ME8792-POWER PLANT ENGINEERING

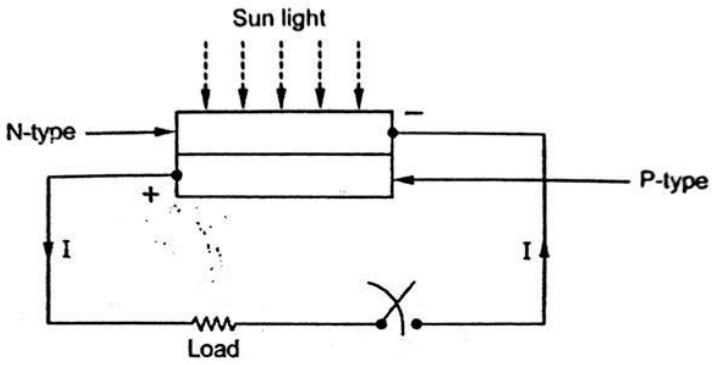
UNIT IV-POWER FROM RENEWABLE ENERGY

4.4 SOLAR PHOTO VOLTAIC (SPV)

SOLAR PHOTOVOLTAIC POWER SYSTEM

Principle of photovoltaic or solar cell

Conversion of light energy in electrical energy is based on a phenomenon called photovoltaic effect. When semiconductor materials are exposed to light, the some of the photons of light ray are absorbed by the semiconductor crystal which causes a significant number of free electrons in the crystal. This is the basic reason for producing electricity dueto photovoltaic effect. **Photovoltaic cell** is the basic unit of the system where the photovoltaiceffect is utilised to produce electricity from light energy. Silicon is the most widely used semiconductor material for constructing the photovoltaic cell.

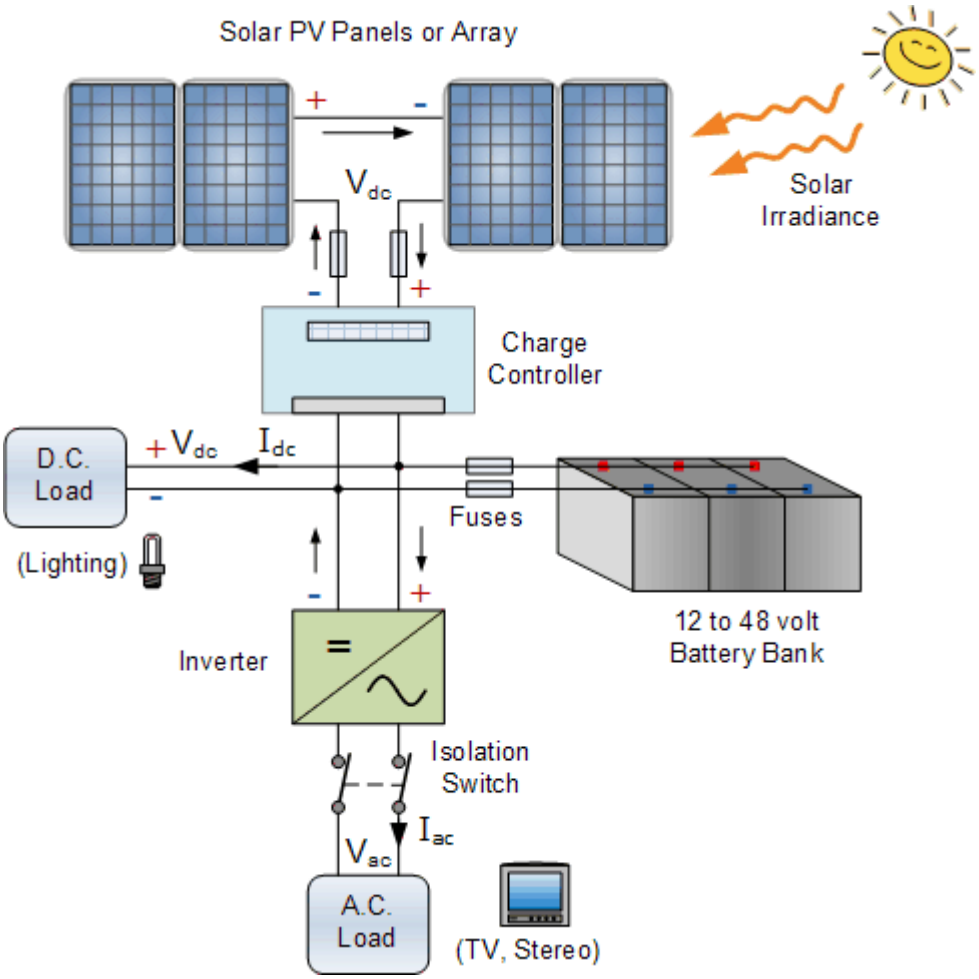


Principle of solar cell

Standalone PV power system

While a major component and cost of a standalone PV system is the solar array, severalother components are typically needed. These include:

- Batteries: Batteries are an important element in any stand alone PV system but can be optional depending upon the design. Batteries are used to store the solar-produced electricity for night time or emergency use during the day. Depending upon the solar array configuration, battery banks can be of 12V, 24V or 48V and many hundreds of amperes in total.
- Charge Controller: A charge controller regulates and controls the output from the solar array to prevent the batteries from being over charged (or over discharged) by dissipating the excess power into a load resistance. Charge controllers within a standalone PV system are optional but it is a good idea to have one for safety reasons.


Solar PV Panels or Array
+
-
V_{dc}
Solar
Irradiance
Charge
Controller
D.C.
Load
+ V_{dc}
I_{dc}
-
Fuses
(Lighting)
12 to 48 volt
Battery Bank
Inverter
=
Isolation
Switch
I_{ac}
V_{ac}
A.C.
Load
(TV, Stereo)

- Fuses and Isolation Switches: These allow PV installations to be protected from accidental shorting of wires allowing power from the PV modules and system to be turned “OFF” when not required saving energy and improving battery life.
- Inverter: The inverter can be another optional unit in a standalone system. Inverters are used to convert the 12V, 24V or 48 Volts direct current (DC) power from the solar array and batteries into an alternating current (AC) electricity and power of either 120 VAC or 240 VAC for use in the home to power AC mains appliances such as TV’s, washing machines, freezers, etc.
- Wiring: The final component required in and PV solar system is the electrical wiring. The cables need to be correctly rated for the voltage and power requirements. Thin telephone wire will not work!.

Batteries are an important element and the heart of any stand alone solar power system, whether that is one using a large array of panels to power a home or a small picosolar system used to power the garden, shed or fish pond.

Batteries are needed because of the fluctuating nature of the output being delivered bythe PV panels or array. They also convert the electrical energy into stored chemical energy for use when the solar array is not producing power. During the hours of sunshine, the PV system is directly fed to the load, with excess electrical energy being stored in the batteries for later use. During the night, or during a period of low solar irradiance, such as a cloudy, rainy days, energy is supplied to the load from the battery.

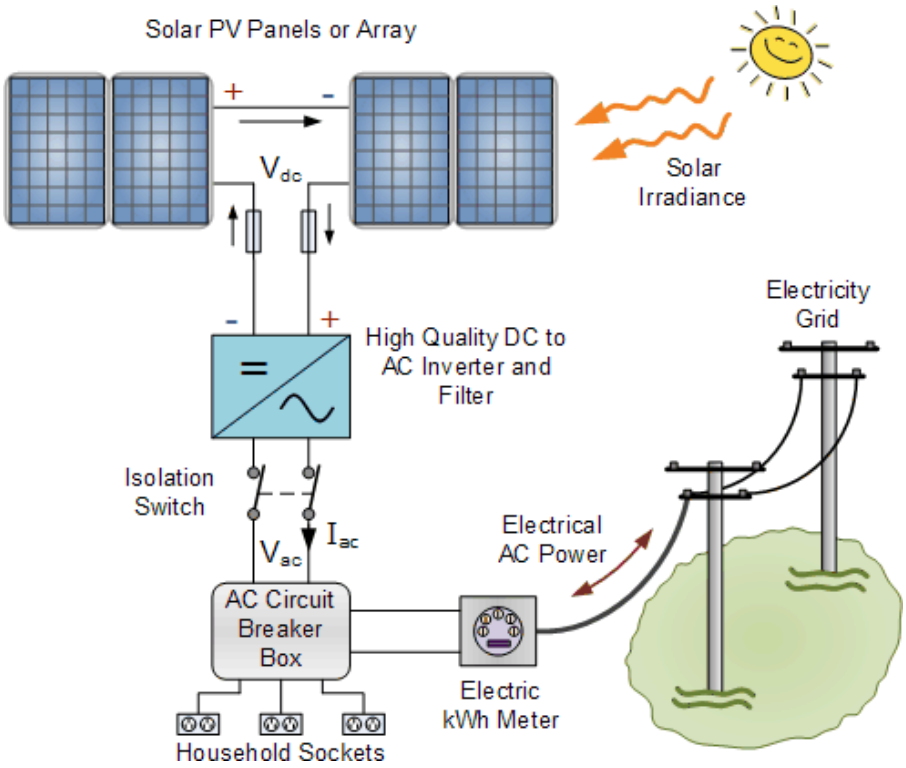
So battery storage allows a standalone PV system to be run when the solar panels are not producing enough energy on their own with the battery storage size tied to the electrical usage.

Grid connected PV systems always have a connection to the public electricity grid via a suitable inverter because a photovoltaic panel or array (multiple PV panels)

only deliver DCpower. As well as the solar panels, the additional components that make up a grid connected PV system compared to a stand alone PV system are:

- Inverter: The inverter is the most important part of any grid connected system. Theinverter extracts as much DC (direct current) electricity as possible from the PV array

and converts it into clean mains AC (alternating current) electricity at the right voltage and frequency for feeding into the grid or for supplying domestic loads. It is important to choose the best quality inverter possible for the budget allowed as the main considerations in grid connected inverter choice are: *Power* – Maximum high and low voltage power the inverter can handle and *Efficiency* – How efficiently does the inverter convert solar power to AC power.



- Electricity Meter: The electricity meter also called a Kilowatt hour (kWh) meter is used to record the flow of electricity to and from the grid. Twin kWh meters can be used, one to indicate the electrical energy being consumed and the other to record the solar electricity being sent to the grid. A single bidirectional kWh meter can alsobe used to indicate the net amount of electricity taken from the grid. A grid connected PV system will slow down or halt the aluminium disc in the electric meter and may cause it to spin backwards. This is generally referred to as *net metering*.
- AC Breaker Panel and Fuses: The breaker panel or fuse box is the normal type of fuse box provided with a domestic electricity supply and installation

with the exception of additional breakers for inverter and/or filter connections.

- Safety Switches and Cabling: A photovoltaic array will always produce a voltage output in sunlight so it must be possible to disconnect it from the inverter for maintenance or testing. Isolator switches rated for the maximum DC voltage and current of the array and inverter safety switches must be provided separately with easy access to disconnect the system. Other safety features demanded by the electrical company may include earthing and fuses. The electrical cables used to connect the various components must also be correctly rated and sized.
- The Electricity Grid: Finally the electricity grid itself to connect too, because without the utility grid it is not a Grid Connected PV System.

An grid connected system without batteries are the simplest and cheapest solar power setup available, and by not having to charge and maintain batteries they are also more efficient. It is important to note that a grid connected solar power system is not an independent power source unlike a stand alone system. Should the mains supply from the electrical grid be interrupted, the lights may go out, even if the sun is shining. One way to overcome this is to have some form of short term energy storage built into the design.

Advantages

1. Sun is essentially an infinite source of energy. Therefore solar energy is avery large inexhaustible and renewable source of energy and is freely available all over the world.
2. It is environmentally very clean and is hence pollution-free.
3. It is a dependable energy source without new requirements of a highly technical and specialized nature for its wide spread utilization.
4. It is the best alternative for the rapid depletion of fossil fuels.

Disadvantages

1. It is available in a dilute and is at low potential. The intensity of solar energy ona sunny day in India is about 1.1 kW/square meter area. Hence

very large collecting areas are required.

2. Also the dilute and diffused nature of the solar energy needs large land area for the power plant for instance, about 30 square kilometers area is required for a solar power station to replace a nuclear plant on a 1 square kilometer site. Hence capital cost is more for the solar plant.

3. Solar energy is not available at night or during cloudy or rainy days.

Applications of Solar Energy:

Applications of solar energy enjoying most success today are:

1. Solar engines for pumping.
2. Solar water heaters.
3. Solar cookers.
4. Solar driers.
5. Solar furnaces.
6. Photo-voltaic conversion (solar cells)
7. Solar power generation.

SOLAR THERMAL POWER SYSTEM

SOLAR COLLECTOR

A **solar collector** is a device that collects and/or concentrates solar radiation from the Sun. These devices are primarily used for active solar heating and allow for the heating of water for personal use. These collectors are generally mounted on the roof and must be very sturdy as they are exposed to a variety of different weather conditions.

The use of these solar collectors provides an alternative for traditional domestic water heating using a water heater, potentially reducing energy costs over time. As well as indomestic settings, a large number of these collectors can be combined in an array and used to generate electricity in solar thermal power plants.

TYPES OF SOLAR COLLECTORS

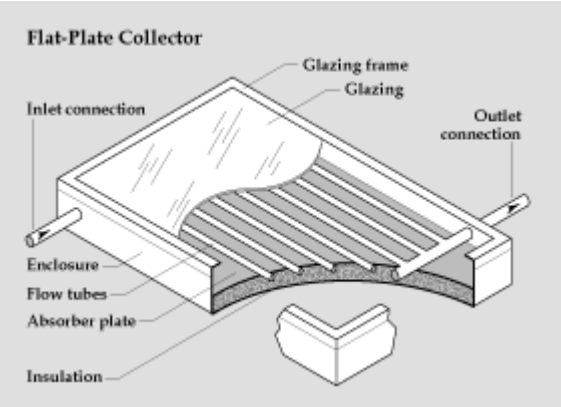
There are many different types of solar collectors, but all of them are constructed withthe same basic premise in mind. In general, there is some material

that is used to collect and focus energy from the Sun and use it to heat water. The simplest of these devices uses a blackmaterial surrounding pipes that water flows through. The black material absorbs the solar radiation very well, and as the material heats up the water it surrounds. This is a very simple design, but collectors can get very complex. Absorber plates can be used if a high

temperature increase isn't necessary, but generally devices that use reflective materials tofocus sunlight result in a greater temperature increase.

1. FLAT PLATE COLLECTOR

These collectors are simply metal boxes that have some sort of transparent glazing asa cover on top of a dark-coloured absorber plate. The sides and bottom of the collector are usually covered with insulation to minimize heat losses to other parts of the collector. Solar radiation passes through the transparent glazing material and hits the absorber plate.



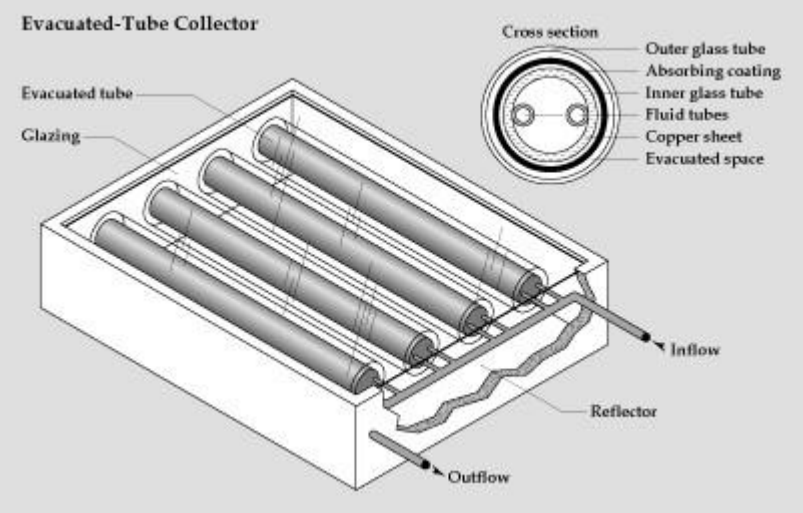
This plate heats up, transferring the heat to either water or air that is held between the glazing and absorber plate. Sometimes these absorber plates are painted with special coatings designed to absorb and retain heat better than traditional black paint. These plates are usually made out of metal that is a good conductor - usually copper or aluminum.

2. EVACUATED SOLAR COLLECTOR

This type of solar collector uses a series of evacuated tubes to heat water for use. These tubes utilize a vacuum, or evacuated space, to capture the suns energy while minimizing the loss of heat to the surroundings. They have an inner metal tube which acts as the absorber plate, which is connected to a heat pipe to carry the heat

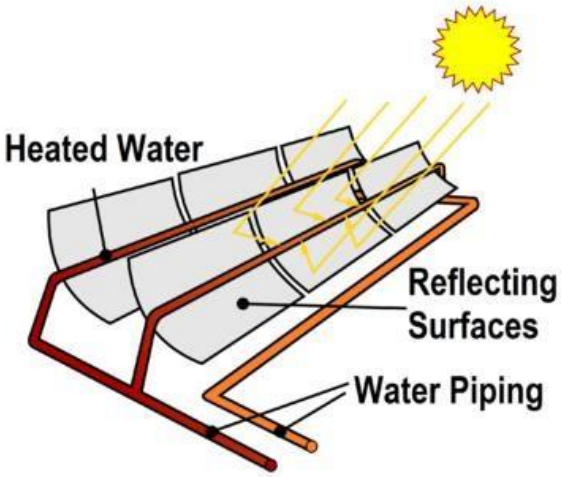
collected from the Sun to the water. This heat pipe is essentially a pipe where the fluid contents are under a very particular pressure. At this pressure, the "hot" end of the pipe has boiling liquid in it while the "cold" end has condensing vapour. This allows for thermal energy to move more efficiently from one end of the pipe to the other. Once the heat from the Sun moves from the

hot end of the heat pipe to the condensing end, the thermal energy is transported into thewater being heated for use.



3. LINE FOCUS SOLAR COLLECTOR

These collectors, sometimes known as parabolic troughs, use highly reflective materials to collect and concentrate the heat energy from solar radiation. These collectors are composed of parabolically shaped reflective sections connected into a long trough. A pipe that carries water is placed in the center of this trough so that sunlight collected by the reflective material is focused onto the pipe, heating the contents. These are very high powered collectors and are thus generally used to generate steam for Solar thermal power plants and are not used in residential applications. These troughs can be extremely effective in generating heat from the Sun, particularly those that can pivot, tracking the Sun in the sky to ensure maximum sunlight collection.


Heated Water
Reflecting
Surfaces
Water Piping

4. POINT FOCUS COLLECTOR

These collectors are large parabolic dishes composed of some reflective material that focus the Sun's energy onto a single point. The heat from these collectors is generally used for driving Stirling engines. Although very effective at collecting sunlight, they must activelytrack the Sun across the sky to be of any value. These dishes can work alone or be combined into an array to gather even more energy from the Sun.

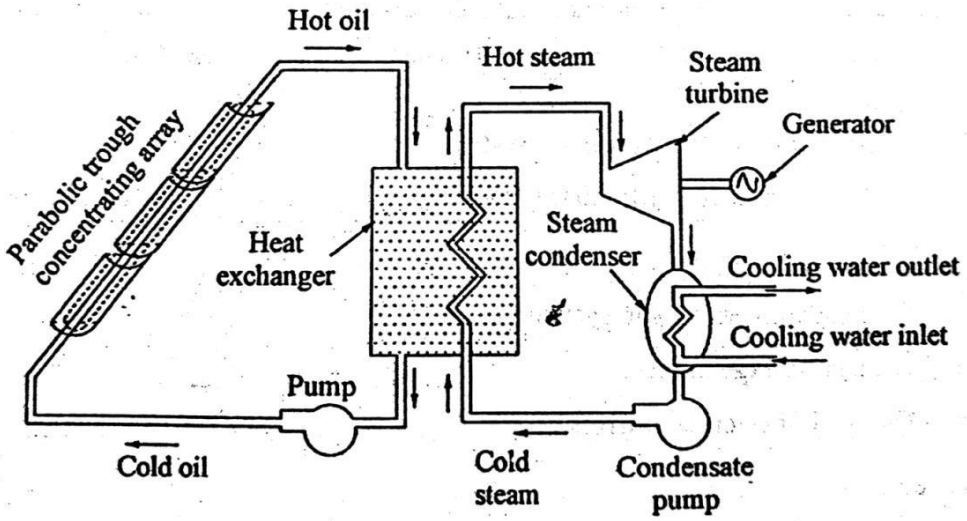
Point focus collectors and similar apparatuses can also be utilized to concentrate solar energy for use with Concentrated photovoltaics. In this case, instead of producing heat, the Sun's energy is converted directly into electricity with high efficiency photovoltaic cells designed specifically to harness concentrated solar

energy.

DISTRIBUTED COLLECTOR SOLAR THERMAL POWER PLANT

In parabolic trough collector, long, U-curved mirrors focus the rays of the sun into an absorber pipe. The mirrors track the sun on one linear axis from north to south during the day. The pipe is seated above the mirror in the center along the focal line and has a heat- absorbent medium (mineral oil, synthetic oil, molten salt etc.) running in it. The sun’s energy heats up the oil, which carries the energy to the water

in a boiler heat exchanger, reaching a temperature of about 400°C. The heat is transferred into the water, producing steam to drive turbine. Turbine is the prime mover for the generator and generator produce electrical power.



Distributed collector solar thermal power plant