ABSTRACT:
Energy in one form or the other is a basic input for sustenance of life on this planet not only for human beings living on it, but also the flora and fauna. The most abundant and never failing source of energy that is bestowed on the earth is, of course, solar energy without which there will be no wind, no rain, no vegetation, no rivers, no tides, no agriculture and so on.

In the present day context, commercial energy is one of the basic inputs for the accelerated economic development. The source from which this energy is derived are coal, lignite, oil, natural gas, nuclear energy, Hydro power and traditional forms of energy as fuel, wood, dung etc., used by millions of our countrymen living in the rural areas. Coal, oil and natural gas are also referred to as fossil fuels as they are derived from fossilization of vegetative matter over millions of years.

After the energy crisis in the year 1973, every one is seriously concerned with non-availability of conventional sources of energy to meet the energy requirements for various development activities. Hence, a lot of attention is being given for the development of renewable sources of energy in the country. Other factors in favor of renewable sources of energy are least impact on environment, ecology and ideally suited for de-centralized variety of applications. As an outcome extensive research and development activities during the last 10-15 years a number of devices/system have been
developed, which can be deployed for a variety of applications. A few of the devices/system have become commercially viable.

By the turn of the century, energy demand studies have predicted that the generating capacity of the country would have to be tapped around 250000 MW to sustain its economic growth. Since the country has inadequate conventional energy resources, it is absolutely essential that determined efforts be made to harness source or all of the indigenous renewable energy sources such as Biomass, Solar, Wind and Geo-thermal. All these sources are termed renewable in the sense that they are fuelled by nature and essentially in exhaustible in the time of man’s existence.

It is necessary to make adequate energy available to the people at an affordable price to facilitate this process and enhance the quality of life of all sections of the people especially in the case of the majority of people who live in rural areas. The production and distribution of energy to the consumers have to be simultaneously supplemented with concentrated efforts to use energy efficiently as otherwise the wasteful energy consumption will defeat the very purpose of economic development and lead to serious problems in all sectors of economy - whether industry, agriculture or other social sectors. In this scenario, it is very important to focus on energy conservation aspects and take necessary steps at the earliest to ensure that energy is produced with maximum efficiency, transformed and transmitted with minimum losses and at the same time technologies to maximize end use energy efficiently are adopted. There is urgent need for conservation of energy in domestic, agriculture, commercial, transport and industrial sectors. The promotion of energy efficiency devices and technologies will not only reduce the need to create new capacities requiring mobilization of huge resources but also results in significant environmental benefits. Energy security can be enhanced by supply side as well as demand side measures. While the former aimed at increasing energy availability has limitations, the latter targets reduction in energy demand through conservation, demand restraint and fuel-switching which is more sustainable in the long term. Large-scale development of renewable energy and efficient use of available conventional energy. Together, constitute Energy Security.

Buildings are major consumers of energy in their construction, operation and maintenance. About 50% of global energy demand is estimated to be due to buildings. Energy requirements in buildings are further increasing in developing countries with rising economy. In India, buildings accounts for 30-40% of total energy consumption. ENERGY CONSCIOUS ARCHITECTURE addresses these issues.

The energy management program is a systematic on-going strategy for controlling a building’s energy consumption pattern. It is to reduce waste of energy and money to the minimum permitted by the climate the building is located, its functions, occupancy schedules, and other factors. It establishes
and maintains an efficient balance between a building’s annual functional energy requirements and its annual actual energy consumption.

The energy management, it not only serves to identify energy use among the various services and to identify opportunities for energy conservation, but it is also a crucial first step in establishing an energy management programme. The energy audit will produce the data on which such a programme is based. The study should reveal to the owner, manager, or management team of the building the options available for reducing energy waste, the costs involved, and the benefits achievable from implementing those energy-conserving opportunities (ECO).

Energy is one of the major inputs for economic development of any country. In the case of developing countries like us, the energy sector assumes critical importance in view of the ever-increasing energy needs, widening of supply demand gaps and also huge investments required to meet them. The availability of energy is limited and known resources of energy are exhausting fast. In order to conserve the available resources, there is need to promote the Renewable Energy and Energy Conservation.

The prime objective of electric energy generation is to satisfy customer needs economically with emphasis on Safety, Reliability and Quality. Most of the conventional energy generation technologies employ exhaustible sources like coal, oil and nuclear fuel. Recent events have posed a setback to the sector of conventional power generation, the reasons for which include Higher fuel prices, Societal pressures to conserve resources, Environmental awareness, Increase in production cost and Concern for safety related to certain technology (like the Nuclear). Hence in present day energy scenario, for meeting the ever-increasing energy demand, efforts have come into focus with a view to develop new generation technologies. The major goals of these approaches are to have reduced environmental damages, Conservation of energy, Exhaustible sources and increased safety. In this context during the past few years, renewable energy sources have received greater attention and considerable inputs have been given to develop efficient energy conversion and utilization techniques.

1. INTRODUCTION

The realization of enormous needs to electrify and energies remote rural areas of developing countries where renewable and Non-conventional energy sources are adequately available. Renewable source of energy has least impact on environment, ecology and is ideally suited for decentralized variety of applications. Since the country has inadequate conventional energy resources, it is absolutely essential that determined efforts be made to harness source or all of the indigenous renewable energy sources such as: Solar, Wind, Biomass, Geo-thermal. The most abundant and never failing source of energy that is bestowed on the earth is, of course, solar energy without which there will be no wind, no rain, no vegetation, no rivers, no tides, no agriculture and so on. All these sources are termed renewable in the
sense that they are fuelled by nature and essentially in exhaustible in the time of man’s existence. renewable energy devices / systems / projects & energy conservation measures that can help to bring about reduction in consumption of conventional energy.

2. TO DEVELOP NEW GENERATION TECHNOLOGIES & RENEWABLE ENERGY SOURCES:
   a) Ever-increasing energy demand
   b) Reduced environmental damages and increased safety.
   c) Conversion of energy and inexhaustible sources.
   d) Received greater attention to develop efficient energy conversion and utilization Techniques.
   e) Realization of enormous need to electrify & energies remote rural areas.
   f) Adequately available, least impact on environment and ecology
   g) The future of fossil fuels has a limited time for their availability
   h) Inaccessible areas and hilly terrain’s, renewable energy becomes very handy.
   i) The cost of generation goes on decreasing as time passes.
   j) Environmental friendly projects

3. LIMITATIONS OF RENEWABLE ENERGY SOURCES:

   SOLAR – Seasonal nature and usefulness is somewhat limited
   BIOMASS – Cost of Raw material increases ever year
   CO-GENERATION – Only in sugar factories
   MINI / MICRO HYDEL - Seasonal nature and Canal based sites
   WIND - Seasonal nature and Requirement of Windy sites

4. SOLAR:

   INTRODUCTION: - Solar energy is a very large, inexhaustible source. The power from the Sun intercepted by the Earth is approximately $2.9 \times 10^{15}$ MW, which is many thousands of times larger than the present consumption rate on the earth of all commercial energy source. Thus in principal, solar energy could supply all the present and future energy needs of the world as a continuous basis. This makes it one of the most promising of the unconventional energy sources.

4.1 WHY SOLAR ENERGY:
   a) Non availability of conventional sources of energy.
   b) Environment friendly
   c) Suitable for decentralized application

4.2 SOLAR ENERGY UTILIZATION:

   1. Direct methods ---- Thermal and Photovoltaic
   2. Indirect methods ---- Water power generation, Wind power, and Biomass and Ocean temperature differences.

   Photo-voltaic (PV) solar energy conversion is one of the most attractive non conventional energy sources of proven reliability from micro watts to
The most useful way of harnessing solar energy is by directly converting it into electricity by means of solar photo voltaic cells, when Sunshine is incident on solar cells, they generate DC electricity without the involvement of any mechanical generators i.e. there is direct conversion of solar radiation into electricity. In this system stage of conversion into thermo dynamic form is absent. The Photovoltaic effect is defined as the generation of electromotive forces as a result of the absorption of ionizing radiation. Energy conversion devices, which are used to convert Sun, light to electricity by use of the photovoltaic effect. Photovoltaic system employ energy conversion devices called solar cells.

4.4. ADVANTAGES / DISADVANTAGES OF PHOTOVOLTAIC SYSTEM
A] Advantages:
1) Director room temperature conversion of light to electricity through simple solid state devices.
2) Ability to function unattended for long periods as evidence in space program. They do not create pollution. They have a long effective life and They are highly reliable
3) Power levels – voltage/current can be achieved by more integration.
4) Maintenance cost is low, as they are easy to operate. Wider power handling capabilities. And Easy to fabricate, Amenable to on site installation and Absence of moving parts.
5) They consume no fuel to operate, as the Sun’s energy is free. Rapid response in output to input radiation. They can be used with or without Sun tracking making possible wide range of applications possibilities.
6) It is an environmentally clean source of energy. Free and available in adequate quantities in almost all parts of the world where people live.
B] **Disadvantages:**

1. The solar radian flux availability is a low value 1 kW/m² for technological utilization. And Large collecting area required.
2. Cost is more. And Availability varies with time.
3. In many applications, energy storage is required because of insolation at night.
4. The relatively poor conversion efficiency.

5. **Energy from the sun:**

   About half the incoming solar energy is absorbed by water and land; the rest is reradiated back into space. Earth continuously receives 340 Wm-2 of incoming solar radiation (insolation) at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by the atmosphere, oceans and land masses. After passing through the atmosphere, the insolation spectrum is split between the visible and infrared ranges with a small part in the ultraviolet. The absorption of solar energy by atmospheric convection (sensible heat transport) and evaporation and condensation of water vapor (latent heat transport) powers the water cycle and drives the winds. Sunlight absorbed by the oceans and land masses keeps the surface at an average temperature of 14 °C. The conversion of solar energy into chemical energy via photosynthesis produces food, wood and the biomass from which fossil fuels are derived. Solar radiation, along with secondary solar resources such as wind and wave power, hydroelectricity and biomass, account for over 99.9% of the available flow of renewable energy on Earth.

   The flows and stores of solar energy in the environment are vast in comparison to human energy needs:

   1) The total solar energy absorbed by Earth’s atmosphere, oceans and land masses is approximately 3850 zetta joules (ZJ) per year (1 zetta joule = 1021 joules and 1 peta watts = 1015 watts). All usable energy forms, apart from nuclear energy and earth’s heat, are forms of solar energy.

   2) Global wind energy at 80 m is estimated at 2.25 ZJ per year. Fuels from fossils, produced over a period of many million years from solar energy, cannot last indefinitely and Photosynthesis captures approximately 3 ZJ per year in biomass. Conventional forms of energy are stored solar energy in the form of fossil fuels or biomass.
3) Solar energy, which radiates nearly 20,000 times the energy requirement of the world on the surface of the earth, is abundantly available all over India. The Sun is a sphere consisting of hot gases. It's diameter is 1.39 million km (109 times that of earth). On an average, the Sun is 150 million km away from the earth and The Sun’s rays require 9 minutes to cover this distance.

5.1 SOLAR SPECTRUM:
The electromagnetic spectral distribution emitted by the sun or received by a collector or instrument on Earth
1) Sun’s total energy is composed of
   a. 7% UV radiation, b. 47% Visible radiation and c. 46% Infrared radiation
2) Photovoltaic cells primarily use visible radiation
3) Distribution of colours within the light is important - PV cell will produce different amounts of current depending on the various colours shining on it.

5.2 IRRADIANCE:
1) The amount of solar power available per unit area is known as irradiance, Represented as H
2) Unit is – kW/Sq.m or watts/Sq.m or mW/Sq.cm
3) Measuring Device – Pyrometer
4) Peak Value – 1kW/Sq.m and Nominal Value – 0.8kW/Sq.m
5) Irradiation fluctuates according to the Sun’s location in the sky i.e. changes in both Sun's altitude angle and its azimuth angle
6) For India, the total number of sunshine hours is approximately 4000 in a year
7) The power produced by solar cells is proportional to the intensity of global radia. For optimal use in the northern hemisphere, a solar system is oriented southwards at an inclination from the horizontal
8) The appropriate inclination angle, $\alpha$, is dependent upon the latitude and on the time of the year
9) In spring and in the beginning of fall, Sun shines exactly overhead at the equator.
10) The biggest deviation from this position occurs at the beginning of summer (between +23.45 degree) and at the beginning of winter (-23.45 degree).
11) The solar radiations incident on a horizontal surface is comprised of sky radiation and the reflected radiation.

5.3 SOLAR INSOLATION:
The actual amount of sunlight falling on a specific geographical location is known as insolation—or "incident solar radiation." The level of intensity of energy from the sun that strikes earth. Usually given as watts per square meter (W/m²).

When sunlight reaches the Earth, it is distributed unevenly in different regions. Not surprisingly, the areas near the Equator receive more solar radiation than anywhere else on the Earth. Sunlight varies with the seasons, as the rotational axis of the Earth shifts to lengthen and shorten days with the changing seasons.

1) Solar insolation is radiant energy per unit area
2) Expressed in units of kWh/m² /day
3) Average daily solar radiation data for each of the 12 Months
4) Provide average long-term average daily solar radiation data (typically 30 years)
5) Data is useful in predicting long-term performance and in analysing the economics of solar energy system

6) Peak Sun Hours - The number of peak sun hours per day at a given location is the equivalent time at peak sun condition that yields the same total insolation
7) Hourly solar radiation data for each of the 12 Months for a typical year –
8) Typical meteorological year consists of 12 months with each month selected so that it best represents the average of that particular month over past years
9) This data is good for photovoltaic system analysis.

5.4. SOLAR CONSTANT:
1) "A Photovoltaic device, outside the earth's atmosphere which maintains normal incidence to the sun's rays receives nearly constant rate of energy." This amount is called the Solar Constant.
2) Solar constant approx. = 1.36 kW/ Sq.m
3) Solar constant and associated solar spectrum are determined solely by nature of the radiating source and distance between earth and sun
4) The solar constant is the amount of incoming solar radiation per unit area, measured on the outer surface of earth atmosphere, in a plane perpendicular to the rays.
5.5 THE SUN - MAIN FEATURES:
1) Radiant energy output: $3.94 \times 10^{26}$ W
2) Radius of the Sun: $6.960 \times 10^8$ m
3) Mean sun–earth distance: $149.6 \times 10^6$ Km
4) Radius of the Earth: $6.378 \times 10^6$ m
5) Energy intercepted by Earth: $1.8 \times 10^{17}$ W
6) Solar constant: $1367$ W/m²

**SOLAR WINDOW:**
- Solar window represents the effective area through which useful levels of sunlight pass through the year for a specific location.
- Solar window is used to determine potential shading when designing a photovoltaic system.

**Atmospheric Effects**
- Presence of atmosphere and associated climatic effects both attenuate and change the nature of the solar energy resource.
- Because of cloud cover and scattering of sunlight, the radiation received at a point is both direct and diffuse.

**Solar Air Mass**
- Air mass is defined as $(1/\cos \Theta)$ (where $\Theta$ is angle between the Sun and directly overhead).
- Air mass indicates the relative distance that light must travel through the atmosphere to a given location.

**Sensitivity of PV Materials to Various Wavelengths**
- The spectral distribution of power is important because different photovoltaic cell materials are stimulated by different portions of the solar spectrum.
- Photovoltaic cell research involves developing materials or combinations of materials which better utilize the power within the solar spectrum.
Components of Solar Radiation
› Global Horizontal Irradiance (GHI)
› Direct Normal Irradiance (DNI)
› Diffuse Horizontal Irradiance (DHI)

5.6 WHAT IS LATITUDE AND LONGITUDE?

LATITUDE (φ): Latitude is defined as the number of degrees north or south of the equator. The latitude affects where the sun is positioned in the sky throughout each day (relative to the position). Lines of latitude appear straight and horizontal in the projection above, but are actually circular with different radii. All locations with given latitude are collectively referred to as a circle of latitude.

The equator divides the planet into a Northern Hemisphere and a Southern Hemisphere, and has Latitude of 0°. Latitude, usually denoted symbolically by the Greek letter phi (φ), gives the location of a place on Earth (or other planetary body) north or south of the equator. Lines of Latitude are the horizontal lines shown running East–to–West on maps. Technically, latitude is an angular measurement in degrees (marked with °) ranging from 0° at the equator (low latitude) to 90° at the poles (90° N for the North Pole or 90° S for the South Pole; high latitude). The Latitude is approximately the angle between straight up at the surface (the Zenith) and the SUN at an equinox. The Complementary angle of Latitude is called the Colatitude.

LONGITUDE (λ):
Lines of longitude, usually denoted symbolically by the Greek letter lambda (λ), appear curved and vertical in this projection, but are actually halves of great circles. Unlike Latitude, which has the equator as a natural starting position, there is no natural starting position for Longitude. Therefore, a reference meridian had to be chosen. While British cartographers had long used the Greenwich meridian in London, other references were used elsewhere, including: El Hierro, Rome, Copenhagen, Jerusalem, Saint Petersburg, Pisa, Paris, Philadelphia, and Washington. In 1884, the International Meridian Conference adopted the Greenwich meridian as the universal prime meridian or zero point of Longitude.
**ALTITUDE** - The angle of the sun off the horizon varies throughout the year. The amount of variation is consistent across the globe, with the exact measurement dependent on the time of day and the specific Latitude on the earth.

5.7 **SEASONAL EFFECTS:**
The number of daylight hours each day has an obvious effect on a PV array’s production: More sun means more solar energy. As a PV installer, you need to be able to visualize how the position of the sun changes with each season and the effect that has on the arrays you’re designing and installing. In other words, you need to be able to take seasonal effects into account.

One important factor to consider is the motion of the earth around the sun. Earth takes an elliptical path around the sun, meaning that on the summer solstice (approximately June 21), the earth is actually at its farthest point from the sun. On this day, the Northern Hemisphere is tilted toward the sun, and that half of the world has its longest day (and shortest night) of the year. Time moves on, and the earth continues to orbit the sun. On the winter solstice (approximately December 21), the planet is as close to the sun as it’ll ever get; on this day, the Northern Hemisphere is tilted away from the sun, creating the shortest day and longest night.

The other factor to consider when it comes to seasonal effects is the tilt of the earth’s axis. When viewed from space, the earth’s axis has a tilt of 23.5 degrees. Because of this tilt, during the times between the spring equinox (approximately March 21) and the fall equinox (approximately September 21), the Northern Hemisphere is actually pointing toward the sun, whereas the Southern Hemisphere is pointed away from it. As the earth’s orbit continues toward winter, the hemispheres swap their positions, so the Northern Hemisphere points away from the sun, and the Southern Hemisphere points toward the sun. On the equinoxes, the earth isn’t pointing toward or away from the sun; instead, it’s directly perpendicular with it.

5.8 **TILT ANGLE:**
To get the most from solar panels, it needs to point them in the direction that captures the most sun. But there are a number of variables in figuring out the best direction. It is designed to help to find the best placement for the solar panels in the situation. This advice applies to any type of panel that gets energy from the sun: photovoltaic, solar hot water, etc. We assume that the panel is fixed, or has a tilt that can be adjusted seasonally. (Panels that track the movement of the sun throughout the day can receive 10% (in winter) to 40% (in summer) more energy than fixed panels. Solar panels should always face true south. (If you are in the southern hemisphere, they should face north.) The question is, “At what angle from horizontal should the panels be tilted?” Books and articles on solar energy often give the advice that the tilt should be equal to the Latitude, plus 15 degrees in winter or minus 15 degrees in summer. It can do better than this – about 4% better.
1) It is angle between array and horizontal surface, which gives maximum solar irradiation
2) Solar panels should always face true south if you are in northern hemisphere, or true north if you are in the southern hemisphere

5.9 ORIENTING THE ARRAY TO THE AZIMUTH:
Another major component to consider when planning the array location to maximize energy output is the orientation with respect to true north, or the azimuth. The best way to refer to the azimuth of an array is to refer to the number of degrees the array is facing with reference to true north, exactly the same as you refer to the sun’s position.

With this notation, the array has an azimuth of 90 degrees if it faces true east, 180 degrees if it faces true south, and 270 degrees if it faces true west. Bear in mind that true east, true south, and true west don’t refer to compass directions; instead, they take magnetic declination into account. (Magnetic declination is the difference between true north and magnetic north; flip to Chapter 5 to discover how to account for magnetic declination.) For an example of what I mean, look at Figure 4-12. It shows a PV module that has an azimuth that’s east of south. You could also say that this module has an azimuth of approximately 165 degrees based on how far it is from true north.

SOLAR ENERGY CONVERSION
SOLAR THERMAL
Converting incident solar energy into heat and then using that heat for water / space heating, cooking, drying and also for electricity generation
**SOLAR PHOTOVOLATIC**
Converting the incident solar energy directly into DC electricity using solar cell and then converting into AC for power the load or feeding to grid

### SOLAR ENERGY

1. **LIGHT ENERGY**
2. **HEAT ENERGY**

### SOLAR TECHNOLOGY LANDSCAPE

<table>
<thead>
<tr>
<th>Photovoltaic</th>
<th>Solar Thermal</th>
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<tbody>
<tr>
<td>TRADITIONAL PV</td>
<td>TROUGH</td>
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<tr>
<td>CPV</td>
<td>TOWER</td>
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<tr>
<td>DISH ENGINE</td>
<td>FRESNEL REFLECTOR</td>
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</tbody>
</table>

#### Pyranometer
1. A **pyranometer** is a type of actinometer used to measure broadband solar irradiance on a planar surface and is a sensor that is designed to measure the solar radiation flux density (in watts per metre square) from a field of view of 180 degrees.
2. The solar radiation spectrum extends approximately from 300 to 2,800 nm. Pyranometers usually cover that spectrum with a spectral sensitivity that is as “flat” as possible.

### Global Radiation Parameters
1. Global Radiation is measured by unshaded pyranometer
2. Global Radiation – Instantaneous: Global radiation at a given time
3. Global Radiation – Average- Selected Time interval: Average global radiation at user selectable interval
4. Global Radiation – Integrated- Selected Time period: Integrated values of global radiation in selected time period
5. Global Energy – Average (kwh/meter²): Averaged values of global radiation in Watt units

### Weather parameters
1. Air Temperature- Average- Selected Time interval: Average air temperature at user selectable interval. It is also known as Dry Bulb temperature. Averaging interval currently is 10 seconds.
2. Wind Direction -Average- Selected Time interval: Average wind direction at user selectable interval (currently used 10 sec).
3. Wind Speed -Average- Selected Time interval: Average wind speed at user selectable interval
Averaged values of global radiation in Joule units

4. Relative Humidity - Average:
Selected Time interval: Average relative humidity at user selectable interval (currently used 10 sec).

5. Dew Point - Average:
Selected Time interval: Average dew point at user selectable interval (currently used 10 sec).

Solar Radiation at the top of Earth’s Atmosphere
Three factors determine the amount of solar radiation that enters the top of the atmosphere.
1. Time of year
2. Latitude
3. Time of day
These factors are determined by the Sun’s altitude.
Sun’s altitude is the angle between the Sun, a point on the surface of the Earth and the nearest horizon.

5.10 STANDARD TEST CONDITIONS
All PV module manufacturers test their modules under standard test conditions (STC).
The three main elements to the STC are: cell temperature, irradiance, and air mass — all of which are variable conditions that the PV modules will be exposed to after they’re installed. Because these conditions affect the modules’ power output, PV manufacturers had to establish a value for each of these elements that everyone could test to and report their results. Those standard values are as follows:

1) **Cell temperature**: The STC for cell temperature is 25 degrees Celsius or 77 degrees Fahrenheit. (Note that it’s cell temperature, not air temperature.) When a PV module is operating in the sun, it typically gets much hotter than 25 degrees Celsius. Depending on the location and the way the module is mounted, cell temperatures of 75 degrees Celsius aren’t uncommon when the modules are in full sun.

2) **Irradiance**: Irradiance, simply stated, is the intensity of the solar radiation striking the earth. The STC value for irradiance is 1,000 watts per square meter (W/m²). Irradiance values vary from 0 W/m² to 1,250 W/m². The 1,000 W/m² value represents full sun, or peak sun, which is common to many terrestrial locations.

3) **Air mass**: Air mass is a representation of how much atmosphere sunlight must pass through to strike the earth. The STC value for air mass is 1.5 (AM 1.5). Actual air mass values vary widely depending on one’s
location on the globe, the time of year, and the time of day. Of these	hree elements, you should concern yourself with compensating for
differences in cell temperature and irradiance values because these
two variables directly and measurably affect a PV module’s voltage
and current in the following ways:

6. THEORY SOLAR CELLS:
A solar cell is based upon the "photovoltaic effect" discovered in 1839 by
Edmund Becquerel, a French physicist. In his experiments he found that certain
materials would produce small amounts of electric current when exposed to
sunlight. Sunlight is made up of packets of energy called photons. When the
photons strike the semi-conductor layer (usually silicon) of a solar cell a portion
of the photons are absorbed by the material rather than bouncing off of it or
going through the material. When a photon is absorbed the energy of that
photon is transferred to an electron in an atom of the cell causing the electron
to escape from its normal position. This creates, in essence, a hole in the atom.
This hole will attract another electron from a nearby atom now creating yet
another whole, which in turn is again filled by an electron from another atom.
This moment of electron and holes process is repeated a few zillion times and voila,
an electric current is formed.

6.1 PV DEVICES
Photovoltaic devices can be made from various types of semiconductor
materials, deposited or arranged in various structures, to produce solar cells
that have optimal performance. The three main types of materials used for
solar cells.

1. The first type is silicon, which can be used in various forms, including
   single-crystalline, multicrystalline, and amorphous.
2. The second type is polycrystalline thin films, with specific discussion of
copper indium di selenide (CIS) cadmium telluride (CdTe), and thin-
   film silicon.
3. The third type of material is single-crystalline thin film, focusing
   especially on cells made with gallium arsenide.
   The various ways that these materials are arranged to make complete
   solar devices. The four basic structures we describe include
   homojunction, heterojunction, and multifunction devices.

6.2 SOLAR CELL MATERIALS AND STRUCTURES
The absorption coefficient of a material indicates how far light having a
specific wavelength (or energy) can penetrate the material before being
absorbed. A small absorption coefficient means that light is not readily
absorbed by the material. Again, the absorption coefficient of a solar cell
depends on two factors: the material making up the cell, and the wavelength
or energy of the light being absorbed. Solar cell material has an abrupt edge in
its absorption coefficient. The reason is that light whose energy is below the material's
band gap cannot free an electron. And so, it isn't absorbed.
6.3 PHOTOVOLTAIC EFFECT

The photovoltaic effect involves the creation of a voltage (or a corresponding electric current) in a material upon exposure to electro-magnetic radiation. Though the process is directly related to the photoelectric effect, the two processes are different and should be distinguished. Photovoltaic Effect is the effect that causes a voltage to be developed across the junction of two different materials when they are exposed to light. In the photoelectric effect electrons are ejected from a material's surface upon exposure to radiation of sufficient energy. The photovoltaic effect is different in that the generated electrons are transferred from one material to another resulting in the buildup of a voltage between two electrodes.

In most photovoltaic applications the radiation is sunlight and for this reason the devices making use of the photovoltaic effect to convert solar energy into electrical energy are known as solar cells. In the case of a p-n junction solar cell, illumination of the material results in the creation of an electric current as excited electrons and the remaining holes are swept in different directions by the built in electric field of the depletion region.

6.4 PHOTOVOLTAIC BASICS

What do we mean by photovoltaics? First used in about 1890, the word has two parts: photo, derived from the Greek word for light, and volt, relating to the electricity pioneer Alessandro Volta. So, photovoltaics could literally be translated as light-electricity. And that's what photovoltaic (PV) materials and devices do — they convert light energy into electrical energy (Photoelectric Effect), as discovered by renowned physicist Albert Einstein. Commonly known as solar cells, individual PV cells are electricity-producing devices made of semiconductor materials. PV cells come in many sizes and shapes — from smaller than a postage stamp to several inches across. They are often connected together to form PV modules that may be up to several feet long and a few feet wide. Modules, in turn, can be combined and connected to form PV arrays of different sizes and power output.

The size of an array depends on several factors, such as the amount of sunlight available in a particular location and the needs of the consumer. The modules of the array make up the major part of a PV system, which can also include electrical connections, mounting hardware, power-conditioning equipment, and batteries that store solar energy for use when the sun isn't shining. Simple PV systems provide power for many small consumer items, such as calculators and wristwatches. More complicated systems provide power for communications satellites, water pumps, and the lights, appliances, and machines in some people's homes and workplaces. Many road and traffic signs along highways are now powered by PV. In many cases, PV power is the least expensive form of electricity for performing these tasks.

6.5 FUNDAMENTALS OF SOLAR CELL:

Semiconductors as basic solar cell material, materials and properties, P – N junction and solar cell. Sources of Losses and prevention. Solar Electric Systems-
Photovoltaic (PV) systems convert light energy directly into electricity. Commonly known as “solar cells.” A solar cell, sometimes called a photovoltaic cell, is a device that converts light energy into electrical energy. A single solar cell creates a very small amount of energy (about 0.6 Volts DC), so they are usually grouped together in an (Series and Parallel integration under Kirchhoff’s Voltage and Current Law) integrated electrical panel called a solar panel. Sunlight is a somewhat diffuse form of energy and only a portion of the light captured by a solar cell is converted into electricity. The current generation of solar cells convert only 12 to 15 per cent of the sun's light into electricity. However, in recent years there have been significant advances in their design. Some new cells on the market now are around 20% efficient and some laboratory prototypes are reaching as high as 30%. Given this it is likely that their efficiency will continue to improve over time.

1) Solar Cells: Convert sunlight into Electricity (DC)
2) SOLAR CELL MATERIALS - Solar cells can be made from a wide range of semiconductor materials (elements and compounds)
3) Silicon (Si)—including single-crystalline Si, Multi crystalline Si, and amorphous Si
4) Polycrystalline thin films—including copper indium diselenide (CIS), cadmium telluride (CdTe), and thin-film silicon
5) Single-crystalline thin films—including high-efficiency material such as gallium arsenide (GaAs). The aspects we will cover are crystallinity, absorption, band gap, and complexity of manufacturing.
6) Material Form: Crystalline & Amorphous: (wafer, ribbon, sheet, thin film)
7) Material Properties: Band gap, absorption coefficient of light, semiconductor doping, metal contacts, raw material availability and affordability
8) Current Technology Materials: Silicon, Gallium Arsenide, Cadmium, Telluride (CdS-CdTe), Copper Indium-diSelenide (CdS-CuInSe2)

6.6 SOLAR CELL STRUCTURES
1) Homojunction Device
Crystalline silicon is the primary example of this kind of cell. A single material crystalline silicon is altered so that one side is p-type, dominated by positive holes, and the other side is n-type, dominated by negative electrons. The p/n junction is located so that the maximum amount of light is absorbed near it. The free electrons and holes generated by light deep in the silicon diffuse to the p/n junction, and then separate to produce a current if the silicon is of sufficient high quality.

2) Heterojunction Device
This type of device structure is a CIS cell, where the junction is formed by contacting two different semiconductors—CdS and CuInSe2. This structure is often chosen for producing cells made of thin-film materials that absorb light much better than silicon. The top and bottom layers in a heterojunction device have different roles. The top layer, or “window” layer, is a material with a high band gap selected for its transparency to light. The
window allows almost all incident light to reach the bottom layer, which is a material with low band gap that readily absorbs light. This light then generates electrons and holes very near the junction, which helps to effectively separate the electrons and holes before they can recombine.

3) Multifunction Devices
This structure, also called a cascade or tandem cell, can achieve higher total conversion efficiency by capturing a larger portion of the solar spectrum. In the typical multifunction cell, individual cells with different band gaps are stacked on top of one another. The individual cells are stacked in such a way that sunlight falls first on the material having the largest band gap. Photons not absorbed in the first cell are transmitted to the second cell, which then absorbs the higher-energy portion of the remaining solar radiation while remaining transparent to the lower-energy photons. These selective absorption processes continue through to the final cell, which has the smallest band gap. A multifunction device is a stack of individual single-junction cells in descending order of band gap (Eg). The top cell 
Eg1 > Eg2 > Eg3, Cell 1 (Eg1), Cell 2 (Eg2) and Cell 3 (Eg3) 
Captures the high-energy photons and passes the rest of the photons on to be absorbed by lower-band gap cells.

A multifunction cell can be made in two different ways. In the mechanical stack approach, two individual solar cells are made independently, one with a high band gap and one with a lower band gap. Then the two cells are mechanically stacked, one on top of the other. In the monolithic approach, one complete solar cell is made first, and then the layers for the second cell are grown or deposited directly on the first.

4) Band Gap
The band gap of a semiconductor material is an amount of energy, specifically, it's the minimum energy needed to move an electron from its bound state within an atom to a free state. This free state is where the electron can be involved in conduction. The lower energy level of a
A semiconductor is called the "Valence Band." And the higher energy level where an electron is free to roam is called the "Conduction Band." The band gap (often symbolized by $E_g$) is the energy difference between the Conduction Band and Valence Band.

5) **Photovoltaic Effect**
- The term "photovoltaic" comes from Greek *phos* meaning 'light', and the name of the Italian physicist Volta, after whom the volt (and consequently ‘voltage’) are named. It means literally, of light and electricity.
- Result of two phenomena:
  - Light absorption in a material: Light imparts energy to free some electrons & holes (Absorption & Generation).
  - A built-in potential in the material separates the carriers which are collected and drive a current (dc) (Collection).

6) **Physics of PV**
Connecting cell construction to the photovoltaic effect. The phrase *photovoltaic effect* describes solar cells’ ability to produce voltage and current when exposed to sunlight. Here’s a step-by-step breakdown of how a cell’s construction allows that to happen:
1. Energy from the sunlight’s photons excites the electrons located on the solar cell’s N type, giving them the potential (voltage) to move.
2. When the solar cells are connected to a load, the excited electrons start moving (current flow) from the N type to the P type, performing useful work along the way.
3. The electrons go to the cell’s P type and combine with the electron holes.
4. As sunlight continues to strike the cell and more electrons are sent through the circuit, the electrons are forced from the P type back to the N type through the PN junction to continue the process.

**The Anatomy of a PV Cell**

![Diagram of PV Cell](image)

- The photon, or light ray hits the cell and its electrons are pulled to the p-type (positive side).
- At the electric field, or meeting surface between p-type and n-type (negative side) of the cells, positive and negative charges are exchanged creating a current.
7) STRUCTURE OF A SOLAR CELL
A typical solar cell is a multi-layered material:

1) **Cover Glass** - This is a clear glass layer that provides outer protection from the elements.
2) **Transparent Adhesive** - This holds the glass to the rest of the solar cell.
3) **Anti-reflective Coating** - This substance is designed to prevent the light that strikes the cell from bouncing off so that the maximum energy is absorbed into the cell.
4) **Front Contact** - Transmits the electric current.
5) **N-Type Semiconductor Layer** - This is a thin layer of silicon which has been doped with phosphorous.
6) **P-Type Semiconductor Layer** - This is a thin layer of silicon which has been doped with boron.
7) **Back Contact** - Transmits the electric current.

6.7 WORKING OF PHOTOVOLTAIC CELL
The energy of the absorbed light is transferred to electrons in the atoms of the PV cell. With their newfound energy, these electrons escape from their normal positions in the atoms of the semiconductor PV material and become part of the electrical flow, or current, in an electrical circuit. A special electrical property of the PV cell—what we call a "built-in electric field"—provides the force, or voltage, needed to drive the current through an external "load," such as a light bulb.

To induce the built-in electric field within a PV cell, two layers of somewhat differing semiconductor materials are placed in contact with one another. One layer is an "n-type" semiconductor with an abundance of electrons, which have a negative electrical charge. The other layer is a "p-type" semiconductor with an abundance of "holes," which have a positive electrical charge. Although both materials are electrically neutral, n-type silicon has excess electrons and p-type silicon has excess holes. Sandwiching these together creates a p/n junction at their interface, thereby creating an electric field.
• Sunlight is composed of photons, or bundles of radiant energy. When photons strike a PV cell, they may be reflected or absorbed (transmitted through the cell). Only the absorbed photons generate electricity. When the photons are absorbed, the energy of the photons is transferred to electrons in the atoms of the solar cell.

• Solar cells are usually made of two thin pieces of silicon, the substance that makes up sand and the second most common substance on earth.

• One piece of silicon has a small amount of boron added to it, which gives it a tendency to attract electrons. It is called the p-layer because of its positive tendency.

• The other piece of silicon has a small amount of phosphorous added to it, giving it an excess of free electrons. This is called the n-layer because it has a tendency to give up negatively charged electrons.

When n- and p-type silicon come in contact with each other, excess electrons move from the n-type side to the p-type side. The result is a buildup of positive charge along the n-type side of the interface and a buildup of negative charge along the p-type side.

How do we make the p-type ("positive") and n-type ("negative") silicon materials that will eventually become the photovoltaic (PV) cells that produce solar electricity? Most commonly, we add an element to the silicon that either has an extra electron or lacks an electron. This process of adding another element is called doping.

6.8 DIRECT AND DIFFUSE LIGHT

The Earth's atmosphere and cloud cover absorb, reflect, and scatter some of the solar radiation entering the atmosphere. Nonetheless, an enormous amount of the sun's energy reaches the Earth's surface and can therefore be used to produce PV electricity. Some of this radiation is direct and some is diffuse, and the distinction is important because some PV systems (flat-plate systems) can use both forms of light, but concentrator systems can only use direct light.

Flat-plate collectors, which typically contain a large number of solar cells mounted on a rigid, flat surface, can make use of both direct sunlight and the diffuse sunlight reflected from clouds, the ground, and nearby objects.
Direct light consists of radiation that comes straight from the sun, without reflecting off the clouds, dust, the ground, or other objects. Scientists also talk about direct normal radiation, referring to the portion of sunlight that comes directly from the sun and strikes the plane of a PV module at a 90-degree angle.

Diffuse light is sunlight that is reflected off clouds, the ground, or other objects. It obviously takes a longer path than a direct light ray to reach a module. Diffuse light cannot be focused by the optics of a concentrator PV system.

Global radiation refers to the total radiation that strikes a horizontal surface. Global sunlight is composed of direct-normal and diffuse components of sunlight. Additionally, diffuse and direct-normal sunlight generally have different energy spectra or distributions of color.

6.9 BASIC PHYSICS OF SOLAR INTENSITY
The amount of solar intensity of light that impinges upon the surface of solar photovoltaic panels is determined by an equation referred to as Lambert’s cosine law, which states that the intensity of light (L) falling on a plane is directly proportional to the cosine of the angle (A) made by the direction of the light source to the normal of the plane:

\[ L = k \cos(Z) \]

Where \( k \) is Lambert’s constant. This equation is depicted in Figure. In other words, during the summer when the angle of the sun is directly overhead, the magnitude of intensity is at its highest, since the cosine of the angle is zero;
therefore, \( \cos \Theta = 1 \), which implies \( L = k \). The main objective of all solar trackers is to minimize the value of the cosine angle and maximize the solar intensity on the PV planes.

6.10 TYPES OF SOLAR CELLS:
The extensive research being done on solar energy there are now many types of solar cells. All of them follow the principles described when it comes to generating an electric current. However, many different approaches are now used to create the structures in order to reduce the costs of production. These approaches involve a tradeoff between lower manufacturing costs versus lower efficiency in converting sunlight to electricity. Most prevalent material used for manufacturing solar cells is solar grade Silicon and Major types of crystalline Silicon are mono crystalline, multi or poly crystalline. The three most common approaches are:

6.11 PV MODULE TECHNOLOGY
Solar Panels are a form of active solar power, a term that describes how solar panels make use of the sun’s energy: solar panels harvest sunlight and actively convert it to electricity. Solar Cells, or photovoltaic cells, are arranged in a grid-like pattern on the surface of the solar panel. Solar panels are typically constructed with crystalline silicon, which is used in other industries (such as the microprocessor industry), and the more expensive gallium arsenide, which is produced exclusively for use in photovoltaic (solar) cells.

Solar panels collect solar radiation from the sun and actively convert that energy to electricity. Solar panels are comprised of several individual solar cells. These solar cells function similarly to large semiconductors and utilize a large-area p-n junction diode. When the solar cells are exposed to sunlight, the p-n junction diodes convert the energy from sunlight into usable electrical energy. The energy generated from photons striking the surface of the solar panel allows electrons to be knocked out of their orbits and released, and electric fields in the solar cells pull these free electrons in a directional current, from which metal contacts in the solar cell can generate electricity. The more solar cells in a solar panel and the higher the quality of the solar cells, the more total electrical output the solar panel can produce. The conversion of sunlight to usable electrical energy has been dubbed the Photovoltaic Effect.

1) There are major Photovoltaic technologies available in the Market
   • Crystalline technology
• Mono Crystalline
• Multi Crystalline
• Thin film technology
  • Amorphous crystalline/ CIGS/CIS / CdTe

2) Types of solar power technology in the future:
• Plastic solar cells
• Nano-structured materials
• Dye-synthesized cells

• Mon crystalline Silicon - This type of solar cell uses a single layer of silicon for the semi-conductor. In order to produce this type of silicon it must be extremely pure which means it is the most expensive type of solar cell to produce.
  a) Crystalline framework is homogeneous
  b) Produced by growing high purity, single crystal Si rods and slicing them into thin wafers
  c) Most commonly made by Czochralski process
  d) Cell has an even, smooth look

• Polycrystalline Silicon - To make polycrystalline silicon cells liquid silicon is poured into blocks that are subsequently sawed into plates. This type of approach produces some degree of degradation of the silicon crystals which makes them less efficient. However, this type of approach is easier and cheaper to manufacture.
  a) Made by sawing a cast block of silicon first into bars and then wafers
  b) Each cell is composed of a block of multiple crystals, rather than out of a single silicon crystal
  c) Cells have distinct look grainy or mosaic

• Amorphous Thin Film Silicon - This type of solar cell uses layers of semiconductor that are only a few micrometers thick (about 1/100th the thickness of a human hair). This lower the material cost but makes it even less efficient than the other types of silicon. However, because it is so thin this type of cell has the advantage that it can be placed on a wide
variety of flexible materials in order to make things like solar shingles or roof tiles.

Another way of looking at solar cells is in terms of the types of materials they are made with. While silicon is the most commonly used crystal a number of other materials can be used as well. These include the following:

- Gallium arsenide
- Copper indium diselenide
- Cadmium telluride

Different types of substances perform better under certain light conditions. Some cells perform better outdoors (i.e., optimized for sunlight), while others perform better indoors (optimized for fluorescent light).

### 6.12 CRYSTALLINE SILICON PV TECHNOLOGY

The Crystallinity of a material indicates how perfectly ordered the atoms are in the crystal structure. Silicon, as well as other solar cell semiconductor materials, can come in various forms: single-crystalline, multicrystalline, polycrystalline, or amorphous. In a single-crystal material, the atoms making up the framework of the crystal are repeated in a very regular, orderly manner from layer to layer. In contrast, in a material composed of numerous smaller crystals, the orderly arrangement is disrupted moving from one crystal to another.

- **Crystalline Silicon PV technology** Matured and Proven
  1) Proven field reliability (>20 years)
  2) Technology partners/vendors easily available
  3) Raw material is universally available
  4) Rapid advances in crystalline materials & processes
  5) Cost-to-efficiency ratio likely to improve
  6) Thin film technologies not yet proven commercially, with respect to long term performance evaluation
  7) Deposition of thin film solar cell materials on large areas employ sophisticated manufacturing processes;
  8) R&D breakthroughs needed for simpler, large-scale production.

### 6.13 PV SUPPLY CHAIN

![Silicon Wafer Based Solar Cells](image_url)
6.14 SPHERICAL SI

1) Spherical cells are solidified silicon drops measuring 1.8 mm in diameter and are highly transparent. Can be embedded in glass to create a transparent solar cell window.

2) Capable of absorbing light from any direction or angle. Can be connected either in parallel or in series.

3) Produced using a unique process, where they use microgravity under space-like conditions to make them. Reduced wastage helps in reduction in production costs.

4) 

6.15 THIN FILM

1) Very thin layers of chosen semiconductor material (Nano to micro meter thickness) are deposited on to either coated glass or stainless steel or a polymer.

2) Chosen semiconductors may be Amorphous Silicon or compound.

3) Semi-conductors like CdTe, CIS etc.
DYE SENSITISED SOLAR CELLS

1) Consist primarily of photosensitive dye and other substances
2) Generate electricity by converting energy from light absorbed by the dye
3) Consists of an electrolyte sandwiched between a photo electrode and a catalytic electrode (counter electrode)
4) Photo electrode in this case, is a conductive glass plate coated with porous titanium dioxide to create a layer which can adsorb photosensitive dye molecules
5) Light energy absorbed in the dye is converted to electricity via solar cell electrochemical properties
6) Overall manufacturing expenditures are expected to be comparatively low
7) Ability to use a variety of designs and colors and achieve high performance under indoor and low light settings
8) Ideal for a variety of consumer-related applications in which conventional solar cells are unsuitable

HIT Solar Cells (Heterojunction with Intrinsic Thin layer)

1) HIT solar cell is composed of a single thin crystalline silicon wafer sandwiched by ultra-thin amorphous silicon layers
2) Two distinct advantages
   • More capacity in limited area due to high conversion efficiency
   • Better performance at higher temperatures

HOW DYE – SENSITIZED SOLAR CELLS GENERATE ELECTRICITY SOLAR INTENSITY EQUATION
6.17 COMPONENTS OF PHOTOVOLTAIC POWER SYSTEM:

1. Solar Power: Electricity generated by conversion of sunlight, either directly through the use of photovoltaic panels, or indirectly through solar-thermal processes.

2. Solar Cells:
   - Convert sunlight into electricity
   - Material Options: Silicon (Si), Cadmium Telluride (CdTe), Copper Indium Gallium Selenide (CuInGaSe), and Gallium InP2- GaAs-Ge).

3. Solar Module: A device used to convert light from the sun directly into dc electricity by using the photovoltaic effect. Usually made of multiple silicon solar cells bonded between glass and a backing material.
   - Solar PV modules: Series and Parallel connections, Mismatch between cell and module, Design and structure, PV module power output
   - Photovoltaic Modules: Glass superstrate, Tedlar substrate, Encapsulant, Aluminium, Frame, Junction Box, Connector Cables

4. Solar Cell technologies
   - Crystalline Cells: Mono- crystalline and poly – crystalline cells, Metallurgical Grade Si, Electronic Grade Si, wafer production, Mono – crystalline Si Ingots, Poly – crystalline Si Ingots, Si – wafers, Si – sheets, Solar grade Silicon, Si usage in solar PV, Commercial Si solar cells, process flow of commercial Si cell technology, process in solar cell technologies, Sawing and surface texturing, diffusion process, thin film layers, Metal contact.
   - Polycrystalline Silicon: Silicon used to manufacture photovoltaic panels, which is made up of multiple crystals clumped together to form a solid mass.
   - Mon crystalline Solar Cell: A form of solar cell made from a thin slice of a single large crystal of silicon.
   - Amorphous Silicon: A Noncrystalline form of silicon used to make photovoltaic modules (commonly referred to as solar panels).
   - Thin Film Cells: Advantage of thin film, thin film deposition techniques, Evaporation, Sputtering, LPCVD and APCVD, Plasma Enhanced, Hot Wire CVD, closed space sublimation, Ion Assisted Deposition.
5. Concentrators and PV Modules:

- Concentration: Advantages and disadvantages, Series Resistance optimization, Concentrating techniques; tracking / non-tracking systems, Cooling requirements, High concentration solar cells.

6.18 SPV MODULES WITH CRYSTALLINE TECHNOLOGY:

The photovoltaic modules are made of mono-crystalline / poly-crystalline silicon solar cells, which are connected in series to give required output. The interconnected cells are laminated in vacuum to withstand adverse environmental conditions. Module technology having high cell efficiency, reduced size, high reliability, with lesser cost shall be used.

a. Ethylene Vinyl Acetate – EVA

1) Ethylene Vinyl Acetate has two major functions in a solar PV module
   a) Connect glass, cells and back sheets
   b) Protect cells from moisture and dust

2) Typical characteristics of EVA sheets are
   a) Light management in terms of clarity or reflectivity
   b) Moisture resistance
   c) Adhesion to back sheets / glass
   d) Laminate strength and cross-linking
e) No acid generation in presence of light or moisture
f) Dielectric properties
g) Photo-thermal stability

b. Back sheet
Primary functions of a solar back sheet are to act as a vapor barrier, provide physical protection to wiring and other sensitive components, electrical insulation and reduction of cell operating temperatures
1) Characteristics of a good back sheet are
   a) UV resistance, Moisture barrier, Resistance to weathering, Mechanical properties
   b) Strength and durability, Electrical Insulation, Inertness towards a wide variety of chemicals, solvents, and staining agents
2) Typically made from polyvinyl fluoride (PVF) or poly vinylidene fluoride (PVDF)
3) Most popular construction is a trilaminate sandwich of polyester (PET) film between two layers of PVF

c. Glass
Glass is an integral part of the construction of the solar module
1) Front glass and back glass characteristics slightly differ
2) Front Glass
   a) For thin film modules, front glass is coated with Transparent Conductive Oxide (TCO) which is an Anti-Reflective coating to improve transmissivity of glass
   b) For crystalline modules, front glass is low iron rolled glass that is toughened; low iron float glass may also be used
3) Back Glass
   a) In thin film modules, substrate is deposited on the back glass;
   b) Generally not coated but for CIS modules, back glass is coated with Molybdenum that is used as a back contact

6.19 MANUFACTURING PROCESS STEPS

Solar Cell
1) Wafer Surface Texturing
2) p-n Junction (Semiconductor) Doping
3) Junction isolation, Anti-reflection layer coating
4) Back Surface Field & Contact Metallization
5) Solar Cell Test

PV Module
1) Cell Interconnections & Lay-up
2) Lamination & Module Framing
3) PV Module Test
6.20 COMPLEXITY OF MANUFACTURING
The most important parts of a solar cell are the semiconductor layers, because
this is where electrons are freed and the electric current is created—it’s the active
layer “where the action is,” so to speak. Several different semiconductor materials
are used to make the layers in different types of solar cells, and each material has
its benefits and drawbacks.

The cost and complexity of manufacturing may vary across these materials and
device structures based on many factors, including deposition in a vacuum
environment, amount and type of material utilized, number of steps involved,
need to move cells into different deposition chambers or processing processes,
and others. Sunlight Antireflection coating Transparent adhesive Cover glass Front
Contact Current n-Type semiconductor p-Type semiconductor Substrate Back
contact.

A typical solar cell consists of a glass or plastic cover or other encapsulants, an
antireflective layer, a front contact to allow electrons to enter a circuit, a back
contact to allow them to complete the circuit, and the semiconductor layers
where the electrons begin and complete their journey.
6.21 CHARACTERISTICS

- Maximum Current ($I_{\text{max}}$)
  - The current at which maximum power is extracted is the desired operating current for a photovoltaic cell, module or array.

- Maximum Voltage ($V_{\text{max}}$)
  - The voltage at which maximum power is extracted is the desired operating voltage for a photovoltaic cell, module or array.

- Short Circuit Current ($I_{\text{sc}}$)
  - The current at which power is not extracted and voltage becomes zero.

- Open Circuit Voltage ($V_{\text{oc}}$)
  - The voltage at which power is not extracted and current becomes zero.

- Maximum Power ($P_{\text{max}}$)
  - The maximum power point ($P_{\text{max}}$) is the point on I-V curve for which maximum power is extracted.

6.22 PV MODULE TECHNOLOGY-COMPARISON

<table>
<thead>
<tr>
<th>MANUFACTURING METHODS</th>
<th>MONO Crystalline Silicon Modules</th>
<th>MULIT /POLY Crystalline Silicon Modules</th>
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<tr>
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<td></td>
<td>a. SOLAR POWER</td>
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<td>generation and utilisation</td>
<td></td>
<td>generation and utilisation</td>
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<tr>
<td>b. Proven technology</td>
<td></td>
<td>b. Proven technology</td>
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<tr>
<td>2. Small to large</td>
<td></td>
<td>c. Small to large installations</td>
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<tr>
<td>installations</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CELL EFFICIENCY</td>
<td>14-18% (APPROX)</td>
<td>13-17% (APPROX)</td>
<td>6-8% (APPROX)</td>
</tr>
<tr>
<td>AREA REQUIRED FOR 1 kW</td>
<td>7-9 SQ.M (APPROX)</td>
<td>8-10SQ.M (APPROX)</td>
<td>16-20 SQ.M</td>
</tr>
<tr>
<td>CAPACITY</td>
<td>5 to 250W</td>
<td>5 to 250W</td>
<td>Large Form-2.2m x 2.6m= 5.72m²</td>
</tr>
<tr>
<td></td>
<td>5 to 270 W</td>
<td>5 to 270 W</td>
<td>Mid Size</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>2.2m x1.3m = 2.86 m²</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Conventional 1.1m x 1.3m= 1.43 m²</td>
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</table>
A solar panel is nothing more than a collection of solar cells on a single panel. Each individual solar cell in the solar panel can generate approximately half a volt of current so if you combined 36 cells you would get around 18 volts of current. The panels usually have light aluminum frames to hold the solar cells in place and are covered with a non-reflective glass to protect the cells from weather and damage since silicon cells are very fragile. Solar panels vary in size and in electric output. In general, the more solar cells on each panel the more watts of electricity they can produce.

The output of a solar panel is usually stated in watts. The amount of watts of electricity generated by the panel is determined by multiplying the rated voltage by the rated amperage. The formula for wattage is:

\[ \text{VOLTS} \times \text{AMPS} = \text{WATTS} \]

Let's use as an example a large solar panel measuring about 37.5 inches by 61.8 inches that might be used in a typical home energy system. The solar panel has a rated voltage of 26 volts and a rated amperage of 6.9 amps. The wattage calculation would look like this: 26 volts x 6.9 amps = 180 watts

If a particular location has an average of 6 hours of peak sun per day, then the solar panel in this example can produce an average 1080 watt-hours (6 x 180) of power per day or a little over 1 kilowatt-hour per day. Most homes use far more than one kilowatt-hour per day. Most use between 10 and 25 kilowatt hours per day. Given this it is going to take a lot more than one solar panel to generate enough electricity to completely power your home. For a homeowner running on 20 kilowatt hours per day it would take approximately 19 panels to provide 100% of the electricity they need on a daily basis. That is a lot of solar panels. Many homeowners do not have enough space on their south facing roof for this many panels. Consequently, in most home PV applications where you are connected to the grid you should think of the system as providing part, but not all of your energy. Whenever you receive a bid from a solar contractor they should tell you what percentage of your energy consumption the system is likely to produce.
6.24 TYPES OF SOLAR PANELS

There are a number of different types of solar panels manufactured today. Briefly, they are:

1) **MONO-CRYSTALLINE** - These types of solar panels uses solar cells which are made from a very pure single large crystal, cut from ingots. They are the most efficient type of solar panels but are also the most expensive. Their performance is somewhat better in low light conditions (but not as good as some advertising hype would have you believe). Overall efficiency on average is about 12-15%. Most panels of this type are warranted for 20-25 years. They are usually blue-grey in color and have a fairly uniform consistency.

2) **BIFACIAL MONO-CRYSTALLINE** - A new type of solar panel has recently emerged on the market which uses mono-crystalline solar cells but which has glass on both sides so that it can collect energy from both sides of the solar panel. By collecting light from both sides the bifacial panels have higher efficiency for about the same cost. Efficiency levels up to 20% have been reported for these types of panels. Typically these panels are installed in a pole mounted solar array so that ambient light can reach the panel from both the front and the back. They can also be effective if roof mounted on a roof that has a white matt or has been painted white to allow light to reflect on to the back of the panel. Because these panels are fairly new there is not a lot of information yet on their durability but most are warranted for 20-25 years, the same as for traditional panels. Bi-facial panels are a particularly attractive solution for pole mounted systems since a given pole mount can usually only hold 9-12 solar panels. By using more efficient panels the cost tradeoff of the panels versus the cost of the tracking system is improved. Currently Sanyo is the leading manufacturer of bifacial solar panels.

3) **POLY-CRYSTALLINE BLOCK** - With most poly-crystalline solar panels the silicon in the solar cells is cast from large blocks of silicon which may contain many small crystals. Some manufacturers use a slightly different approach for creating poly-crystalline solar cells. Currently, poly-crystalline solar panels are the most common. They are slightly less efficient than single crystal, but once set into a frame with 35 or so other cells, the actual difference in watts per square foot is not much. Poly-crystalline cells look somewhat like shattered glass and have a dark blue to almost black color. Overall efficiency on average is about 11-13%.

4) **POLY-CRYSTALLINE STRING RIBBON** - String ribbon photovoltaics use a variation on the polycrystalline production process, using the same molten silicon but slowly drawing a thin strip of crystalline silicon out of the molten form between two strings. These strips of photovoltaic material are then assembled in a panel with the same metal conductor.
strips attaching each strip to the electrical current. This technology saves on costs over standard polycrystalline panels as it eliminates the sawing process for producing wafers. Some string ribbon technologies also have higher efficiency levels than other polycrystalline technologies. Overall efficiency on average are from 11-14%. Evergreen is the primary provider of string ribbon solar panels.

5) **AMORPHOUS** - Amorphous solar panels are also referred to as "thin film" solar panels. In these types of panels the silicon is spread directly on large plates, usually of something like stainless steel. The thin film type of solar cells can also be spread on to more flexible plastic materials to make very flexible solar panels. These types of solar cells are much cheaper but also much less efficient than mono crystalline or polycrystalline solar panels. Therefore in order to provide as many watts as the other types of solar panels they must be much bigger in size. However, because they can be put on to flexible backings they have proven very valuable in certain types of applications where flexibility is more critical than power. For example, these types of solar panels are often used in portable products such as solar backpacks and solar bags. Overall efficiency on average is about 5-6%.

6) **CONCENTRATING PHOTOVOLTAIC SOLAR PANELS** - These types of panels employ a lens or mirror to concentrate the sun's energy on to the individual solar cells. In theory these types of panels will be more efficient because by concentrating the sun's energy fewer solar cells are needed to create the same amount of energy. Many of the concentrating panels use a type of plastic lens, called a Fresnel lens, to concentrate the sun's energy. Another type of concentrating solar panel called a Heliotube uses a series of troughs which track the movement of the sun to provide greater solar exposure to the solar cells. Concentrating solar panels reduce the amount of photovoltaics needed to produce electricity, and also reduce the amount of space needed for a photovoltaic installation. Their main disadvantage is that they depend solely on direct light to produce electricity, while stand-alone photovoltaic panels can use both direct and diffuse light. Many regions do not receive enough direct light throughout the year for these systems to make these types of panels practical. Another disadvantage is their complexity of their construction, which makes these systems more difficult to build and install than conventional PV panels. Concentrating panels are also considerably heavier than conventional PV panels and have a number of moving parts which makes them more susceptible to failure than conventional panels. These types of panels are not widely used in residential solar PV systems.

7) **GROUP III-V TECHNOLOGY PANELS** - Currently there is a great deal of research targeted at creating very advanced solar cells and panels. Solar cells created with these types of advanced technologies are often
referred to as Group II and IV cells. These sophisticated solar cells use a variety of materials with very high conversion efficiencies to capture more of the light spectrum. A typical material used in this technology is gallium arsenide, which can be combined with other materials to create semiconductors that can respond to different types of solar energy. Though these technologies are very effective, their current use is limited due to their very high costs. They are currently employed only in space applications for use with satellites or lunar rovers such as the Mars rovers. Group III-IV solar panels can have efficiencies as high as 25%.

In most home energy applications the home owner will probably want to go with either mono-crystalline or poly-crystalline solar panels. Which of the two really depends upon price? Because roof space on a south facing roof is at a premium for most home PV applications we don’t usually don’t recommend thin-film amorphous panels. Amorphous solar panels have to be much larger to provide as much as electric output other types of panels and on most roofs there is not enough space to generate as much power as you need.

6.25 SOLYNDRA TECHNOLOGY
Solyndra panels capture direct, diffuse and reflected sunlight across a 360 degree photovoltaic surface. Solyndra panels can be placed in virtually any orientation and significantly closer together than conventional tilted panels. The unique cylindrical design allows wind to flow through the panels and as a result no additional ballast or penetrations are required in winds up to 130 mph. Designed for maximum performance in the rooftop environment, Solyndra panels offer superior wind, soiling and snow performance.

![Cylindrical Module Enhances Light Collection](image)

![Benefits of Tubular Package](image)
7. SOLAR – POTENTIAL IN INDIA

<table>
<thead>
<tr>
<th>Location:</th>
<th>8.4 and 37.6 Deg. N Latitude 68.7 and 97.25 Deg. E Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area:</td>
<td>3214 km from North to South and 2933 km from East to West</td>
</tr>
<tr>
<td>Sunny Days</td>
<td>About 300 days/year at majority of places</td>
</tr>
<tr>
<td>Solar Energy Availability</td>
<td>4-7 kWh/sq. m</td>
</tr>
</tbody>
</table>

7.1 WHY SOLAR POWER GENERATION?

1) Solar energy is perennial and abundant
2) Solar Power is the utmost clean energy without emissions
3) Solar Plants are easy to build
4) Solar Plants systems have minimum Aux consumption
5) Solar Plants require minimum maintenance to operate
6) Solar Plants have a life of more than 25 years
7) Solar Power Grid connected Solar Systems small or big contribute in supporting peak demands and energy efficiency
8) Small Solar Power Plants can be located at load points, without any T&D losses

7.2 APPLICATIONS OF SOLAR ENERGY

Solar energy technologies use solar radiation for practical ends. Solar technologies such as photo-voltaics and water heaters increase the supply of energy and may be characterized as supply side technologies. Technologies such as passive design and shading devices reduce the need for alternate resources and may be characterized as demand side. Optimizing the performance of solar technologies is often a matter of controlling the resource rather than simply maximizing its collection.

7.3 APPLICATION OF SOLAR PHOTOVOLTAIC SYSTEM:

A] The terrestrial application of these system include provision of power supply to
1) Water pumping and Radio beacons for ship navigation at ports
2) Community radio and television sets, Cathodic protection of oil pipe lines and Weather monitoring, Railway signaling equipment
3) Battery charging and Telecommunication
4) **Cooking:** solar cookers are commercially available and can be conveniently used for the purpose of cooking food.
5) **Heating:** solar water heaters and air heaters are being used for a variety of applications both in industrial sector and domestic sector
6) **Distillation:** solar stills can be used for the production of portable water in remote areas
7) **Lighting:** solar photovoltaic lighting system can be effectively used in remote rural areas for both domestic lighting and street lighting
13) **Process heating:** cylindrical parabolic collectors can be used for the production of low-pressure steam for industrial application. These systems are still in the developmental stage
14) **Refrigeration:** solar energy can be used for the purpose of cold storage as well as air conditioning application. Vapour compressor system using solar photovoltaic panels and vapour absorption system using thermal collectors can be used for these purposes.

**B) Main Three Applications of PV System Are:**
1. Power sources from PV systems
2. Remote and isolated applications
3. Utility power generation facilities.

**C) SOLAR CELLS ARE USED IN SPACE BECAUSE OF THE FOLLOWING FEATURES:**
1). Operation is with no maintenance
2). Operation is in an intense radiation field of high-energy particles
3). Launch cost make light weight, high efficiency cells attractive
4). Lack of area and complexity of development makes high packing factors attractive. And The only cell cooling is by radiation.

**7.4 TYPES OF PV INSTALLATION**
SPV system configurations can be of three types as described below:
1) Stand-alone SPV systems without storage battery and storage battery
2) Grid interactive

**1. STAND ALONE**
These systems can generate, store and deliver power without depending on the electricity supply. Small stand-alone SPV systems can power systems like:
1) Home lighting and Street lights
2) Garden lights and Illuminated hoardings
3) Water pumps
4) Depending on the nature of the load, stand-alone SPV systems are designed with or without storage battery:
Those who would like to achieve long-term energy independence solar photovoltaic (PV) systems using solar panels are one of the very best options. Solar energy systems for the home are relatively simple, last for decades and over the long term can save homeowners significant money, particularly in those states or countries that provide incentives for solar energy. Moreover, solar PV systems create no pollution and give off no hydrocarbons which make them one of the best energy options from an environmental standpoint. A key thing to remember with PV systems is that what they are harvesting is light energy, not heat or solar thermal energy. That means they work as well in colder climates as they do in warmer climates. All that matters is how much light a location gets and how many hours of sunlight per day your area gets at different times of the year with is more than sufficient light on average for PV systems to be very effective solar photovoltaic systems (PV systems for short) are any energy generation systems that make use of photovoltaic cells. A photovoltaic cell is a cell which generates electricity directly from light energy. Photovoltaic cells come in many sizes, but most are 10 cm by 10 cm and generate a little more than half a volt of electricity. PV cells are bundled together in interconnected solar panels to produce higher voltages and increased power. A 12-volt solar panel typically used in home solar energy applications has 30 to 50 PV cells, and can generate anywhere between 80 to 200 volts of electricity. In a residential application multiple solar panels are strung together into one or more modules. The number of panels you need is a function of your energy use and the amount of space you have available on your southern (South Facing) facing roof.

A). STAND ALONE SPV Systems without Storage Battery

These systems are the simplest and least expensive as compared to other types of photovoltaic systems. They are designed for usage only during the day time. The appliances use the electricity as it is generated. Depending on the magnitude of the incident solar radiation the electricity output of these types of systems varies during the day. These types systems are mostly used for water pumping application as well as garden sprinklers.
B) Stand-alone SPV Systems with Storage Battery
These systems have batteries for storing electrical energy to operate during night or during periods with cloudy weather conditions. Batteries store the electrical energy generated by the SPV modules and power can be drawn from the batteries as and when required.

3. GRID INTERACTIVE
These systems are connected to the electricity grid. DC electricity generated by the PV system is converted to AC electricity at the grid voltage through a specially designed inverter. Grid-interactive systems can be designed with or without battery storage. The main advantage of this system is that the power can be fed into the grid or can be drawn from the grid as required.

GRID CONNECTED SOLAR PV POWER PLANT
A typical grid-tied photovoltaic system will have the following components:

1) SYSTEM COMPONENTS:
Pre-engineered photovoltaic systems can be purchased that come with all the components it will need, right down to the nuts and bolts. Any good dealer can size and specify systems for the given a description of the site and needs. Nevertheless, familiarity with system components, the different types that are available, and criteria for making a selection is important. Basic components of grid-connected PV systems with and without batteries are:

1) Solar photovoltaic modules and Array mounting racks
2) Grounding equipment and Combiner box
3) Surge protection (often part of the combiner box)
4) Inverter and Meters – system meter and kilowatt-hour meter
5) Disconnects:
   • Array DC disconnect and Inverter DC disconnect,
   • Inverter AC disconnect and Exterior AC disconnect
2). PHOTOVOLTAIC SYSTEM TYPES:
Systems that are connected to the utility transmission grid, variously referred to as utility-connected, grid-connected, grid-interconnected, grid-tied or grid-intertied systems. These systems generate the same quality of alternating current (AC) electricity as is provided by the utility. The energy generated by a grid-connected system is used first to power the AC electrical needs of the home or business. Any surplus power that is generated is fed or “pushed” onto the electric utility’s transmission grid. Any of the building’s power requirements that are not met by the PV system are powered by the transmission grid. In this way, the grid can be thought of as a virtual battery bank for the building.

3). COMMON SYSTEM TYPES:
Most new PV systems being installed are grid-connected residential systems without battery back-up. Many grid-connected AC systems are also being installed in commercial or public facilities. These are: 1. Grid-connected AC system with no battery or generator back-up. And 2. Grid-connected AC system with battery back-up.

GRID-TIED VS OFF-THE-GRID SYSTEMS:
Photovoltaic systems for the home can generally be classified into those that are designed to make use of an existing electric grid (grid-tied system) or those that are designed for rural use where no electric grid is available (off-the-grid system).

<table>
<thead>
<tr>
<th>SI. No.</th>
<th>GRID-TIED GRID SYSTEMS</th>
<th>STAND ALONE /OFF-THE-GRID SYSTEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Photovoltaic systems for the home can generally be classified into those that are designed to make use of an existing electric grid (grid-tied system)</td>
<td>Photovoltaic systems for the home that are designed for rural use where no electric grid is available (off-the-grid system).</td>
</tr>
<tr>
<td>2</td>
<td>In a grid-tied system there is no need for a battery system to store the energy that the solar panels generate. Instead the power grid itself acts in a sense as a giant battery that uses any excess electricity that your solar panels may generate, and which you can draw from on cloudy days when there is insufficient sunlight to fully power your home.</td>
<td>Grid-tied systems offer a number of advantages over off-the-grid PV systems. 1. Overall they are less expensive than off-the-grid</td>
</tr>
<tr>
<td></td>
<td>In an off-the-grid system, 1. Batteries are fully charged, any excess electricity being</td>
<td></td>
</tr>
</tbody>
</table>
systems
2. They do not require either batteries or battery charging controllers.
3. They require less equipment they are also much simpler systems to set up and use.
4. They take less time to install and require very little maintenance.
5. They are far more efficient and environmentally friendly than off-the-grid systems.
6. With a grid-tied system none of the energy PV panels generate is wasted.
7. During sunny days when your panels are producing more electricity than using the energy is transferred to the grid where it can immediately be used by others.

generated by panels has to be dumped to prevent the batteries from being overcharged. This results in wasted electricity.
2. However, in some situations, particularly in rural areas which have no grid, there may be no option other than to go with an off-the-grid system.
3. Off-the-grid systems require more care and maintenance but can give a homeowner a strong sense of independence. They also have the advantage that the homeowner is no longer subject to the risk of a brownout or a loss of power from the grid.

7.5 HYBRID SYSTEMS
When SPV systems are combined with any other power generating systems like wind turbines or diesel generators, they are called hybrid systems.

Lighting for schools: Education/Information

7.6 Building Integrated Photovoltaic (BIPV):
With the help of new technologies in the field of PV, photovoltaic can be integrated into the building envelope itself making them an integral part of the building roof or facade structure. BIPVs are PV panels integrated into the building structure during construction. They can be used in areas like skylights,
glass atrium roofs, curtain and structural glazing systems on the façade. BIPVs help in cutting the heat gain while allowing light to pass through.

8. SYSTEM DESIGN AND OBJECTIVES:
The general objective in designing a Solar Power Plant to adequately match the capabilities to the load requirements of the consumer, at a minimum cost of the system to the consumer. In order to accomplish this, the designer will need to know the following types of questions about the system.


8.1 PROJECT STUDY:
STAGE – 1 PROJECT STUDY AND ANALYSIS:
1. Solar Data And Site Study
2. Design of Solar Power Plant
3. Planning And Layout of Solar Power Plant
5. Evaluation of Techno – Economic Analysis

STAGE – 2 SELECTION OF SOLAR PV POWER PLANT TYPE:
- The Size of The Solar Power Plant
- Type of Solar Power Plant Technology
- Type of Output and Utilisation of Electric Output
Solar Power Plant Energy Conversion System

STAGE – 3 CONCLUSIONS:

- Choose / Install The Optimum generating Technology Solar PV Power Plant
- Forecast Accurate Power Output
- Choose The Best Solar Power Plant Location / Site
- Overcome The Project Uncertainties.

8.2 FACTORS SHOULD BE CONSIDERED WHILE DESIGNING THE SYSTEM

1) The power of the electrical appliances and its working hours per day.
2) The efficient sunshine hours in the location.
3) The proportion of the rainy/cloudy days in the location.
4) How many rainy-cloudy days for the system to work normally.
5) The database of the local weather report, such as sunshine hours, wind power, cloudy-rainy days, and natural disaster and so on.
6) The installation location should be wide, and make sure that there is no high building or other things to cover the solar panels & the sunshine.
7) Should take full investigation while designing the system,
   a) Survey the local climatic conditions,
   b) The current needs and future potential demands clearly,
   c) Focus on performance and consider energy composition,
   d) Structure, cost, transportation, construction conditions,
   e) System protection should be complete and easy to operate and the Maintenance, other conditions and the maintenance should be as little as possible.

8.3 DC SIDE PV PLANT DESIGN- ELECTRICAL SINGLE LINE DIAGRAM

a. Modules in Series
   1. Total MPP voltage at Max Module temperature > Inverter Min MPP Voltage
   2. Total Open circuit voltage at Min Module temp < Inverter Max Voltage
b. Modules in Parallel
   1. Max current shall not be more than Inverter Max Input current
   2. No of Array combiner boxes – with or without string monitoring based on number of inputs selected for each box
c. No. of Main Junction Boxes – based on the Number of Inverter inputs

8.4 PV SYSTEM DESIGN:

Photovoltaic Power plant AC side design Power Evacuation
1. Typical Electrical Single line diagram
2. AC side cable
3. LT Switchgear and MV switchgear
4. Power Transformer (LV to MV)
5. HT Switchyard, Protection and Metering
6. Transmission line

8.5 PV SYSTEM DESIGN:
Photovoltaic Power Plant Energy Generation Estimate
1. Solar Radiation resource assessment - Using data based
2. Energy generation Estimates - Can be done using PV SYST software – (commercial available) or Mathematical Calculation

Inputs required
a) Solar Radiation database for the location of installation
b) Module used – series parallel and Quantity
c) Inverter used - Qty
d) System losses factors - Cables losses, Module mismatch losses, Module quality losses and Soiling losses.

8.6 SIZING A PV SYSTEM
Examining efficiency values
For the array to produce enough energy for the loads, it needs to look at the losses within the system. This means considering two main efficiency values: the batteries’ charging and discharging efficiency and the efficiency of the PV array to deliver the energy. These values vary, but use the following estimations, which are based on typical equipment and technologies:

1) **Battery efficiency**: A common value for battery efficiency is 85 percent, which represents the fact that we can never get 100 percent of the energy used to charge the battery when discharging the battery. This efficiency value represents losses internal to the battery as well as the ability for the charge controller to charge the battery.

2) **PV array efficiency**: This value is affected by, among other things, the temperature of the array, how dirty the modules are voltage losses in the wiring, and the age of the array. If look at all the individual losses and estimate their effect on the total array, but I prefer to estimate the average value at 74 percent. This percentage is on the conservative side in terms of estimating the losses, but for a stand-alone situation, this approach allows you to supply all the energy required more often.

8.7 Design of PV Rooftop with Battery
SIZING THE ARRAY IN A STAND-ALONE SYSTEM
1) For the battery-based system sizing is of the stand-alone variety, the PV array needs to produce an amount of energy equal to average daily energy consumption (Determining the average daily energy consumption for stand-alone systems); if it doesn’t, the battery bank will never be able to recharge fully.
2) In addition, the array should be able to help recharge the battery bank after there has been little to no charging by any source (such as the PV array or a generator) and the battery bank has dipped into the reserve supplied by desired days of autonomy.

3) In reality, the amount of energy consumed isn’t a constant value; it changes throughout the year. Typically, people use more energy during the winter, which happens to correspond to the time of year with the lowest solar resource (if large cooling loads, such as air conditioners, this may be different). This situation presents a problem for / as a PV system designer.

4) Design the PV array around the scenario of high consumption and low solar resource. Come summertime, when the energy consumption is reduced and the solar resource is increased, the PV array will be oversized and have the batteries charged very early in the day, which is bad because the PV array will be underutilized those times of the year, and the initial system cost will be outrageous.

5) To determine the appropriate array size in watts, it needs to gather some information about the site and make some assumptions regarding the operation of the system. These values will help to estimate the array size needed based on the total energy consumption.

8.8 Design of PV Grid Connected without Battery
   (1) Decide on Wattage of SPV Modules
   (2) No. of Modules in a String
      a. Total Voc of the string must be within the Maximum Vdc of the Inverter, after considering the temperature effect.
      b. Total Vmp of the String must be within the MPPT range of the Inverter
   (3) No. of Strings for Parallel Operation
      a. The Total Imp must be within the Maximum DC Current of the Inverter

8.9 Designing of Solar PV Connected System:
   1) Roof Top Stand Alone/Off Grid Solar Power Plant With Battery Grid
   2) Design of Solar PV Water Pump
   3) Design of Grid Connected SOLAR PV Power Plant System
9. **CONCLUSIONS:**

1). Every country should have abundant, affordable and reliable energy.

2). During the past few years, renewable energy sources have received greater attention and considerable inputs have been given to develop efficient energy conversion and utilization techniques.

3). Energy Conservation is the Best Reservation for the Future Generation.

4). Today’s clean environment is tomorrow’s safe environment and today’s is yesterday’s creation, tomorrow’s world will be today’s conservation.

5). **Today’s wastages is tomorrow shortage**, Saving energy is simple, it needs a change in attitude, using and buying energy efficient equipment’s.

6). Standalone wind with Solar Photovoltaic is known as the best hybrid combination of all renewable energy systems and suitable for most of the applications taking care of seasonal changes.

7). The packaged systems are ideally suited to remote homes, schools, clinics and other off-grid applications. Remote and Rural village Electrification & domestic lighting applications.

8). **It is the responsibility of the society to conserve energy, energy resources and protect the environment and SAVE our MOTHER LAND.**