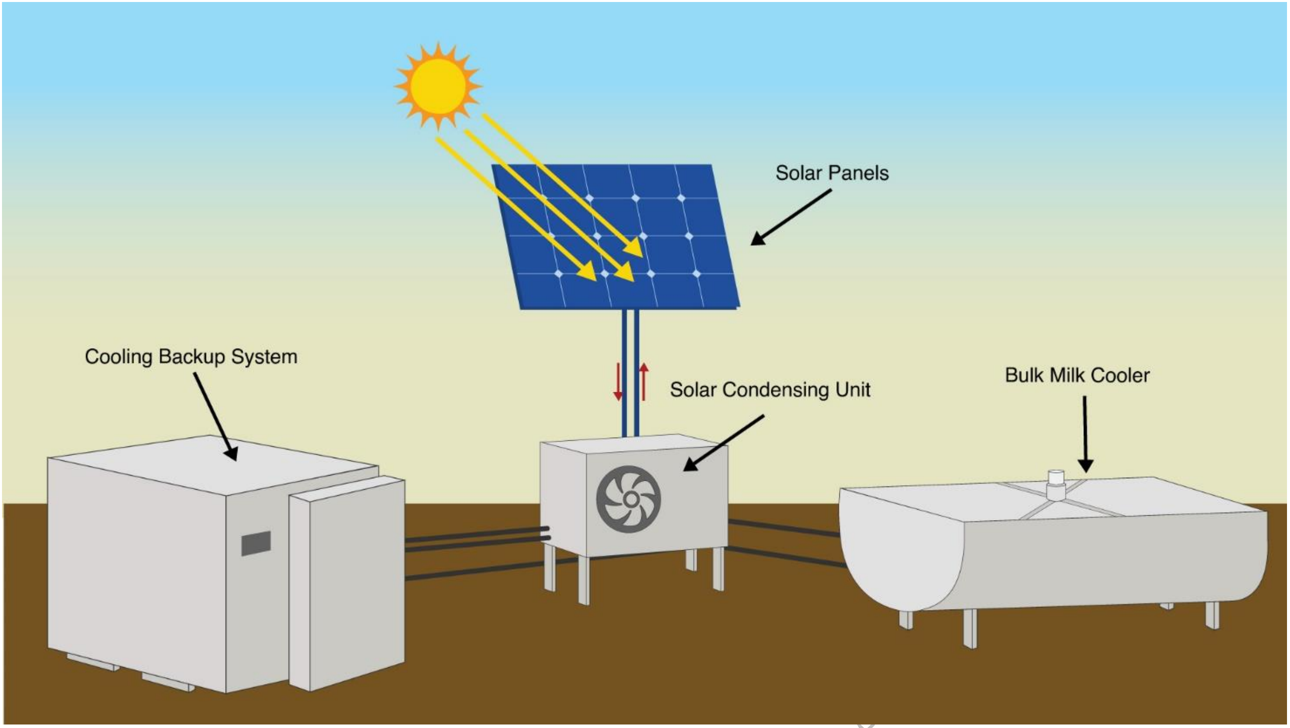


Fig.4.8: Solar-Powered Bulk Milk Chiller

SESSION 01

Practical Exercises

1. Create a list of products powered by sunlight.
2. Draw the line diagram of e-rickshaw
3. Write the main components of the solar street light.
4. Draw a line diagram of the solar charging station.

Check Your Progress

A. Short Answer Questions

1. What is a solar charging station?
2. What are the advantages of solar streetlights?
3. Which battery is used in e rickshaw?
4. Write the advantages of e-rickshaw.

B. Fill in the blank

1. The full form of LED is ....
2. .... type of battery used in solar street light
3. In battery, "**Ah**" indicates...........
4. A Solar Lantern is a simple application of ....technology.

C. Multiple Choice Questions

1. A fast-charging station involves…
   a) DC Charging
   b) AC Charging
   c) a & b
   d) None of the above

2. A battery is used in which of the solar product?
   a) E-Rickshaws
   b) Solar Street Light
   c) Solar Lantern
   d) All of the above

3. ……..is the name of India's First Solar-Powered EV Charging Station installed in Mumbai.
   a) ATUM Charge
   b) Quantum charge
   c) Atom charge
   d) Electron charge

4. Zero Carbon Footprint means
   a) Releasing greenhouse gases
   b) Releasing no greenhouse gases
   c) Both a & b
   d) None of the above

SESSION 02: NEW SOLAR TECHNOLOGIES

Solar energy has emerged the third-largest renewable energy source, after hydropower and wind, as a clean, sustainable, and powerful alternative to fossil fuels. The sunlight striking the Earth is more than 10,000 times the world's total energy use, and technologies to harvest as much solar energy as possible are surging rapidly. The most common technologies today use different forms of Si-based solar cells and convert up to 20% of the sunlight to electricity.

A typical solar cell consists of semiconducting materials such as p- and n-type silicon with a layered p-n junction connected to an external circuit. Sunlight illumination on the panels causes electron ejection from silicon. The ejected electrons under an internal electric field create a flow through the p-n junction and the external circuit, resulting in a current (electricity).

Currently, several exciting new solar panel technologies are either in the line or already on the market. These promising technologies will transform the way we think about not just solar, but energy production in general.

There are various new solar technologies in the world few are of them we discuss:

1. **BIPV solar technology:**

Building-integrated photovoltaics, as the name suggests, seamlessly blend into building architecture in the form of roofs, curtain walls, facades, and skylight systems. Unlike traditional solar PV panels, BIPV can be aesthetically appealing rather than a compromise to a building's design.

The BIPV solar panel systems enable homeowners to save on building materials and electric power costs. By substituting BIPV for standard building materials, you can cut down on the additional cost of solar panel mounting system.

BIPV technology, when used on the building's facades, atrium, terrace floor, and canopies, provides the following benefits:

- Increased energy efficiency.
- High thermal and sound insulation.
- Clean and free power output from the sun.
- Decreased O&M costs.

- Zero carbon footprint.

The photovoltaic PV glasses installed as building materials act as an energy-generating device, allowing natural light inside homes and offices, just as conventional architectural glasses.

2. Floating solar plants/farms:

Floating solar PV plants are an emerging form of PV systems that float on the surface of drinking water reservoirs, quarry lakes, irrigation canals, or remediation and tailing ponds. They consist of a floating system. Also known as a pontoon, it is a sturdy structure that holds the solar panel.

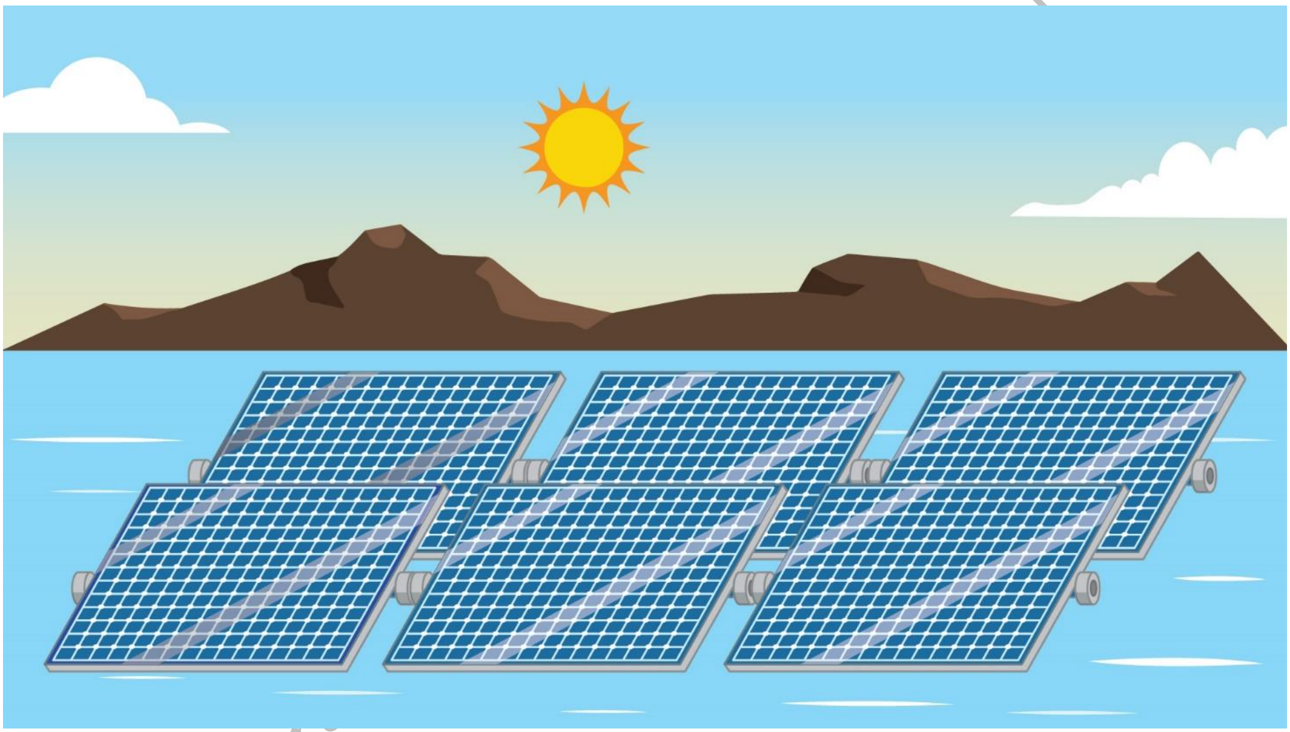


Fig. 4.9: Floating solar plant/farms

India's biggest floating solar power plant, by generation capacity (100MW), is being developed by the National Thermal Power Corporation Limited (NTPC) at Ramagundam in the Peddapalli district of Telangana.

The main advantage of floating solar plants is that they do not take up any land, except for the limited surfaces necessary for electric cabinet and grid connections. Their price is comparable with land-based plants, but they provide a good way to avoid land consumption.

3. Solar dryer:

The principle of the solar drying technique is to collect solar energy by heating up the air volume in solar collectors and conduct the hot air from the collector to an attached enclosure, the meat-drying chamber. Here the products to be dried are laid out.

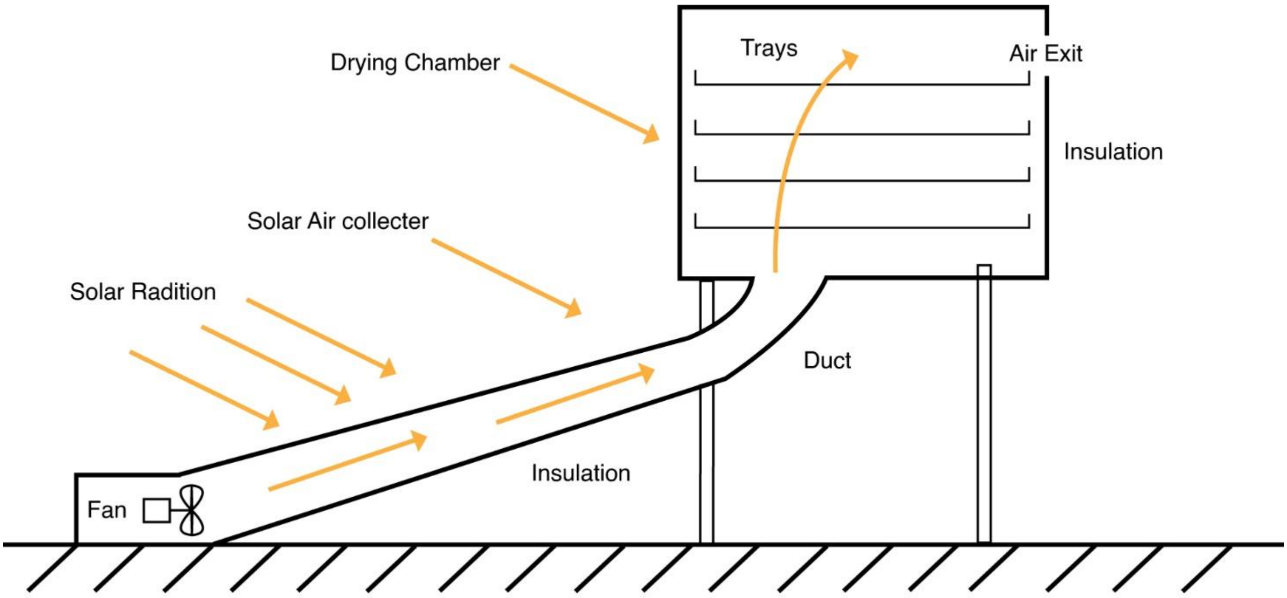


Fig. 4.10: Solar dryer

In this closed system, consisting of a solar collector and a meat drying chamber, without direct exposure of the meat to the environment, meat drying is more hygienic as there is no secondary contamination of the products through rain, dust, insects, rodents or birds. The products are dried by hot air only. There is no direct impact of solar radiation (sunshine) on the product. Solar energy produces hot air in the solar collectors. Increasing the temperature in a given volume of air decreases the relative air humidity and increases the water absorption capacity of the air. A steady stream of hot air into the drying chamber circulating through and over the meat pieces result in continuous and efficient dehydration.

4. Bifacial solar module:

Bifacial solar modules offer many advantages over traditional solar panels beacause it produces solar power from both sides of the panel. Power can be produced from both sides of a bifacial module, increasing total energy generation.

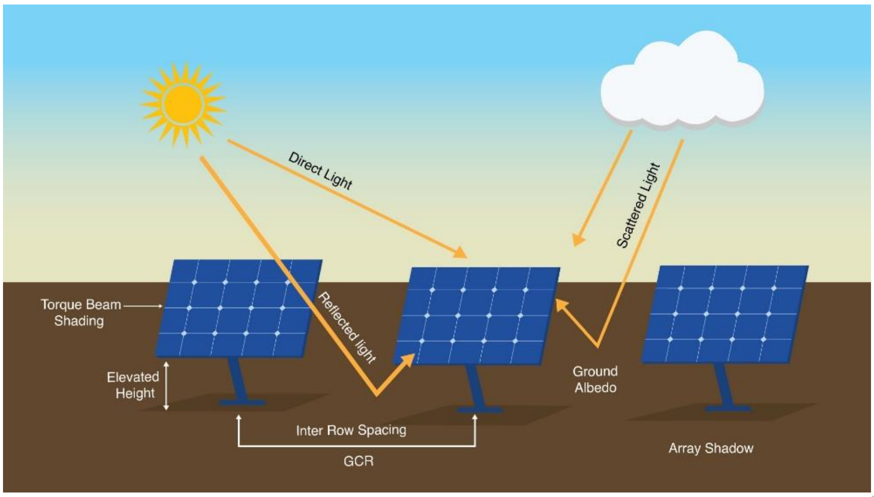


Fig.4.11: Bifacial solar panel

Sun Power is one of the most well-known companies in the solar industry. The new bifacial solar panel conversion efficiency is up to 27%. The main advantages of this panel are increased energy generation, small space requirement for installation, and energy generation even in cloudy or bad weather.

5. Flexible solar panels:

There are different types of solar panels available in the market. The three main types are monocrystalline, polycrystalline and thin-film solar panels – all of which differ based on the purity of the material from which they are made (usually silicon). While the monocrystalline and polycrystalline panels are quite similar, they differ when it comes to the finer details. Monocrystalline solar panels are more space-efficient and powerful, while thin-film cells belong to an entirely different category. Flexible solar panels are ideal for portable solar applications given their light weight.

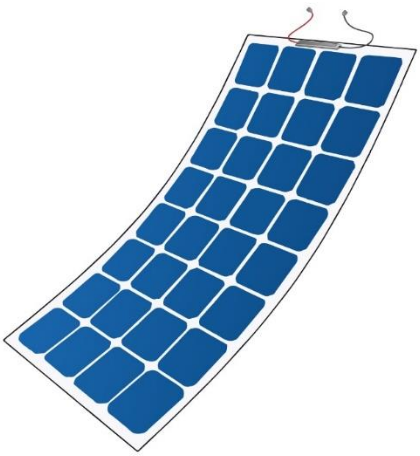


Fig.4.12: Flexible solar panels

STANDARDS OF SOLAR PANELS:

The safe and reliable installation of photovoltaic (PV) solar energy systems and their integration with the nation's electric grid requires the timely development of the foundational codes and standards governing solar deployment. Standards are norms or requirements that establish a basis for the common understanding and judgment of materials, products, and processes. Standards are an invaluable tool in industry and business because they streamline business practices and provide a level playing field for businesses to develop products and services. They are also critical to ensuring that products and services are safe for consumers and the environment**.** The Solar Energy industry relies on standardization for many things, including testing energy conversion, reflectance or materials properties, fabricating arrays, integrating into the smart grid, or assuring workplace safety. Numerous national and international bodies set standards for photovoltaic.

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC) CODES

The International Electro-Technical Commission (IEC) is the leading global organization that develops and publishes consensus-based International Standards for electric and electronic products, systems, and services, collectively known as electrotechnology. A few IEC codes are discussed below:

For Balance of System-

IEC 62093:2005: Balance-of-system components for photovoltaic systems - design qualification natural environments

IEC 62109-1:2010: Safety of power converters for use in photovoltaic power systems - part 1: general requirements

IEC 62109-2:2011: Safety of power converters for use in photovoltaic power systems - part 2: particular requirements for inverters

IEC 60269-6 ed1.0: Low-voltage fuses - part 6: supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems

For PV Characteristics-

IEC 61727 ed2.0: Photovoltaic (PV) systems - characteristics of the utility interface.

For PV Commissioning-

IEC 62446-1:2016: Photovoltaic (PV) Systems - requirements for testing, Documentation, and Maintenance - Part 1: Grid-connected systems - documentation, commissioning tests, and inspection.

For PV Design-

IEC 62124 ed 1.0: Photovoltaic (PV) stand-alone systems - design verification

IEC 62253 ed 1.0: Photovoltaic pumping systems - design qualification and performance measurements

For PV Installation-

IEC 60364-1 ed5.0: Low-voltage electrical installations - part 1: fundamental principles, assessment of general characteristics, definitions

IEC 60364-7-712:2017: Low-voltage electrical installations - part 7-712: requirements for special installations or locations - solar photovoltaic (PV) power supply systems

For PV Monitoring-

IEC 61724-1:2017: Photovoltaic system performance - part 1: monitoring

IEC TS 61724-2:2016: Photovoltaic system performance - part 2: capacity evaluation method

IEC TS 61724-3:2016: Photovoltaic system performance - part 3: energy evaluation method.

For PV Performance-

IEC 62509 ed1.0: Battery charge controllers for photovoltaic systems - performance and functioning.

For Rural Electrification

IEC TS 62257-1:2015: Recommendations for renewable energy and hybrid systems for rural electrification - part 1: General introduction to IEC 62257 series and rural electrification

For Safety-

IEC 61730-1:2016: Photovoltaic (PV) module safety qualification - part 1: requirements for construction

IEC 61730-2:2016: Photovoltaic (PV) module safety qualification - part 2: requirements for testing

For PV related terms-

IEC TS 61836:2016: Solar photovoltaic energy systems - terms, definitions, and symbols

For Testing-

IEC 61215-1:2016: Design qualifications & type approval part 1: testing requirements (All chemistries)

IEC 61215-2:2016: Design qualifications & type approval part 2: testing procedures (all chemistries)

IEC 62116:2014: Utility-interconnected photovoltaic inverters - test procedure of islanding prevention measures

IEC 62253:2011 Photovoltaic pumping systems – design qualification and performance measurements.

BIS:

BIS stands for Bureau of Indian Standards. It is the national standard body of India established under the BIS Act 2016 for the harmonious development of the activities of standardization, marking and quality certification of goods and for matters connected therewith or incidental thereto. The Ministry of New and Renewable Energy (MNRE) has also issued the list of BIS standards applicable for components of solar PV applications. The Ministry of New and Renewable Energy (MNRE) is implementing a Quality Control Order on SPV Systems, Devices and Components Goods Order 2017 under BIS Act (Compulsory Registration Scheme). The said order includes SPV Modules, Inverter and Battery Storage with specified Indian Standards adopted from IEC Standards for these products.

Table 4.1 Indian standards on renewable energy notified by BIS (Bureau of Indian Standards)

S.No.	Product	Standards	Remarks
1.	Crystalline Silicon Terrestrial Photovoltaic (PV) modules (Si wafer-based)	IS 14286	Crystalline Silicon Terrestrial Photovoltaic (PV) modules– Design Qualification and Type Approval
2.	Thin-Film Terrestrial Photovoltaic (PV) Modules (a-Si, CiGs, and CdTe)	IS 16077	Thin-Film Terrestrial Photovoltaic (PV) Modules - Design Qualification and Type Approval
3.	PV Module (Si wafer and Thin-film)	IS/IEC 61730 (Part 1) IS/IEC 61730 (Part 2)	Photovoltaic (PV) module safety qualification part 1 requirements for construction Photovoltaic (PV)Module Safety Qualification Part 2 Requirements for Testing
4.	Power converters for use in photovoltaic power system	IS 16221 (Part 1) IS 16221 (Part 2)	Safety of Power Converters for Use in Photovoltaic Power Systems Part 1- General Requirements Safety of Power Converters for Use in Photovoltaic Power Systems Part 2- Particular Requirements for Inverters
5.	Utility –Interconnected Photovoltaic inverters	IS 16169	Test Procedure of Islanding Prevention Measures for Utility-Interconnected Photovoltaic Inverters

S.No.	Product	Standards	Remarks
6.	Storage battery	IS 16270	Secondary Cells and Batteries for Solar Photovoltaic Application General Requirements and Methods of Test

SESSION 02

Practical Exercise

Activity 01: Draw the line diagram of the solar dryer.

Material required:

1. Pen
2. Drawing sheet
3. Pencil
4. Scale
5. Eraser

Procedure:

1. Take the permission from the solar dryer shop owner
2. Visit the shop
3. Identify the solar dryer in the shop
4. Write the specification of solar dryer specification
5. Draw a neat sketch of the solar dryer and label it.

Check Your Progress

A. Short Answer Questions

1. Explain the bifacial technology.
2. Write the five solar BIS codes with significance.
3. Write the advantages Bifacial module
4. What are BIS codes and their importance?
5. Write a short note on the Floating solar plant

B. Fill in the blank

1. The full form of IEC is …………

2. The full form of BIS is ....
3. IEC............ Code used for the design of solar photovoltaic pumping system.
4. Full form of BIPV...................

C. Multiple Choice Questions

1. Which IEC code gives details regarding safety?
   a) IEC 61724-1:2017
   b) IEC 62446-1:2016
   c) IEC 62116:2014
   d) IEC 61730
2. Which IS code gives details regarding Utility –Interconnected Photovoltaic inverters?
   a) IEC 61730
   b) IS 14286
   c) IS 16169
   d) IS 16077
3. Which IS code gives details regarding Thin-Film Terrestrial Photovoltaic (PV) Modules?
   a) IS 16077
   b) IS/IEC 61730 (Part 1)
   c) IS/IEC 61730 (Part 2)
   d) IS 16221 (Part 1)
4. In which state India's biggest floating solar power plant by generation capacity (100MW) is being developed by the National Thermal Power Corporation Limited (NTPC) situated at-
   a) Telangana
   b) Tamil Nadu
   c) Andhra Pradesh
   d) Karnataka

Answer Key

Module 1: Installation and Commissioning

SESSION 1: Site Survey and Selection of Site

B. Fill in the blank

1. Kilowatt
2. 1000 watt
3. 100 sq feet
4. 4 - 7 kWh/sq. meter/day

C. Multiple choices Question

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

SESSION 2: Selection of Solar Panel System

B. Fill in the blank

1. Solar photovoltaic
2. 3 KVA
3. regulating the voltage and current
4. AC

C. Multiple choice question

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

SESSION 3: Design Criteria for Solar Panel System

A. Fill in the blank

1. Site analysis
2. Load Analysis
3. System
4. Component Selection

B. Multiple Choice question

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

SESSION 4: Material requirement and Construction of the foundation for the solar panel system

B. Fill in the blank

1. MC4 Connecters
2. Optimum angle
3. Inverter

C. Multiple Choice Question:

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

Module 2: REPAIR AND MAINTENANCE

Session 1: Cleaning and testing of solar panel

B. Fill in the blank

1. Voltage, Current, and Resistance
2. Ampere (A)
3. Protected Enclosure
4. ohms (Ω)

C. Multiple Choice Questions.

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

Session 2: Checking and identifying the different faults in the solar panel system

B. True and False.

1. True
2. True
3. True
4. False
5. True

C. Match the Columns:

1) PV module is not working	b)	Repair/Replacement
2) Shadow on PV module	d)	Removal of the source
3) Dirt on the PV module	a)	Cleaning
4) Cable Damage	c)	If bad, replace it

Module 3: Cost Economics of Solar PV Systems and Opportunities

Session 1: Economics

B. Multiple Choice Question

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

Session 2: Business Strategies, Government Scheme and Policy

B. Fill in the blank

1. Jawaharlal Nehru National Solar Mission
2. Strengths, Weaknesses, Opportunities, Threats
3. 2 MW
4. 2018

C. Multiple Choice Questions

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

Module -4 Innovation and Development in Solar Energy

SESSION :1 Innovations in the field of solar energy products

B. Fill in the blank

1. Light Emitting Diode

2. Lithium-ion
3. ampere-hour
4. photovoltaic (PV)

C. Multiple Choice Question

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

Session 02: New Solar Technologies

B. Fill in the blank

1. International Electrotechnical Commission
2. Bureau of Indian Standards
3. IEC 61836 Code
4. Building Integrated Photovoltaics.

C. Multiple Choice Question

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

Abbreviations

AC	Alternating current
CPV	Concentrating solar photovoltaics
DC	Direct current
DESCO	Distributed Energy Service Company
DH	Discharge Head
EPC	Engineering, Procurement, and Construction
EV	Electric Vehicle
GW/GWh	Gigawatt/gigawatt-hour
HP	Horse Power
JNNSM	Jawaharlal Nehru National Solar Mission
KVK	Krishi Vikas Kendra
kW/ kWh	Kilowatt/Kilowatt-hour
LCC	Life Cycle Cost
MNRE	Ministry of New and Renewable Energy
MPPT	Maximum Power Point Tracker
MW/MWh	Megawatt/Megawatt-hour
NABARD	National Bank for Agriculture and Rural Development
PAYG	Pay as-you-go — a financing model involving payments for use to the service provider
PM KUSUM	Pradhan Mantri Kisan Urja Suraksha Evam Utthan Mahabhiyan
PMKSY	Pradhan Mantri Krishi Sinchai Yojana
PV	Photo Voltaic
SH	Suction Head
SNA	State Nodal Agency
SWH	Solar Water Heater
SWP	Solar Water Pumps
TH	Total Head
UID	Unique Identification Number
VFD	Variable-Frequency Drive

W/Wh	Watt/watt-hour
Wp	Peak Watt, also known as Watt-peak

GLOSSARY

Alternating Current (AC) — A type of electrical current, the direction of which is reversed at regular intervals or cycles.

Ampere (Amp) — A unit of electrical current or rate of flow of electrons.

Angle of Incidence — The angle that a ray of sun makes with a line perpendicular to the surface.

Array — Photovoltaic cells which are then grouped together to make solar panels.

Battery — Two or more electrochemical cells enclosed in a container and electrically interconnected in an appropriate series/parallel arrangement to provide the required operating voltage and current levels. Under common usage, the term battery also applies to a single cell if it constitutes the entire electrochemical storage system.

Battery Capacity — The maximum total electrical charge, expressed in ampere-hours, which a battery can deliver to a load under a specific set of conditions.

Battery Cell — The simplest operating unit in a storage battery.

Battery Life — The period during which a cell or battery is capable of operating above a specified capacity or efficiency performance level. life may be measured in cycles and/or years, depending on the type of service for which the cell or battery is intended.

Bypass Diode — A diode connected across one or more solar cells in a photovoltaic module such that the diode will conduct if the cell(s) become reverse-biased. It protects these solar cells from thermal destruction

Charge Controller — A component of a photovoltaic system that controls the flow of current to and from the battery to protect it from over-charge and over-discharge.

Conductor — The material through which electricity is transmitted, such as an electrical wire, or transmission or distribution line.

Crystalline Silicon — A type of photovoltaic cell made from a slice of single-crystal silicon or polycrystalline silicon

Electric Current — The flow of electrical energy (electricity) in a conductor, measured in amperes.

Gigawatt (GW) — A unit of power equal to 1 billion watts; 1 million kilowatts, or 1,000 megawatts.

Load — The demand on an energy-producing system.

Ohm — A measure of the electrical resistance of a material equal to the resistance of a circuit in which the potential difference of 1 volt produces a current of 1 ampere.

Parallel Connection — A way of joining solar cells or photovoltaic modules by connecting positive leads together and negative leads together; such a configuration increases the current, but not the voltage.

Photoelectric Cell — A device for measuring light intensity that works by converting light falling on, or reach it, to electricity, and then measuring the current; used in photometers

Photovoltaic (PV) Effect — The phenomenon that occurs when photons, the "particles" in a beam of light, knock electrons loose from the atoms they strike.

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

Stand-Alone System — An autonomous or hybrid photovoltaic system not connected to a grid. It may or may not have storage, but most stand-alone systems require batteries or some other form of storage.

Standard Test Conditions (STC) — Conditions under which a module is typically tested in a laboratory.

String — Several photovoltaic modules or panels interconnected electrically in series to produce the operating voltage required by the load.

Tilt Angle — The angle at which a photovoltaic array is set to face the sun relative to a horizontal position. The tilt angle can be set or adjusted to maximize seasonal or annual energy collection.

Watt — The rate of energy transfer equivalent to one ampere under an electrical pressure of one volt. One watt equals 1/746 horsepower or one joule per second. It is the product of voltage and current (amperage).

List of Credits

Reference

Notes