Unit-2

Solar Energy:

Introduction:

Solar energy is an important, clean, cheap and abundantly available renewable energy. It is received on Earth in cyclic, intermittent and dilute form with very low power density 0 to 1 kW/m2.Solar energy received on the ground level is affected by atmospheric clarity, degree of latitude, etc. For design purpose, the variation of available solar power, the optimum tilt angle of solar flat plate collectors, the location and orientation of the heliostats should be calculated.

Units of solar power and solar energy:

In SI units, energy is expressed in Joule. Other units are angley and Calorie where

1 angley = 1 Cal/cm2.day

1 Cal = 4.186 J

For solar energy calculations, the energy is measured as an hourly or monthly or yearly average and is expressed in terms of kJ/m2/day or kJ/m2/hour. Solar power is expressed in terms of W/m2 or kW/m2.

Essential subsystems in a solar energy plant:

1. **Solar collector or concentrator**: It receives solar rays and collects the energy. It may be of following types:

a) Flat plate type without focusing

b) Parabolic trough type with line focusing

c) Paraboloid dish with central focusing

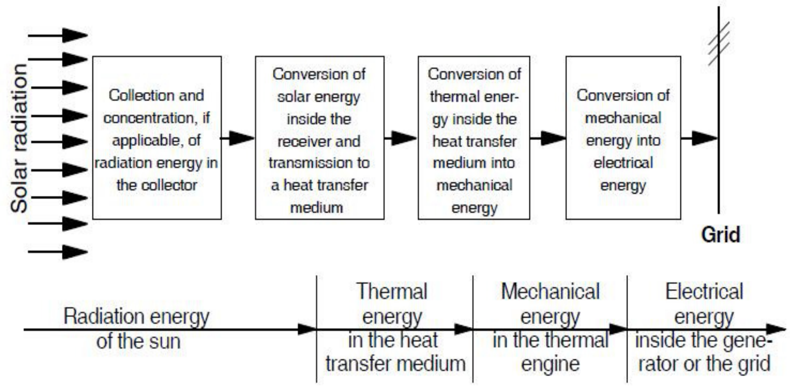
d) Fresnel lens with centre focusing

e) Heliostats with centre receiver focusing

2. **Energy transport medium**: Substances such as water/ steam, liquid metal or gas are used to transport the thermal energy from the collector to the heat exchanger or thermal storage. In solar PV systems energy transport occurs in electrical form.

3. **Energy storage**: Solar energy is not available continuously. So we need an energy storage medium for maintaining power supply during nights or cloudy periods. There are three major types of energy storage: a) Thermal energy storage; b) Battery storage; c) Pumped storage hydro-electric plant.

4. **Energy conversion plant**: Thermal energy collected by solar collectors is used for producing steam, hot water, etc. Solar energy converted to thermal energy is fed to steamthermal or gas-thermal power plant.



Solar Collectors

A solar collector is a device for collecting solar radiation and transfer the energy to fluid passing in contact with it. Utilization of solar energy requires solar collectors. These are generally of two types.

(i) Non- concentrating (or) flat plate solar collector.

(ii) Concentrating (focusing) type solar collector.

The solar energy collector, with its associated absorber, is the essential component of any system for the conversion of solar radiation in to more usable form (e.g heat or electricity). In the non-concentrating type, the collector area is the same as the absorber area. On the other hand, in concentrating collectors, the area intercepting the solar radiation is greater.

By means or concentrating collectors, much higher temperatures can be obtained than with the non-concentrating type. Concentrating collectors may be used to generate medium pressure steam. They use many different arrangements of mirrors and lenses to concentrate the sun's rays on the boiler. This type shows better efficiency than the flat plate type. For best

efficiency, collectors should be mounted to face the sun as it moves through the sky.

(i) Flat plate collectors (non-concentrating)

Where temperatures below about 90oC are adequate as they are for space and service water heating flat plate collectors, which are of the nonconcentrating type, are particularly convenient. They are made in rectangular panels from about 1.7 to 2.9 sq.m, in area, and are relatively simple to construct and erect. Flat plates can collect and absorb both direct and diffuse solar radiation, they are consequently partially effective even on cloudy days

when there is no direct radiation. Flat plate solar collectors may be divided into two main classifications based on the type of heat transfer fluid used.

Liquid heating flat plate collector

A. Liquid heating Flat Plate Collector

Liquid heating flat plate collectors are used for heating water and nonfreezing aqueous solutions. There are many flat-plate collector designs, . It is the plate and tube type collector. It basically consists of a flat surface with high absorptivity for solar radiation called the absorbing surface. Typically a metal plate, usually of copper, steel or aluminum material with tubing of copper in thermal contact with the plates are the most commonly used materials. The absorber plate is usually made from a metal sheet 1 to 2 mm in thickness, while the tubes, which are also of metal, range in diameter from 1 to 1.5cm. They are soldesed, brazed or clamped to the bottom of the absorber plate with the pitch ranging from 5 to 15 Cm, In some designs, the tubes are also in line and integral with the absorber plate. The primary function of the absorber is to absorb maximum radiation reaching it through the glazing, to lose maximum heat upward to the atmosphere and down ward through the back of the container and to transfer the retained heat to the working fluid. Black painted absorbers are preferred because they are considerably cheaper and good absorbers of radiation.

Heat is transferred from the absorber plate to a point of use by circulation of fluid (usually water) across the solar heated surface. Thermal insulation of 5 to 10cm. Thickness is usually placed behind the absorber plate to prevent the heat losses from the rear surface. Insulation materials is generally mineral wool or glass wool or fiber glass. The front covers are generally glass that is transparent to incoming solar radiation and opaque to the infra-red re-radiation from the absorber. The glass covers act as a convection shield to reduce the losses from the absorber plate beneath. The glass thickness of 3 and 4 mm are commonly used. The usual practice is to have 2 covers with specific ranging from 1.5 to 3cm.

Advantages of second glass which is added above the first one are

(i) Losses due to air convection are further reduced. This is important in windy areas.

(ii) Radiation losses in the infra-red spectrum are reduced by a further 25%, because half of the 50% which is emitted out wards from the first glass plate is back radiated.

(ii) Concentrating (focusing) type solar collector

Focusing collector or concentrating type solar collector is a device to collect solar energy with high intensity of solar radiation on the energy absorbing surface. Such collectors generally use optical system in the form of reflectors or refractors. A focusing collector is a special form of flat-plate collector modified by introducing a reflecting or refracting surface between the Solar Radiation and the absorber. In these collectors radiation falling on a relatively large area is focused on to a receiver or absorber of considerably smaller area. As a result of the energy concentration, fluids can be heated to temperatures of 5000C or more.

Solar Geometry

The Earth’s daily rotation about the axis through its two celestial poles (North and South) is perpendicular to the equator, but it is not perpendicular to the plane of the Earth’s orbit. In fact, the measure of tilt or obliquity of the Earth's axis to a line perpendicular to the plane of its orbit is currently about 23.5°. We call the plane parallel to the Earth's celestial equator and through the center of the sun the plane of the Sun. The Earth passes alternately above and below this plane making one complete elliptic cycle every year.

Summer Solstice.

On the occasion of the summer solstice, the Sun shines down most directly on the Tropic of Cancer in the northern hemisphere, making an angle $\delta = +23.5°$ with the equatorial plane. In general, the **Sun declination angle**, δ, is defined to be that angle made between a ray of the Sun, when extended to the center of the earth, O, and the equatorial plane. We take δ to be positively oriented whenever the Sun's rays reach O by passing through the Northern hemisphere. On the day of the summer solstice, the sun is above the horizon for the longest period of time in the northern hemisphere. Hence, it is the longest day for daylight there. Conversely, the Sun remains below the horizon at all points within the Antarctic Circle on this day.

Winter Solstice

On the day of the winter solstice, the smallest portion of the northern hemisphere is exposed to the Sun and the Sun is above the horizon for the shortest period of time there. In fact, the Sun remains below the horizon everywhere within the Arctic Circle on this day. The Sun shines down most directly on the tropic of Capricorn in the southern hemisphere on the occasion of the winter solstice.

The Sun declination angle, δ □, has the range: $-23.5° <$ □ $< +23.5°$ during its yearly cycle . Accurate knowledge of the declination angle is important in navigation and astronomy. For most solar design purposes, however, an approximation accurate to within about 1 degree is adequate. One such approximation for the declination angle is:

The Sun declination angle is δ □□ $= -23.5°$ on the winter solstice.

$\sin \delta = 0.39795$ □ $\cos [\, 0.98563$ □ $(\, N - 173 \,)\,]$

where the argument of the cosine here is in degrees and N denotes the number of days since January1.

Vernal and Autumnal Equinox

There are two occasions throughout the year when the center of the Earth lies in the plane of the Sun. Since the Earth's North – South axis of rotation is perpendicular to this plane, it follows that on these two days every location on the Earth receives 12 hours of sunshine. These two events are known as the **vernal** and **autumnal equinoxes**.

Note that

• The Earth is **above** the plane of the Sun during its motion from the autumnal equinox to winter solstice to vernal equinox. Hence, $\delta < 0$ during the fall and winter.

• The Earth is **below** the plane of the sun as it moves from vernal equinox to summer solstice and back to autumnal equinox (i.e. during spring and summer). So $\delta > 0$ during these seasons.

The **latitude** of a location on the Earth is the angle between the line joining that location to the center of the earth and the equatorial plane. The great semicircles along the surface of the Earth joining the North to the South poles are called **lines of longitude**.

The Sun declination angle has measure: $\delta = 0°$ on the days of the vernal and the autumnal equinox.

The line of longitude through Greenwich, England is called the prime meridian.

Solar Noon

Solar Noon is defined to be that time of day at which the Sun's rays are directed perpendicular to a given line of longitude. Thus, solar noon occurs at the same instant for all locations along any common line of longitude. Solar Noon will occur one hour earlier for every 15 degrees of longitude to the east of a given line and one hour later for every 15 degrees west. (This is because it takes the Earth 24 hours to rotate 360°.)