1. A) Earth-Sun Geometry

Earth Rotation and Revolution

The term **Earth rotation** refers to the spinning of our planet on its axis. Because of rotation, the Earth's surface moves at the equator at a speed of about 467 m per second or slightly over 1675 km per hour. If you could look down at the Earth's North Pole from space you would notice that the direction of rotation is counter-clockwise (**Figure 6h-1**). The opposite is true if the Earth is viewed from the South Pole. One rotation takes exactly twenty-four hours and is called a **mean solar day**. The Earth's rotation is responsible for the daily cycles of day and night. At any one moment in time, one half of the Earth is in sunlight, while the other half is in darkness. The edge dividing the daylight from night is called the **circle of illumination**. The Earth's rotation also creates the apparent movement of the Sun across the horizon.

The orbit of the Earth around the Sun is called an **Earth revolution**. This celestial motion takes 365.26 days to complete one cycle. Further, the Earth's orbit around the Sun is not circular, but oval or **elliptical** (see **Figure 6h-2**). An elliptical orbit causes the Earth's distance from the Sun to vary over a year. Yet, this phenomenon is not responsible for the Earth's seasons! This variation in the distance from the Sun causes the amount of solar radiation received by the Earth to annually vary by about 6%. **Figure 6h-2** illustrates the positions in the Earth's revolution where it is closest and farthest from the Sun. On January 3, **perihelion**, the Earth is closest to the Sun (147.3 million km). The Earth is farthest from the Sun on July 4, or **aphelion** (152.1 million km). The average distance of the Earth from the Sun over a one-year period is about 149.6 million km.

Tilt of the Earth's Axis

The **ecliptic plane** can be defined as a two-dimensional flat surface that geometrically intersects the Earth's orbital path around the Sun. On this plane, the Earth's axis is not at right angles to this surface, but inclined at an angle of about 23.5° from the **perpendicular**. **Figure 6h-3** shows a side view of the Earth in its orbit about the Sun on four important dates: **June solstice**, **September equinox**, **December solstice**, and **March equinox**. Note that the angle of the Earth's axis in relation to the ecliptic plane and the North Star on these four dates remains unchanged. Yet, the relative position of the Earth's axis to the Sun does change during this cycle. This circumstance is responsible for the annual changes in the height of the Sun above the **horizon**. It also causes the **seasons**, by controlling the intensity and duration of sunlight received by locations on the Earth. **Figure 6h-4** shows an overhead view of this same phenomenon. In this view, we can see how the circle of illumination changes its position on the Earth's surface. During the two equinoxes, the circle of illumination cuts through the North Pole and the South Pole. On the June solstice, the circle of illumination is tangent to the Arctic Circle (66.5° N) and the region above this latitude receives 24 hours of daylight. The Arctic Circle is in 24 hours of darkness during the December solstice.

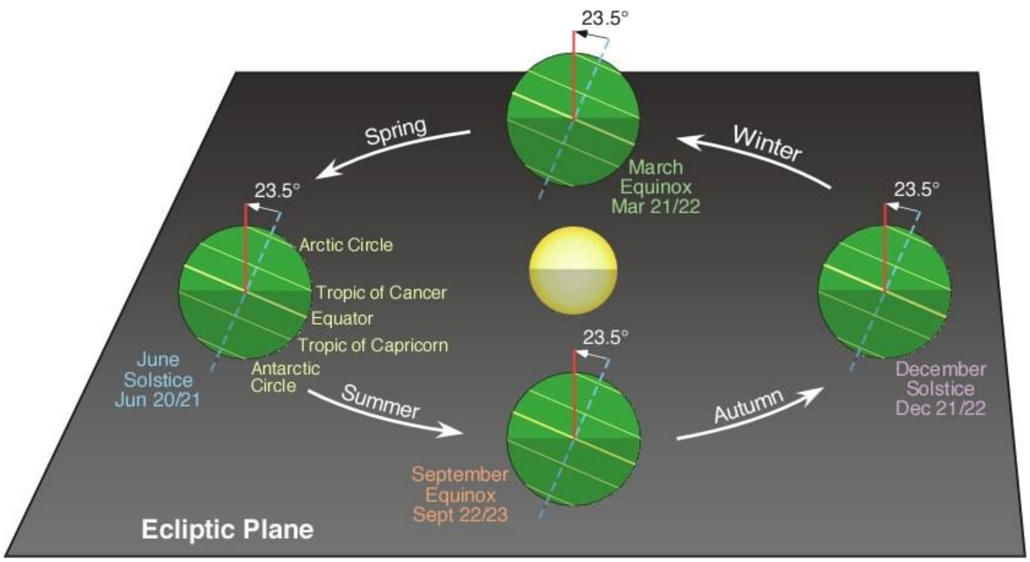


Figure 6h-3: The Earth's rotational axis is tilted 23.5° from the red line drawn perpendicular to the ecliptic plane. This tilt remains the same anywhere along the Earth's orbit around the Sun. Seasons are appropriate only for the Northern Hemisphere.

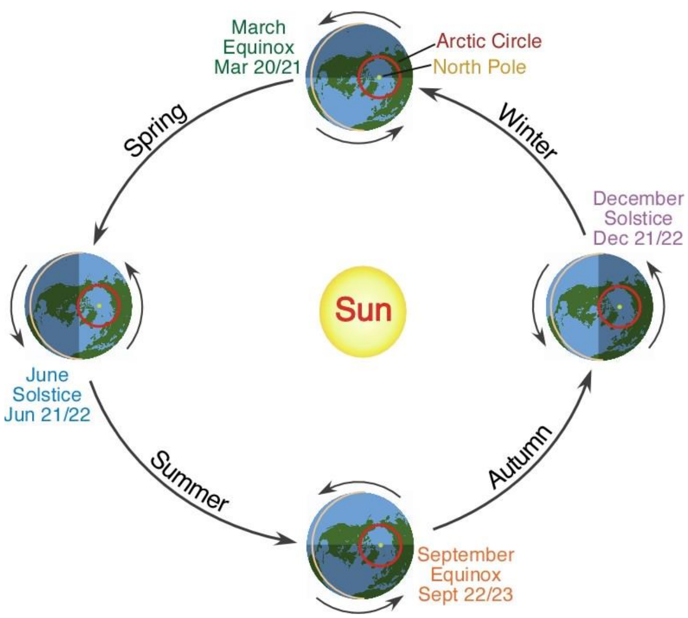


Figure 6h-4: Annual change in the position of the Earth in its revolution around the Sun. In this graphic, viewing the Earth from a position in space that is above the North Pole (yellow dot) at the summer solsti winter solstice, and the two equinoxes. Note how the position of the North Pole on the Earth's surface dc change. However, its position relative to the Sun does change and this shift is responsible for the season red circle on each of the Earths represents the Arctic Circle (66.5 degrees N). During the June solstice, tl above the Arctic Circle is experiencing 24 hours of daylight because the North Pole is tilted 23.5 degrees t the Sun. The Arctic Circle experiences 24 hours of night when the North Pole is tilted 23.5 degrees awa the Sun in the December solstice. During the two equinoxes, the circle of illumination cuts through the axis and all locations on the Earth experience 12 hours of day and night. Seasons are appropriate only Northern Hemisphere.

On June 21 or 22 the Earth is positioned in its orbit so that the North Pole is leaning 23.5° toward the Sun (**Figures 6h-3**, **6h-4**, **6h-5** and see **animation - Figure 6h-7**). During the June solstice (also called the **summer solstice** in the Northern Hemisphere), all locations north of the equator have day lengths greater than twelve hours, while all locations south of the equator have day lengths less than twelve hours (see **Table 6h-2**). On December 21 or 22 the Earth is positioned so that the South Pole is leaning 23.5 degrees toward the Sun (**Figures 6h-3**, **6h-4**, **6h-5** and see **animation - Figure 6h-8**). During the December solstice (also called the **winter solstice** in the Northern Hemisphere), all locations north of the equator have day lengths less than twelve hours, while all locations south of the equator have day lengths exceeding twelve hours (see **Table 6h-2**).

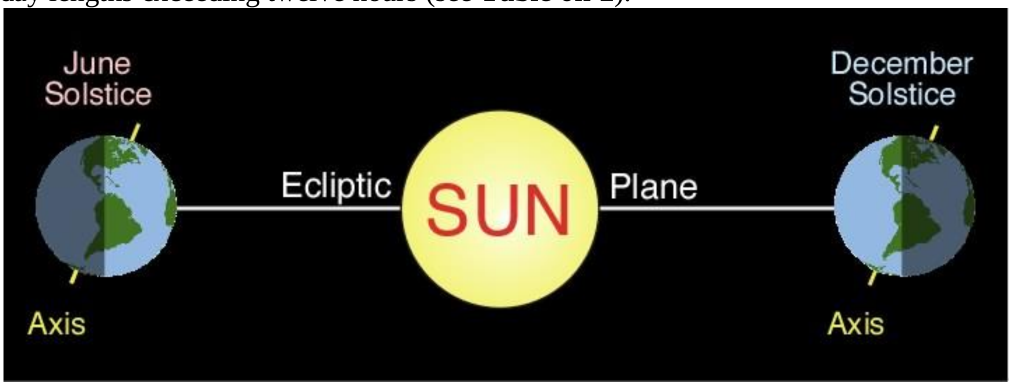


Figure 6h-5: During the June solstice the Earth's North Pole is tilted 23.5 degrees towards the Sun relat the circle of illumination. This phenomenon keeps all places above a latitude of 66.5 degrees N in 24 ho sunlight, while locations below a latitude of 66.5 degrees S are in darkness. The North Pole is tiltec degrees away from the Sun relative to the circle of illumination during the December solstice. On this da places above a latitude of 66.5 degrees N are now in darkness, while locations below a latitude of 66.5 de S receive 24 hours of daylight.

On September 22 or 23, also called the **autumnal equinox** in the Northern Hemisphere, neither pole is tilted toward or away from the Sun (**Figures 6h-3**, **6h-4**, **6h-6** and see **animation - Figure 6h-9**). In the Northern Hemisphere, March 20 or 21 marks the arrival of the **vernal equinox** or **spring** when once again the poles are not tilted toward or away from the Sun. Day lengths on both of these days, regardless of latitude, are exactly 12 hours.

1. B

Mainstream technologies

- Monocrystalline Silicon
- Polycrystalline Silicon
- Amorphous silicon

While deciding upon the best type of solar panels for your home, you must be aware of the strength and weaknesses of all the types available. In this section, you'll find out the difference between the basic composition and functionalities of the three types of solar panels.

Mono crystal solar panels are made out of highly pure single piece silicon. While on the other hand, poly crystal solar panels are made out of fragments of silicon which were melted together to form the wafer. Bifacial panels can be made of any of these traditional solar cells though they are usually monocrystalline cells.

1 C.

After reaching our atmosphere, light responds in several ways. The light is partially absorbed and partially scattered, and therefore the intensity is decreased somewhat. Sunlight is attenuated by at least 30% during its passage through the atmosphere[1].

Causes of attenuation in the earth's atmosphere include:

- Absorption by the earth's constituent atmospheric gases. Water and carbon dioxide tend to deplete light intensity in the infrared section of the electromagnetic spectrum, whereas oxygen and ozone weaken light mainly in the visible and ultraviolet ranges respectively[2].
- Scattering of light by aerosols and dust particles in the atmosphere.
- Rayleigh scattering, or the scattering of light by particles in the atmosphere that are smaller than the wavelength of incoming light. This is the reason that sunsets have a red shift; the light reflects off of more particles as the angle of the sun decreases relative to the atmosphere. This type of scattering occurs especially with light of short wavelengths (or high-energy photons).
- Mie scattering occurs in clouds, which appear white because light is scattered equally at all wavelengths. This is due to the size of the cloud's water droplets.

2 A.

i. **Analyze your electricity bill**
The very first step is to analyze your electricity bill before starting the solar panel installation process. By looking at your electricity bill, you will get an idea about your monthly consumption in kWh. Based on this number, you will calculate the "size" of your solar energy system as you will require a solar panel according to your demand for energy consumption. To accurately calculate this value, it is advisable to check the average monthly energy consumption, the average of the last 12 months.

ii. **Choice of panel model and installation company**
Choosing the company that will supply and install solar energy equipment makes all the difference in the final result. There are several options for models and values of solar panels, which vary according to the consumer's objective, the planned investment, and the manufacturer. Start by simulating the cost required and the savings that can be generated. Choose a brand that exists in the market and offers the best solution for your project, allowing you to customize the structure for different environments.

iii. **Technical and feasibility study**
Before installing the photovoltaic system, a study must be carried out to assess the structure of the building and the ideal type of equipment, according to the consumption profile. The electrical appliances in use and the number of people who will use the generated energy are considered. Another point evaluated is the characteristic of the solar radiation received at the installation site, which varies according to geographic region. From the study results, technical experts can define the ideal equipment for the owner's objective and budget for the acquisition.

iv. **Calculate your budget**
Based on your monthly energy consumption shown on your electricity bill, you will be able to simulate the cost of installing solar energy in your home or business. According to your energy consumption, calculating the average cost needed for the solar panel installation process is possible. You need to consider the warranty, maintenance cost, and the number of panels required for the installation process.

v. **Access to the electricity grid**
Once the quantity and weight of the necessary panels and the installation area have been defined, it is essential to evaluate the conditions of integrating the photovoltaic solar system with the electrical network available in the property. For the energy generated by the capture of sunlight to

reach the electrical equipment, the current generated must be conducted to the photovoltaic inverter and converted to the consumption pattern, following the system known as on-grid or off-grid.

vi. **Facility Design, Permits, and Grant**
Once the previous step has been carried out, the installer will make an installation proposal with its respective production objectives and install solar panels on your roof. If you accept the proposal, it would be time to request the permits to legalize the self-consumption installation before mounting the solar panels and find out if there is any subsidy for installing solar panels in your community.

vii. **Authorization of the energy concessionaire**
For the system to be finally implemented, the energy concessionaire operating in the region must authorize the installation in the property and its connection to the electricity grid. The professionals appointed for this task are specialized engineers and technicians, who use the technical study and the characteristics of the building to request approval from the electrical distribution company.

viii. **Site inspection**
It is a very important step in the installation of solar panels. First, we need to inspect or search a site that can be used for installing solar panels. It should be in proper orientation with the sun. Also, the site should be at a good height or must have plain terrain.

ix. **Installation of panels and converter**
Once authorized by the concessionaire, the installation of solar panels can be carried out by the selected company, based on the indicated project and the evaluation of the solar incidence on the property. The brackets for fixing the panels are attached to the location chosen, and the cables connecting the converter and the distribution board are connected. It is essential that all the material used is modern and of quality, with proper approval and certification.

x. **Dealership inspection**
The last step before starting to use photovoltaic solar energy is the inspection of the concessionaire. Technicians from the electric company go to the installation site and make sure that the entire implementation was carried out correctly, authorizing the start of use of the system. During the process, the meter is exchanged or installed for a bidirectional model, which measures how much energy will be injected into the network and consumed per day in the property, allowing energy credits to be made available with the utility.

2.B

i. Solar cell is the basic unit of solar energy generation system where electrical energy is extracted directly from light energy without any intermediate process. The working of a solar cell solely depends upon its photovoltaic effect hence a solar cell also known as photovoltaic cell. A solar cell is basically a semiconductor device. The solar cell produce electricity while light strikes on it and the voltage or potential difference established across the terminals of the cell is fixed to 0.5 volt and it is nearly independent of intensity of incident light whereas the current capacity of cell is nearly proportional to the intensity of incident light as well as the area that exposed to the light. Each of the solar cells has one positive and one negative terminal like all other type of battery cells. Typically a solar or photovoltaic cell has negative front contact and positive back contact. A semiconductor p-n junction is in the middle of these two contacts.

ii. While sunlight falling on the cell the some photons of the light are absorbed by solar cell. Some of the absorbed photons will have energy greater than the energy gap between valence band and conduction band in the semiconductor crystal. Hence, one valence electron gets energy from one photon and becomes excited and jumps out from the bond and creates one electron-hole pair. These electrons and holes of e-h pairs are called light-generated electrons and holes. The light-generated electrons near the p-n junction are migrated to n-type side of the junction due to electrostatic force of the field across the junction. Similarly the light-generated holes created near the junction are migrated to p-type side of the junction due to same electrostatic force. In this way a potential difference is established between two sides of the cell and if these two sides are connected by an external circuit current will start flowing from positive to negative terminal of the solar cell. This was basic working principle of a solar cell now we will discuss about different parameters of a solar or photovoltaic cell upon which the rating of a solar panel depends. During choosing a particular solar cell for specific project it is essential to know the ratings of a solar panel. These parameters tell us how efficiently a solar cell can convert the light to electricity.

iii. Short Circuit Current of Solar Cell

iv. The maximum current that a solar cell can deliver without harming its own constriction. It is measured by short circuiting the terminals of the cell at most optimized condition of the cell for producing maximum output. The term optimized condition I used because for fixed exposed cell surface the rate of production of current in a solar cell also depends upon the intensity of light and the angle at which the light falls on the cell. As the current production also depends upon the surface area of the cell exposed to light, it is better to express maximum current density instead maximum current. Maximum current density or short circuit current density rating is nothing but ration of maximum or short circuit current to exposed surface area of the cell.

$$J_{sc} = \frac{I_{sc}}{A}$$

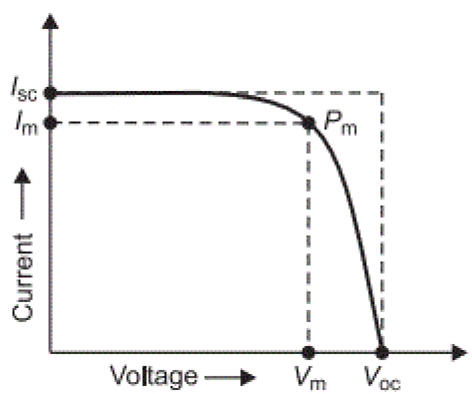
Where, I_{sc} is short circuit current, J_{sc} maximum current density and A is the area of solar cell.

v. Open Circuit Voltage of Solar Cell

vi. It is measured by measuring voltage across the terminals of the cell when no load is connected to the cell. This voltage depends upon the techniques of manufacturing and temperature but not fairly on the intensity of light and area of exposed surface. Normally open circuit voltage of solar cell nearly equal to 0.5 to 0.6 volt. It is normally denoted by V_{oc}.

vii. Maximum Power Point of Solar Cell

viii. The maximum electrical power one solar cell can deliver at its standard test condition. If we draw the v-i characteristics of a solar cell maximum power will occur at the bend point of the characteristic curve. It is shown in the v-i characteristics of solar cell by P_m.



ix. Current at Maximum Power Point

x. The current at which maximum power occurs. Current at Maximum Power Point is shown in the v-i characteristics of solar cell by I_m.

xi. Voltage at Maximum Power Point

xii. The voltage at which maximum power occurs. Voltage at Maximum Power Point is shown in the v-i characteristics of solar cell by V_m.

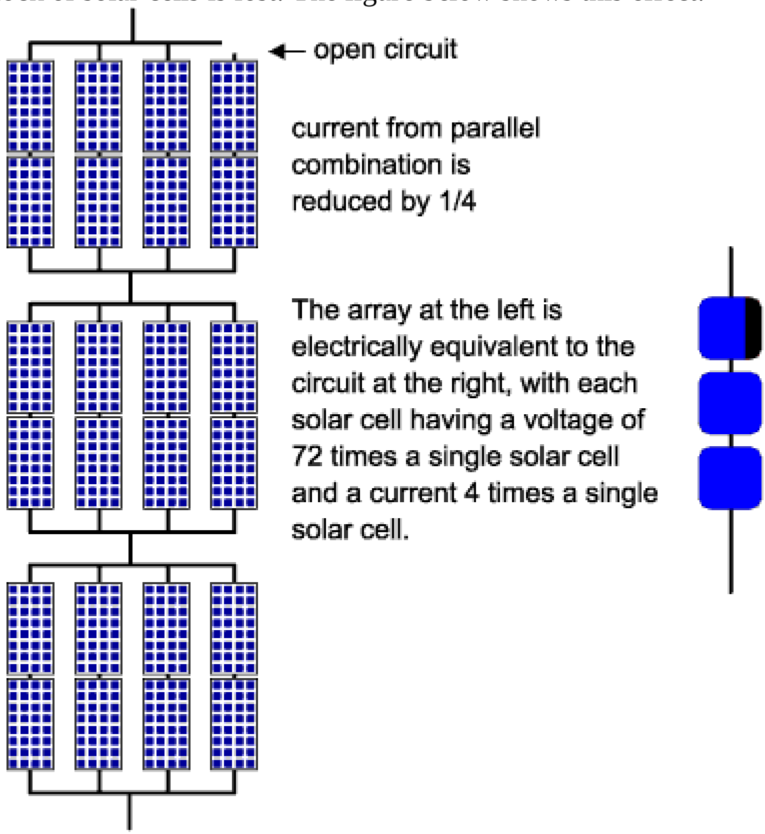
xiii. Fill Factor of Solar Cell

xiv. The ratio between product of current and voltage at maximum power point to the product of short circuit current and open circuit voltage of the solar cell.

$$Fill\ Factor = \frac{P_m}{I_{sc} \times V_{oc}}$$

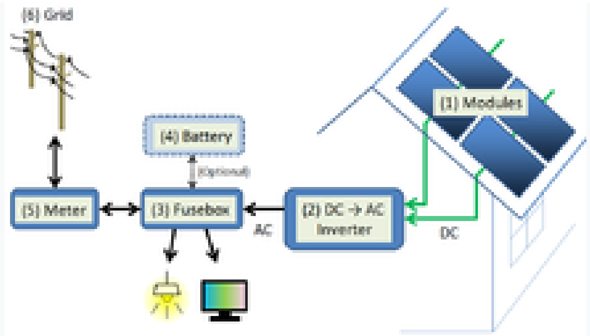
2. C.

In a larger PV array, individual PV modules are connected in both series and parallel. A series-connected set of solar cells or modules is called a "string". The combination of series and parallel connections may lead to several problems in PV arrays. One potential problem arises from an open-circuit in one of the series strings. The current from the parallel connected string (often called a "block") will then have a lower current than the remaining blocks in the module. This is electrically identical to the case of one shaded solar cell in series with several good cells, and the power from the entire block of solar cells is lost. The figure below shows this effect.



3 A.

A **solar inverter** or **PV inverter**, is a type of power inverter which converts the variable direct current (DC) output of a photovoltaic (PV) solar panel into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network. It is a critical balance of system (BOS)–component in a photovoltaic system, allowing the use of ordinary AC-powered equipment. Solar power inverters have special functions adapted for use with photovoltaic arrays, including maximum power point tracking and anti-islanding protection.



Simplified schematics of a grid-connected residential photovoltaic power system[1]

Solar inverters may be classified into four broad types:[2]

a) **Stand-alone inverters**, used in isolated systems where the inverter draws its DC energy from batteries charged by photovoltaic arrays. Many stand-alone inverters also incorporate integral battery chargers to replenish the battery from an AC source, when available. Normally these do not interface in any way with the utility grid, and as such, are not required to have anti-islanding protection.
b) **Grid-tie inverters**, which match phase with a utility-supplied sine wave. Grid-tie inverters are designed to shut down automatically upon loss of utility supply, for safety reasons. They do not provide backup power during utility outages.
c) **Battery backup inverters**, are special inverters which are designed to draw energy from a battery, manage the battery charge via an onboard charger, and export excess energy to the utility grid. These inverters are capable of supplying AC energy to selected loads during a utility outage, and are required to have anti-islanding protection.[*clarification needed*]
d) **Intelligent hybrid inverters**, manage photovoltaic array, battery storage and utility grid, which are all coupled directly to the unit. These modern all-in-one systems are usually highly versatile and can be used for grid-tie, stand-alone or backup applications but their primary function is self-consumption with the use of storage.

3C.

Solar Panel fusing

Commercially made solar panels over 50 watts have 10 gauge wires capable of handling up to 30 amps of current flow. If you connect these panels in series, there will be no increase in current flow so fusing is not required for this string. This is not the case when you have panels connected in parallel, as when connected in parallel the system current is additive. For instance if you have 4 panels each capable of up to 15 amps, then a short in one panel can draw all 60 amps towards that short-circuited panel. This will cause the wires leading to that panel to far exceed 30 amps causing that wire-pair to potentially catch fire. In the case of panels in parallel, a 30-amp fuse is required for each panel. If your panels are smaller than 50 watts, and use only 12 gauge wires, and 20 amp fuses are required.

Parallel/Combiner Box fusing

In a parallel system a combiner box is used that holds the fuses/breakers to each panel, plus one or more “combined” fuse leading to the charge controller or grid tie inverter (see figure). When sizing this “combined” fuse/breaker, we must first determine the worst case current that will flow based on our specific panels.

4 A.

Net metering

The user consumes electricity generated by the rooftop solar system and excess electricity is injected into the grid. For any additional requirement over and above the solar generation, energy can be imported from the grid. At the end of the settlement period, the consumer is only imported from the grid (Discom) the difference between solar energy generated and total energy consumed over the billing period.

Gross metering

In gross metering, total electricity generated by the solar system is injected into the grid, and consumer imports electricity from the grid for consumption at retail tariff. At the end of the settlement period, consumer is compensated for the electricity exported to the grid at Feed-in-Tariff (FiT), as determined by the state commission.

4 B

Standard ground mount

Standard or traditional ground mounts use ground anchors to hold up a racking table that supports the solar panels on rails. The exact method of anchoring will depend on your ground conditions: using concrete piers is most common, but driven piers, helical piles, and concrete ballasts are options, as well.

Standard ground mount systems typically hold the solar array in a fixed position, although options for manual adjustment are gaining popularity.

The standard ground-mount system is the easiest and most cost-effective solution for a ground install, and also the most common.

Pole mount

To build a pole-mount solar system, you dig one big hole into the ground, instead of several smaller holes as with a standard ground-mount. A large pole is set into the ground, upon which you connect your rails and mount your solar panels.

Pole-mount systems offer greater clearance from the ground, which is useful in avoiding foliage or other ground obstructions, and can even be used to provide space and shelter for animals to graze underneath. Another advantage of pole mounts is that they can easily incorporate a single-axis or dual-axis tracking system; these enable the panels to follow the sun over the course of the day and thus produce more energy.

4 C.

solar tracker, a system that positions an object at an angle relative to the Sun. The most-common applications for solar trackers are positioning photovoltaic (PV) panels (solar panels) so that they remain perpendicular to the Sun's rays and positioning space telescopes so that they can determine the Sun's direction. PV solar trackers adjust the direction that a solar panel is facing according to the position of the Sun in the sky. By keeping the panel perpendicular to the Sun, more sunlight strikes the solar panel, less light is reflected, and more energy is absorbed. That energy can be converted into power.

5A

The shading assessment is part of the **solar site analysis**. The tool is popular with solar panel installers and can be used worldwide.It will show exactly where the sun will travel throughout the year. It can help to determine which location is suitable to install **solar panels**, as it shows you how much shading you can expect over the course of the day. It measures and shows data not just during the day when you perform the measurement,

The Solar Pathfinder doesn't require **any specific weather circumstances** to work. It can be used in both cloudy and clear weather, and during anytime of the day.After placing the Solar Pathfinder at the desired location, you will see a reflection of your site from the perspective of the solar panels. Any obstacle that will block **sunlight** can be clearly seen in this **reflection**, and it will tell you when these obstacles will block the sunlight.With the help of these readings you can determine the best position for the installation of solar panels. The best position is of course the location with optimal sun and minimal shading.

5 B.

Most solar panels can be installed in both portrait and landscape. Specifically, this means that they can be clamped on either the long edge of the frame, or the short edge of the frame.

However, some PV modules do not have the ability to be clamped on the short edge of the frame (similar to b in the above image). This is typically either because the module has not been tested to pass this type of installation, or it failed to pass this type of installation. To confirm this, you will want to check with the module manufacturer directly.

5 C.

After the line-line fault, the configuration of the PV array in Fig. 2 has been accordingly changed. Specifically, the (m-2) modules below F1 at String 1 (from Module 3 to Module m) become parallel with the 2 modules below F1 at String 2 (Module m-1 and Module m). Yet modules above F1 and F2 at String 1 and String 2 respectively are in parallel. It would be easier to understand if you imagine that (m-2) modules below F1 at String 1 are sharing the same voltage as 2 modules below F2 at String 2. As a result, the voltage of m-2 modules at String 1 is pulled down to around the 2 times the open-circuit voltage of PV modules (Voc). Therefore, String 1 is significantly mismatched with other strings and the PV array's voltage might be even larger than the open-circuit voltage of faulted String 1. Instead of supplying power, String 1 may be forced to work as a load at the 4th quadrant in its I-V characteristics (see Fig. 3). The current backfeeding into String 1 from other strings is called backfed current (I back, or reverse current)

6A.

Charge Controllers

Charge controllers take some of the electricity from the DC current generated by a solar array and use it to charge a battery or a group of batteries. The charge controller regulates the voltage and current generated by a solar array so that it can properly charge the battery or bank of batteries. The power generated by solar panels varies with light (photon) exposure. If a charge controller was not present in the photovoltaic system, the batteries could be overcharged and may be damaged.

The nominal and maximum voltage and current specifications on the charge controller will determine the number of charge controllers required to gather energy from the solar array. If a solar array generates a maximum current of 16 A, but a charge controller only accepts a maximum current of 10 A, the solar array can be divided into two parts. Each half of the array can generate a maximum 8 A of current, and each half of the array can be connected to the 10 A charge controller. The other option would be to use a charge controller with a larger current rating. Most charge controllers have very high current ratings (at least 40 amps), and the need for more than one charge controller only becomes an issue with very large solar arrays.

Batteries

Batteries are used to store the energy generated by a solar array. Home-based solar arrays generate their largest power output in the middle of the day when most people are away from their homes. If the energy is not used immediately, it can be stored in a battery array. In a grid-hybrid system, any extra electricity generated after the batteries are charged can be sent back to the power grid.

Batteries supply DC power for a certain amount of time. The lifetime of a battery will depend on the current that the battery supplies and the maximum charge the battery can hold. The maximum charge of a battery is typically listed on the battery in units of milliamp-hours (mAh). This unit expresses the current the battery can supply and the amount of time it can supply the current.

Power inverter

There are two types of **power inverters** that are used in all photovoltaic systems. Grid-direct systems use a grid-tied inverter that can interact with the utility grid. This type of inverter is different from the inverters in off-grid or grid-hybrid systems because it does not run off of batteries. The off-grid and grid-hybrid systems use battery-powered inverters. Both types of inverters perform the same essential function in these systems: they convert DC power to AC power.

In the grid-hybrid and off-grid systems, solar energy that is not used immediately is stored in a battery system. The DC power that is stored in a battery can be converted to AC power using a power inverter. A power inverter is a device that converts DC power into AC power. The battery array in a photovoltaic system can be used to run a power inverter, power electronics or other BOS components. The components can be directly powered using DC power or indirectly using AC power. The DC-to-AC converter is required because almost all home electronics require 110 VAC power.

Safety and Grounding Equipment

Safety and grounding equipment is required for safety and fire prevention purposes. Automatic and manual safety disconnects protect the wiring and components of a photovoltaic system from power surges and other equipment malfunctions. They also ensure that your system can be shut down safely for maintenance and repair. In the case of grid-connected systems, safety disconnects also allow a photovoltaic system to be disconnected from the grid; this is important for the safety of people working on the grid transmission and distribution systems.

Grounding equipment provides a low-resistance path from your system to the ground to protect a photovoltaic system against current surges from lightning strikes or other equipment malfunctions. Users will need to create a grounded connection that is common to all of the balance-of-system equipment. This includes any exposed metal (such as the chassis of equipment boxes) that could potentially be touched by the customer or a technician.

6 B.

utility-interactive photovoltaic (PV) system is defined in Section 690.2 of the *National Electrical Code (NEC)* (NFPA 70-2005) as a “photovoltaic system that operates in parallel with and may deliver power to an electrical production and distribution network.”

NEC Article 690 covers Solar Photovoltaic Systems. Utility-interactive PV systems—also commonly referred to as grid-connected PV systems—allow bi-directional power flow to and from the building through the building’s service entrance.

The Public Utilities Regulatory Act of 1978 (PURPA) requires utilities to purchase power from independent power producers such as a building owner with a PV system at the utility’s avoided cost. PURPA provided an incentive for developing distributed generation (DG) resources while interconnecting those DG resources with the utility grid.

However, utility-required metering and relaying requirements for interconnection were usually geared toward industrial cogeneration and were impractical for small residential and commercial PV installations. This has changed in recent years with the development of new standards for small-scale utility-interactive PV systems, advances in PV-system technology, changes to the *NEC* and changes in utility regulatory requirements.

Power quality is an important concern for utility-interactive PV systems because PV system operating characteristics can have an impact on the utility-distribution system operation and affect other nearby utility customers. The inverter is the key to power quality because it transforms the direct-current (DC) power produced by the PV array into alternating-current (AC) power that matches utility power requirements.

The Institute of Electrical and Electronics Engineers (IEEE) publishes the IEEE Recommended Practice for Utility Interface of Photovoltaic (PV) Systems (IEEE Std 929-2000). This standard provides power-quality guidelines for PV system voltage, flicker, frequency and distortion. A companion standard to IEEE Std 929-200 is IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems (IEEE Std 1547-2003), which addresses inverters for all types of DG sources including PV and has identical inverter performance requirements.

The power-quality requirements and the test procedure for inverters contained in IEEE Standard 929 serves as the basis for Underwriters Laboratories’ (UL) testing standard UL 1741. Inverters used in utility-interactive PV systems should be UL-listed and meet the serving utility’s power-quality requirements if they are more stringent than UL 1741.

Safety is also a major concern for utilities when customers have utility-interactive PV systems. When utility power is lost to the residential or commercial building, the PV system may be producing power that will be fed back into the utility-distribution system and pose a danger to unsuspecting linemen working to restore power.

To prevent back feeding PV-generated power into the utility-distribution system during an outage, PV inverters listed for use on utility-interactive PV systems are designed to automatically disconnect from the utility system when an outage or other abnormality is detected. This feature is often referred to as “islanding protection.” A PV inverter with this feature is referred to as a “nonislanding inverter.”

7.

Design and installation of Solar PV Systems

Today our modern world needs energy for various day to day applications such as industrial manufacturing, heating, transport, agricultural, lightning applications, etc. Most of our energy need is usually satisfied by non-renewable sources of energy such as coal, crude oil, natural gas, etc. But the utilization of such resources has caused a heavy impact on our environment.

Also, this form of energy resource is not uniformly distributed on the earth. There is an uncertainty of market prices such as in the case of crude oil as it depends on production and extraction from its reserves. Due to the limited availability of non-renewable sources, the demand for renewable sources has grown in recent years.

Solar energy has been at the center of attention when it comes to renewable energy sources. It is readily available in an abundant form and has the potential to meet our entire planet's energy requirement. The solar standalone PV system as shown in fig 1 is one of the approaches when it comes to fulfilling our energy demand independent of the utility. Hence in the following, we will see briefly the planning, designing, and installation of a standalone PV system for electricity generation.

Planning of a Standalone PV system

Site assessment, surveying & solar energy resource assessment:

Since the output generated by the PV system varies significantly depending on the time and geographical location it becomes of utmost importance to have an appropriate selection of the site for the standalone PV installation.

the efficiency and the cost of the system.

To estimate the output power the solar energy assessment of the selected site is of foremost significance. Insolation is defined as the measure of the sun's energy received in a specified area over a period of time. You can find this data using a pyranometer, however, it is not necessary as you can find the insolation data at your nearest meteorological station. While assessing the solar energy the data can be measured in two ways as follows:

- **Kilowatt-hours per square meter per day (KWh/m^2/day):** It is a quantity of energy measured in kilowatt-hours, falling on square meter per day.
- **Daily Peak Sun Hours (PSH):** Number of hours in a day during which irradiance averages to 1000 W/m^2.

Peak sun hours are most commonly used as they simplify the calculations. Do not get confused with the "**Mean Sunshine Hours**" and "**Peak Sun Hours**" which you would collect from the meteorological station. The "Mean sunshine hours" indicates the number of hours the sunshine's were as the "Peak sun hours" is the actual amount of energy received in $KWh/m^2/day$. Amongst all months over a period of year use the lowest mean daily insolation value as it will make sure that the system will operate in a more reliable way when the sun is least due to unsuitable weather conditions.

Considerations for Standalone PV system

Calculation of Energy Demand

The size of the standalone PV system depends on the load demand. The load and its operating time vary for different appliances, therefore special care must be taken during energy demand calculations. The energy consumption of the load can be determined by multiplying the power rating (W) of the load by its number of hours of operation. Thus, the unit can be written as watt × hour or simply Wh.

A system should be designed for the worst-case scenario i.e. for the day when the energy demand is highest. A system designed for the highest demand will ensure that the system is reliable. If the system meets the peak load demand it will meet the lowest demand. But designing the system for the highest demand will increase the overall cost of the system. On the other hand, the system will be fully utilized only during the peak load demand. So, we have to choose between cost and reliability of the system.

Inverter & Converter (Charge Controller) Ratings

For choosing the proper inverter both the input and output voltage and current rating should be specified. The inverter's output voltage is specified by the system load, it should be able to handle the load current and the current taken from the battery bank. Based on the total connected load to the system the inverter power rating can be specified.

8. A.

System Documentation requirements (Ref. SLS 1522)

1.0 General

The purpose of clause 4 is to list the minimum documentation that should be provided following the installation of a grid connected PV system. This information will ensure key system data is readily available to a customer, inspector or maintenance engineer. The documentation includes basic system data and the information expected to be provided in the operation and maintenance manual.

2.0 System data

2.1 Basic system information

As a minimum, the following basic system information shall be provided. This "nameplate" information would typically be presented on the cover page of the system documentation pack.

a) Project identification reference (where applicable).
b) Rated (nameplate) system power (kW DC or kVA AC).
c) PV modules and inverters – manufacturer, model and quantity.
d) Installation date.
e) Commissioning date.
f) Customer name.
g) Site address.

2.2 System designer information

As a minimum, the following information shall be provided for all bodies responsible for the design of the system. Where more than one company has responsibility for the design of the system, the following information should be provided for all companies together with a description of their role in the project

3.0 Wiring diagram

3.1 General

As a minimum, a single line wiring diagram shall be provided. This diagram shall be annotated to include the information detailed in 4.3.2 to 4.3.6.

In general, it is expected that this information will be presented as annotations to the single line wiring diagram. In some circumstances, typically for larger systems where space on the diagram may be limited, this information may be presented in table form.

3.2 Array – General specifications

The wiring diagram or system specification shall include the following design information.

a) Module type(s).
b) Total number of modules.
c) Number of strings.
d) Number of modules per string.
e) Identify which strings connect to which inverter.

Where an array is split into sub-arrays, the wiring diagram shall show the array – sub- array design and include all of the above information for each sub-array.

3.3 PV string information

The wiring diagram or system specification shall include the following PV string information.

a) String cable specification – size and type.
b) String overcurrent protective device specifications (where fitted) - type and voltage/current ratings.
c) Blocking diode type (if relevant).

3.4 Array electrical details

The wiring diagram or system specification shall include the following array electrical information (where fitted).

a) Array main cable specifications – size and type.
b) Array junction box / combiner box location.
c) DC switch disconnector, location and rating (voltage/current).
d) Array overcurrent protective devices – type, location and rating (voltage/current)
e) Other array electronic protective circuitry (such as arc fault detection), if applicable – type, location and rating.

9.A.

Though solar panels cost money upfront, they are certain to save you money in the long-term. The question of how much solar panels will save you depends on a number of factors, including the hours of daily direct sunlight available to the panels, the angle of your roof and the size of your solar panel system. The most important factor, though, in determining how much money solar panels will save you, is simply your local electricity rates.

In order to determine how much money your solar panels will save you each year, calculate how much you spend on electricity annually (for reference, the typical American family spends about **$1,450 a year** on electricity). Then, determine what your current utility rate is, keeping in mind that utility rates tend to increase 2.2% or so each year (yet another reason to install solar panels).

Use an online calculator to estimate your annual savings by plugging in information like your location, energy usage and the current average price of solar panel installation in your area.

A common misconception is that solar panels will eradicate your electricity bills altogether. While this is sometimes the case, solar panels will significantly reduce your electricity bill each month, and are worth the investment as a whole.

9. B

Sales Comparison and Market Greenness Approach The Sales Comparison and Market Greenness approach estimates PV system value based upon comparison to nearby and similar properties with PV systems. While the Sales Comparison Approach is the general rule in residential appraisal reports and is also intuitive, this approach has the least merit for determining the value of a solar PV system. It is highly unusual to find a recent arm's length sale of a nearby and similar property with a like-sized solar PV system. Thorough market research for sales and listings is a required part of due diligence, even with a slim chance of finding comparables. Importantly, this research should include interviews with market participants to gauge market interest and identify experience with solar systems, so that a qualitative sense of the "market greenness" can be determined. The level of market sophistication on "green" structures is an important consideration on where solar PV should land within the expected value range. This market awareness factor is clearly shown as a value influence in the numerous studies on solar PV.10 Survey interviews that build qualitative data are a typical method used in appraisals where hard quantitative data is lacking. These interviews might be with solar installers, a local chapter of the U.S. Green Building Council, or real estate agents who are promoting themselves as having this specialty

10.A.

Solar systems are made up of **solar panels** (modules), a mounting system, and a **solar inverter** with computerised controller. Solar panels produce **DC electricity** from **sunlight**. Then the inverter converts the generated electricity into **AC**, so that it can be used in the household. The computerised controller manages the solar system and ensures **optimal performance**. If you want battery **backup system** or an off-the-grid solar system, a **battery** is required.

In the following video you can learn more about solar panel installation process.

10. B

1. Set Up Scaffolding

Firstly, you have to **erect scaffolding** to ensure safety during the whole installation process when being on the roof.

2. Install Solar Panel Mounts

Then, the solar panel **mounting system** has to be set up. This will support the base of the solar panels. The whole mounting structure must be tilted and have an angle between **18 to 36 degrees** to have **maximum sunlight exposure**.

3. Install the Solar Panels

When the mounts are set up, the solar panel itself has to be installed on the **mounting structure**. Make sure to tighten up all the bolts and nuts so that it **stays stable**.

4. Wire the Solar Panels

The next step in the installation process is to install the **electrical wiring**. In most cases, **MC4 connectors** are used because they are suited for all types of solar panels. Make sure to **shut off the household's electricity supply** during the wiring installation.

5. Install Solar Inverter

After that, the **solar inverter** must be connected to the system. It is typically installed near the main panel and it could be both **indoors and outdoors**. Inverters are more efficient if kept in a **cooler place**.

If the inverter is outdoors, it should be kept **out from the afternoon sun**. If it is installed indoors, the garage or utility room are usually the best places, since they stay cool for most of the year and have ventilation.

6. Bond Solar Inverter and Solar Battery

Thereafter, the **solar inverter** has to be connected to the **solar battery**. The solar battery storage can save you from worrying about the lack of **usable energy during cloudy times**, it can also lower the **solar battery storage system costs** during installation.

7. Connect the Inverter to the Consumer Unit

The inverter should be connected to the **consumer unit** to generate electricity. A generation meter should also be connected to **monitor** the amount of electricity the solar panels actually produce. You can use your computer or other device to check your **solar system's performance**. For example, you can check how much electricity you generate at different times and decide what time is suitable for using your washing machine or other utilities.

8. Start and Test Solar Panels

The final step is to **switch the power on and test** the newly installed solar panel system. After that, the solar panel installation process is completed.

CBCS SCHEME

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Eighth Semester B.E. Degree Examination, July/August 2022
Operation and Maintenance of Solar Electric System

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Explain the sun Geometry. **(08 Marks)**
b. What is the mainstream technology for semiconductor devices to produce PV array? **(08 Marks)**
c. Explain the affect of the earth's atmosphere on solar radiation. **(04 Marks)**

OR

2 a. Explain the procedure for Buying solar modules. **(08 Marks)**
b. Write about the characteristic of PV cells. **(08 Marks)**
c. What is creating a string of modules? **(04 Marks)**

Module-2

3 a. Briefly explain about the inverters. **(08 Marks)**
b. Explain different types of string inverter. **(08 Marks)**
c. Why are circuit breaker and fuses used in solar system? **(04 Marks)**

OR

4 a. Write a note on net metering and gross metering. **(08 Marks)**
b. Explain different ground mounting system and their application. **(08 Marks)**
c. What is sun tracking system? **(04 Marks)**

Module-3

5 a. What is solar pathfinder? **(08 Marks)**
b. Explain with diagram portrait and landscape installation in site assessment. **(08 Marks)**
c. What is fault-current protection in PV system? **(04 Marks)**

OR

6 a. Explain the choosing system components in designing grid connected PV system. **(10 Marks)**
b. What are the losses in utility-interactive PV system? **(10 Marks)**

Module-4

7 a. Explain in detail about PV array installation. **(10 Marks)**
b. What are the required information for installation of PV system. **(10 Marks)**

OR

8 a. What system documents are to be supplied to the owner after completion of PV installation? **(10 Marks)**
b. How trouble shooting of PV system is done? **(10 Marks)**

Module-5

9 a. What are the main costs associated with the individual components of the PV system. **(10 Marks)**
b. Write a note on marketing of PV system. **(10 Marks)**

OR

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10 a. What are case study of A and B? **(10 Marks)**
b. Explain the valuing of PV system. **(04 Marks)**
c. What is feed in tariff? **(06 Marks)**

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