GMR

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Department of PHYSICS

III B.Sc. SEMESTER-VI

PAPER 7B: SOLAR THERMAL & PHOTO VOLATIC ASPECTS

C1 STUDY MATERIAL

Name of the Student : ______________________________

Roll Number : ______________________________

Group : ______________________________

Academic Year : ______________________________

Prepared by:
Mrs. G.M.Murali Krishna
Senior Lect in Physics
Sri GCSR College

Semester – VI

Cluster Electives – VIII-C

Elective Paper – VIII-C-1: Solar Thermal and Photovoltaic Aspects

No. of Hours per week: 04 **Total Lectures:60**

UNIT-I (12 hrs)

1. Basics of Solar Radiation: Structure of Sun, Spectral distribution of extra terrestrial radiation, Solar constant, Concept of Zenith angle and air mass, Definition of declination, hour angle, solar and surface azimuth angles; Direct, diffuse and total solar radiation, Solar intensity measurement – Thermoelectric pyranometer and pyrheliometer.

2. Radiative Properties and Characteristics of Materials: Reflection, absorption and transmission of solar radiation throughsingle and multi covers; Kirchoff' s law – Relation between absorptance, emittance and reflectance; Selective Surfaces - preparation and characterization, Types and applications; Anti-reflective coating.

UNIT-II (14 hrs)

3. Flat Plate Collectors (FPC) : Description of flat plate collector, Liquid heating type FPC, Energy balance equation,Efficiency, Temperature distribution in FPC, Definitions of fin efficiency and collector efficiency, Evacuated tubular collectors.

4. Concentrating Collectors: Classification, design and performance parameters; Definitions of aperture, rim-angle, concentration ratio and acceptance angle; Tracking systems; Parabolic trough concentrators; Concentrators with point focus.

Unit-III (14 hrs)

5. Solar photovoltaic (PV) cell: Physics of solar cell – Type of interfaces, homo, hetero andschottky interfaces, Photovoltaic Effect, Equivalent circuit of solar cell, Solar cell output parameters, Series and shunt resistances and its effect on cell efficiency; Variation of efficiency with band-gap and temperature.

6. Solar cell fabrication: Production of single crystal Silicon: Czokralski (CZ) and Float Zone (FZ) methods, Silicon wafer fabrication, Wafer to cell formation, Thin film solar cells, Advantages, CdTe/CdS cell formation, Multi-junction solar cell; Basic concept of Dye-sensitized solar cell, Quantum dot solar cell.

UNIT-IV (8 hrs)

Solar PV systems: Solar cell module assembly – Steps involved in the fabrication of solar module, Module performance, I-V characteristics, Modules in series and parallel,

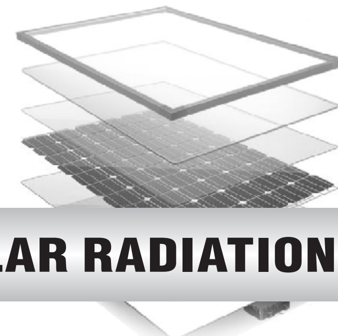
Module protection – use of Bypass and Blocking diodes, Solar PV system and its components, PV array, inverter, battery and load.

UNIT-V (12 hrs)

Solar thermal applications: Solar hot water system (SHWS), Types of SHWS, Standard method of testing the efficiency of SHWS; Passive space heating and cooling concepts, Solar desalinator and drier, Solar thermal power generation.

Solar PV applications: SPV systems; Stand alone, hybrid and grid connected systems, System installation, operation and maintenances; Field experience; PV market analysis and economics of SPV systems.

Unit : I



1 BASICS OF SOLAR RADIATION

STRUCTURE OF SUN

The innermost layer of the sun is called case with density of 160 g/cm^3 having temperature of 20 million degrees. The case might be expected to be solid.

In the core fusion reactions produces energy in the form of gamonarays and neutrinos. Gamma rays are photons with high energy and high frequency. The gamma rays are absorbed and re-emitted by many atoms on their journey from the onvelope to the outside of the sun.

Solar envelope : Outside of the core is the radiative envelope, which is surrounded by a convective envelope. The temperature is *H* million kelvin. The density of the solar envelope is much less than that of core. The solar envelope puts pressure on the core and maintains the cores temperature.

Photosphere : The photosphere is the zone from which the sun light is both seen and emitted. The photosphere is a compartively thin layer and low pressure gasses surrounding the envelope with temperature 6000°C.

The composition, temperature and pressure of the photosphere are revelaved by the spectrum of sunlight.

Reversing layer : The next 300 to 400 km thick layer is called as reversing layer which contains most of the elements in gaseous state. The extension of reversing layer is chromosphere.

Chromosphere : During an eclipse, a red circle can sometimes be seen outside the sun. This circle is called the chromosphere. Its red colouring is caused by the abundance of hydrogen.

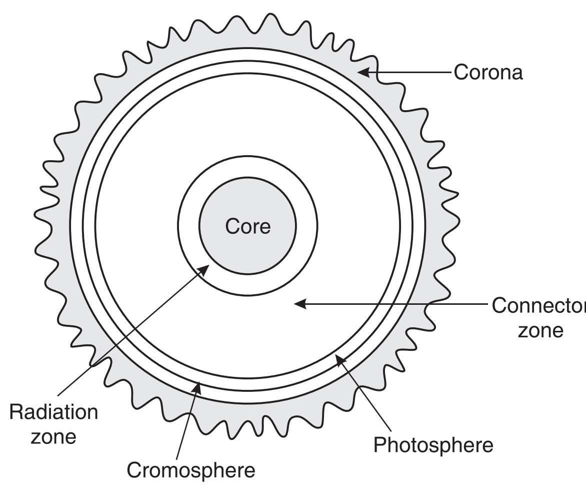


Fig. 1

From the centre of the sun to the chromosphere the temperature decreases propositionally as the distance from the core increases. The chromosphere temperature is 7000 k which is hoter than that of photo sphere. Temperatures continue to increase through the corona.

Corona : The outermost layer of the sun is called the corona or the crown. The corona is very thin and faint and is therefore very difficult to observe from the earth. Typically can observe the corona during total solar eclipse (or) by using a corona grapy telescope, which sionulates an ellipse by covering the bright solar disk.This out layer is very dem. It is the hottest. At 10^6 K. Heat is a measure of molecular energy that is the movement of molecules within a space. Because the corona extands several million kilometer into space there is a lot of room for molecules to move. It is this movement that forms the source of the solar winds.

SPECTRAL DISTRIBUTION OF EXTRA TERRISTRIAL RADIATION

Solar radiation covers a continuous spectrum of electromagnetic radiation in a wide frequency range.

The variation of solar irradiance with wavelength of solar radiation is called solar radiation spectrum as shown in figure.

This spectrum of electromagnetic radiation striking the earths atmosphere range of 0.1 μm to about 3 μm of 99% of extraterrestrial radiation. This can be divide four regions in increasing order of wave length.

About 6.4% of exteraterrestrial radiation energy is contained in the ultraviolet region (< 0.38 μm) another 48% is contained in the visible region (0.38μm to 0.78μm) and the remaining 45.6% is contained in the infrared region (> 0.78 μm) .

The spectral solar-irradiation distribution both for extraterrestrial and terrestrial radiation is shown in figure.

The areas under these curves indicates the total radiation intensities in w/m^2 respectively for extraterrestrial, terrestrial regions.

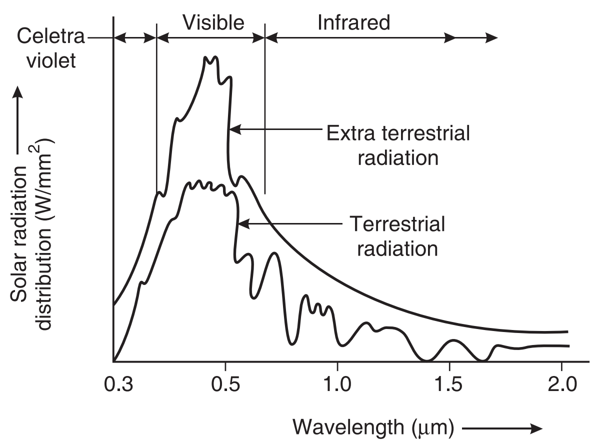


Fig. 2

Extraterrestrial and terrestrial radiations

The intensity of solar radiation keeps on attenuating as it propagates away from the surface of the sun, through the wave length remains unchanged the solar radiation incident on the outer atmosphere of the earth is known as extraterrestrial radiation. The solar constant, I_{sc} is defined as the energy received from the sun per unit time on a unit area of surface propendicular to the direction of propagation of the radiation at the top of atmosphere at the earth's mean distance from the sun.

$$I_{ext} = I_{sc}[1.0 + 0.033 \cos(360n / 365)] \text{ w/m}^2$$

The solar radiation that reaches the earth surface after passing through the earth's atmosphere is known as terrestrial radiation. The term solar insolation is defined as the solar radiation received on a flat horitontal surface on the earth.

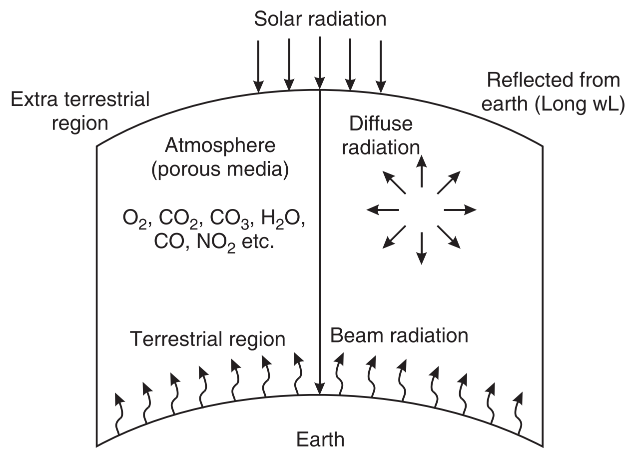


Fig. 3

SOLAR RADIATION GEOMETRY

Declination (δ) : It is defined as the angular displacement of the sun from the plane of the earth's equator. It is positive when measured above the equitorial plane in the northern hemisphere. The declination δ can be approximately determined from the equation.

$$\delta = 23.45 \times \sin\left[\frac{360}{365}(284 + n)\right] \text{degrees}$$

Where n is day of the year counted from 1st January.

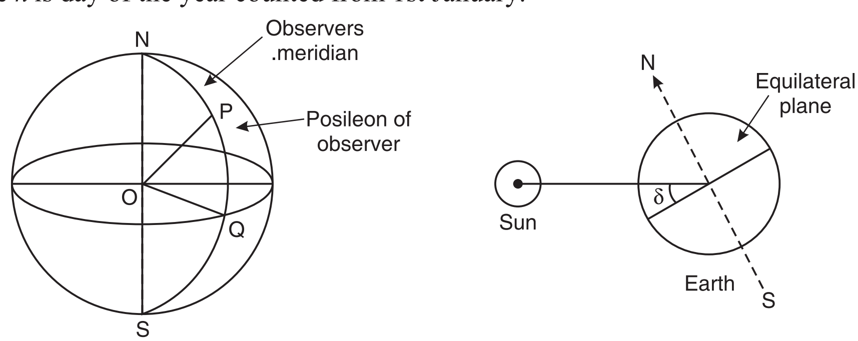


Fig. 4

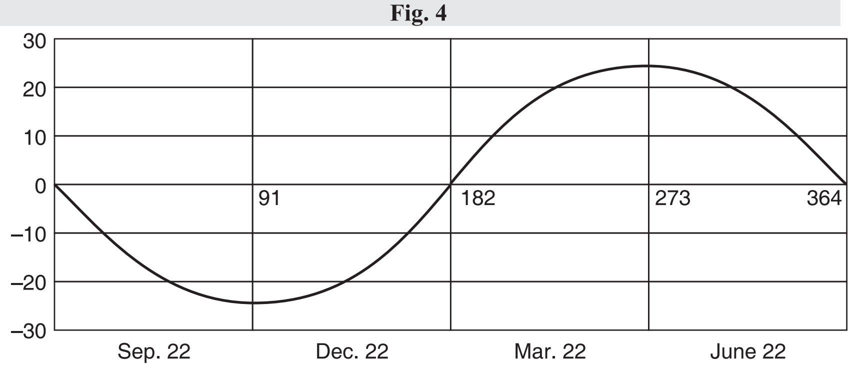


Fig. 4 : Variacions ID sun's declination

Hour angle (ω) : The hour angle at any moment is the angle through which the earth's must even to bring the incridian of the observer directly is core with the sun's rays.

It is the angular displacement of the sun towards cast or west of cocal meridian.The earth completes one rotation is 24 hour's. Therefore, one hour corresponds to 15° of rotation. At solar noon, as the sun's rays are in line with the cocal meridian, the hour angle is 2000. It is +ve in the afternoon and – ve is the forenoon.

It can be calculated as

$$\omega = [\text{solar time} - 12.00] \text{ (in hrs)} \times 15 \text{ degree}$$

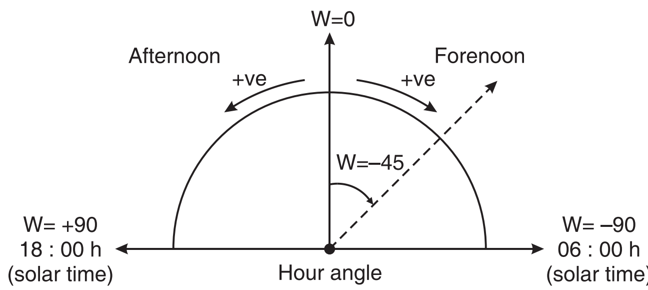


Fig. 5

Zenith angle (O_2) : It is the angle between the sun's ray and the perpendicular to the horizontal plane.

Solar azimuth angle (Y_s) : If the angle on a horizontal plane, between the core due south and the projection of the sun's rays on the horizontal plane. It is taken as +ve when measured from south toward's west.

Surface azimuth angle : It is the angle in the horizontal plane, between the line due south and the horizontal projection of the normal to the inclined plane surface (collector). It is taken as +ve when measured from south towards west.

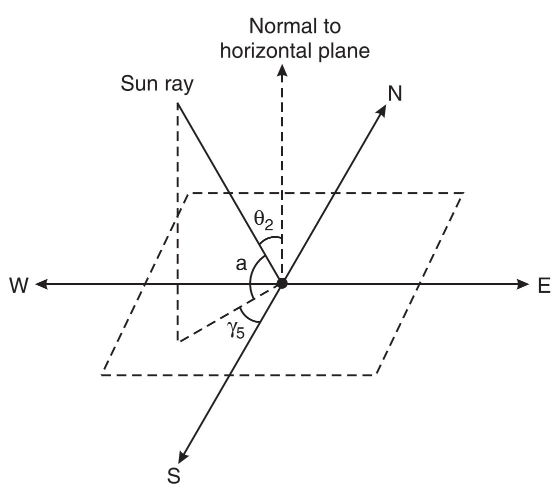


Fig. 6

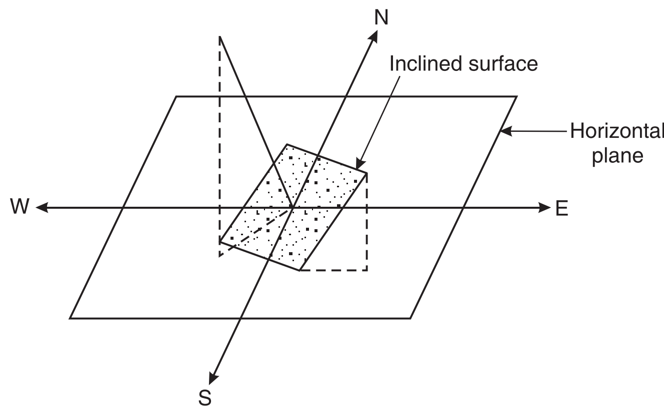


Fig. 7

'Surface azimuth angle'
ap–horizontal projection of normal to surface.

Pyranometer :

A pyranometer is a type of actinometer used to measure global radiation usually on a horizontal surface, but can also used on an inclined surface when shaded from the beam radiation by using a shading ring, a pyranometer measures diffused radiation. And it is also designed co measure the solar radiation flux density (w/m^2) from the hemisphere above within a wavelength range 0.3 µm to 3 µm. The name pyranometer stems from the greek words ''pyr''means fire and ''ano'' means ''above sky''.

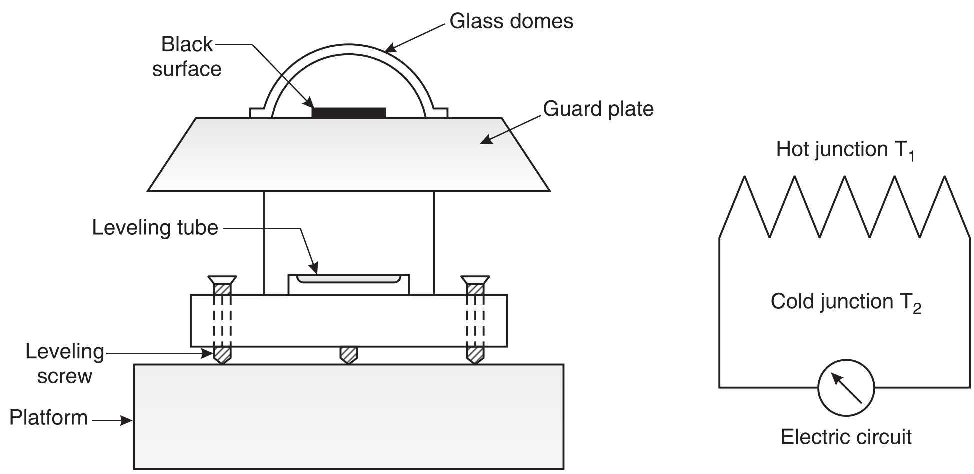


Fig. 8

The pyranometer contains the following components :

1. Black surface
2. Glass domes
3. Guard plate
4. Leveling tube
5. Leveling screw
6. Platform

It contains a thermopile whose sensitive surface consits of circular, blackened, hot junctions, exposed to the sun the cold junctions being completely shaded the temperature difference between the hot and cold junctions is the function of radiation falling on the sensitive surface. The sensing element is counced by two concentric hemispherical glass domes to sheild it from wind and rain. A radiation sheild scerrending the outer dome and coplanar with the sensing element. The pyronometer with a shadow band to present beam radiation from reaching the sensing element measures the diffused only.

Pyroheliometer :

An instrument that measures beam radiation by using a long narrow tube to collect only beam radiation from the sun at normal incidence.

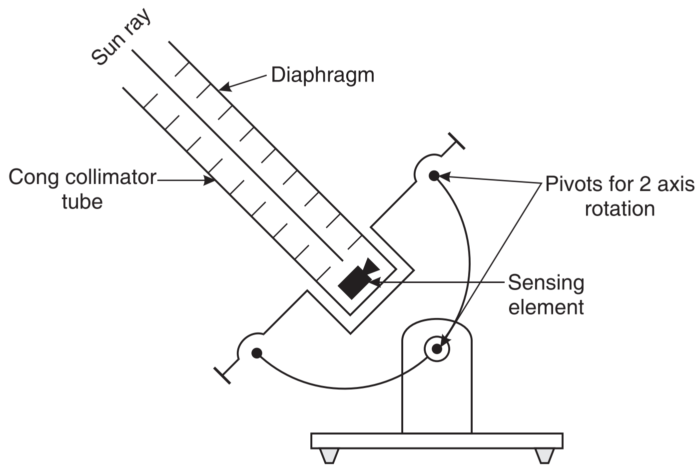


Fig. 7

It contains the following components :

1. Diaphargm
2. Long collimator tube
3. Sensing element
4. Pivots for 2 axis rotation

The normal incidence pyroheliometer having a long collimator tube to collect beam radiation whose field of view is limited to a solid angle of 5.5° by appropriate diaphragms inside the tube the inside of the tube is ocoeaened to absorb any radiations incident at angles outside the collection solid angle. At the base of the tube a wire wound thermopile having a sensitivity of approximately δ $\mu v/\omega/m^2$ and an output impedance of approximately 200 Ω is provided. The tube is sealed with dry air to elimenate absorption of beam radiation within the tube by water vapour.

Applications :

- Material testing reasearch.
- Scentific meterological and climatic observations.
- Assessment of the efficiency of solar collectors and photovolatic devices.

Airmass (m) : Which is defined as the ratio of the path length through the atmosphere, which the solar beam actually traverses upto the ground to the vertical path through the atmosphere.

Mathematically

$$\text{Air mass (m)} = \frac{\text{Path length traversed by beam radiation}}{\text{Vertical path length of atmosphere}}$$

from figure

$$m = BA/CA$$
$$m = \sec\theta_z$$
$$m = \operatorname{cosec}\alpha \qquad (\because \alpha + \theta_z = 90)$$

where α is the inclination angle

θ_z is the zenith angle.

$m = 1$ when the sun is at zenith, directly overhead

$m = 2$ when the zenith angle is 60°

$m = \sec\theta_z$ when $m > 3$

$m = 0$ just above the earth's atmosphere

Solar constant (S) : It is a measure of flux density and is the amount of incoming solar electromagnetic radiation per unit area that would be incident on a plane perpendicular to the rays at a distance of one AU. It includes all types of solar radiation, not just the vissible light.

The rate at which solar energy arrives at the top of the atmosphere is called the solar constant (5) (8) (I_{sc}). This the amount of energy received in unit time on a unit area perpendicular to the sun's direction at the mean distance of the earth from the sun.

The national aeronautics and space administrations (NASA) standard value for the solar constant is as follows :

(1) 1.353 k.watt/sq.m (or) 1353 watt/sq.m
(2) 116.5 langleys (calories/sor.cm)/hour

(or)

1165 kcal per sqm per hour
(3) 429.2 Btu/sq. ft/hour.

SOLAR RADIATION AT THE EARTH'S SURFACE :

OR

DIRECT, DIFFUSE AND TOTAL RADIATION :

The extraterrestrial radiation being outside the atmosphere is not affected by changes in atmospheric conditions. Solar radiation is received at the earth's surface in an attenuated form because it is subjected to the mechanisms of absorption and scattering as it is passes through the earth's atmosphere as shown in figure.

Direct (or) Beam radiation : Solar radiation propagating in a straight line and received at the earth surface without change of direction *i.e.*, in line with the sun is called beam (or) direct radiation as shown in figure.

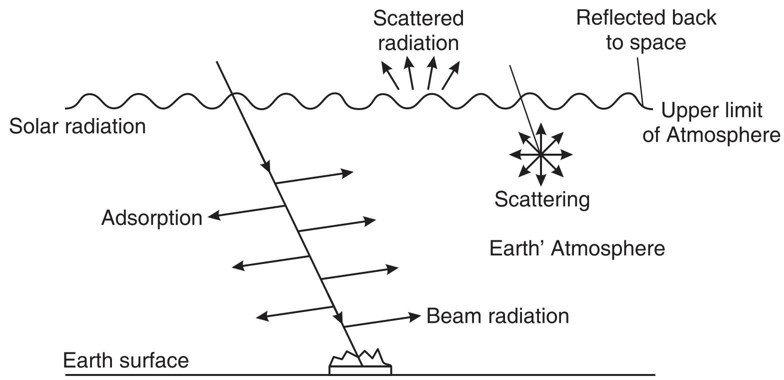


Fig. 8

Diffused radiation : Solar radiation scattered by aerosols, dust and molecules is known as diffused radiation. It does not have a unique direction as shown in figure.

Global radiation : The sun of beam and diffused radiation is reffered as total (or) global radiation.

EXERCISE

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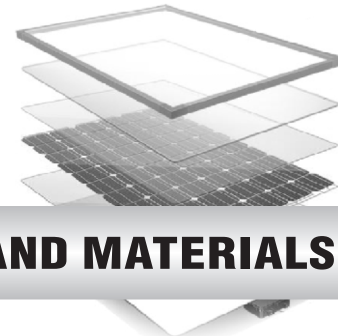
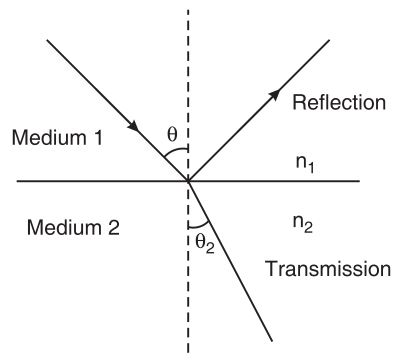


2 RADIATIVE PROPERTIES AND MATERIALS

REFLECTION, ABSORPTION AND TRANSMISSION OF SOLAR RADIATION THROUGH SINGLE AND MULTICOVERS

When solar radiation heats surface, the photons can be absorbed reflected or transmitted. It the case of opaque material none of the photons are transmitted. If the materials is dark and duel, very few of photons are lylected. A majority of the photons are absorbed. As a result of absorption, the photons are convented into thermal energy because of the temperature of the material the surface emits radiations back to its surroundings at a rate that independent on the emissiuity of the materials.



The sun of transmitevily (τ) absorbitevity (α) and reflectivity (ρ) must be equal to unity.

$$\tau + \alpha + \rho = 1$$

Most solar applications involve a slab of materials. Reflection at interfaces. Cover materials used in solar applications require the transmission of radiation through a slab or film of material and there are thus the interface per cover to cause reflection loss.

Single cover : For solar collector analysis, it is necessary to evaluate the transmittance absorptance product (T, α). The transmissivity, aborptance product is defined as the ratio of the radiation absorbed in the absorber plate to the radiative incident on the cover system.

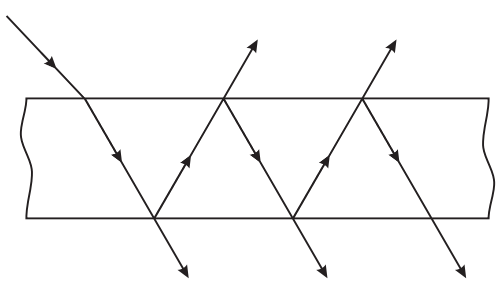


Fig. 2 : Transformer through one cover

Multi covers : To reduce the rate of radiation and convection loss, multicover are placed above the absorber surface.

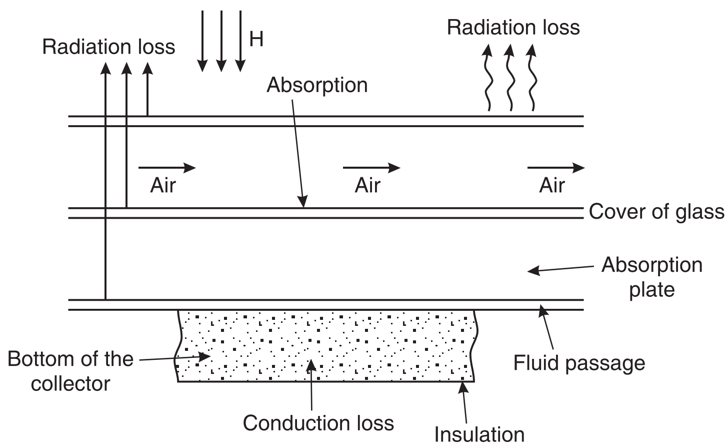


Fig. 2 : Transmmision through one cover

One layer of glass transmit 2 percent of solar radiation striking it, while greatly reducing the heat cost coefficient. It canbe further reduced by using a second transperent cover reduce the heat by convection.

SELECTIVE SURFACE

Introduction :

Selective absorber coatings on the surfaces are used to reduced thermal losses. An ideal selective coating is one that is a perfect absorber of solar radiation while being a perfect reflector of thermal radiation. Such a coating will make a surface, a poor emitter of thermal radiation. Hence a selective coating increase the temperature of an absorbing surface.

Solar flux absorbed thermal flux emitted since 96% of the sun's radiation is concentrated in wavelength ranges of less than 2500 nm and 99% of the thermal radiations from a collector surface is in wavelength of more than 2500 nm. It is possible to have a surface that will absorb all the solar radiation while emitting very little.

Preparation

A selective surface is a surface that has a high absorptance for short wavelength radiation (< 2500 nm) arid low emittanes of long wave radiation (> 2500 nm) selective surfaces are prepared by coating special layers in view of absorptivity and emitivity they are mentioned in below table.

Coating	Type	Absorptance	Emittance
Black chrome	Electroplated	0.96	0.10
Black nickel	Electroplated	0.90	0.10
Black copper	Copper oxide	0.87-0.92	0.07-0.35
Black anodize	Alluminium oxide	0.94	0.07

Characteristic of selective surface :

1. High absorptance for short wave radiation and low emittance of long wave radiation.
2. It's properties should not change with use.
3. It should be able to with stand the temperature levels associated with the absorber plate surface of collector over extended periods of time.
4. It should be able to withstand atmosphere carrision and oxidation.
5. It should be of reasonable cost.

Applications :

1. These selective surface are used in flat plate collectors.
2. They are used as liquid heaters.

Anti reflective coating :

Camera lens are pointed with a separate material (dielectric material) to avoid reflection. In the same manner solar flat plates at collectors are also pointed in such a manner that no light is reflected these coatings are called as Anti reflective coatings. In this district to interface is formed in between incident and reflected rays. The phase difference between these two rays is arranged to occur destructive interference.

Thickness of the layer $d = \lambda/4n$

d = width of the coating

λ = wavelength

n = refraction

EXERCISE

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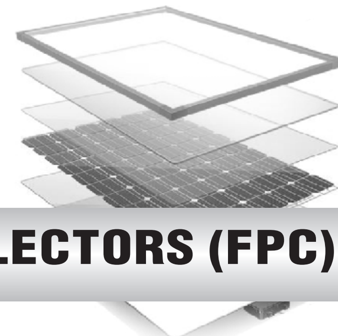
Unit : II

3 FLAT PLATE COLLECTORS (FPC)



DESCRIPTION OF FLAT PLATE COLLECTOR

Flate plate collectors are the most common solar collector for solar water heating system in homes and solar space heating.

These collectors heat liquid or air at temperature less than 90°C. They are made in rectangular panels form about 1.7 to 2.9 sqm in area and are relatively simple to construct and current.

Flat plates can collect and absorb both direct and diffuse solar radiation.

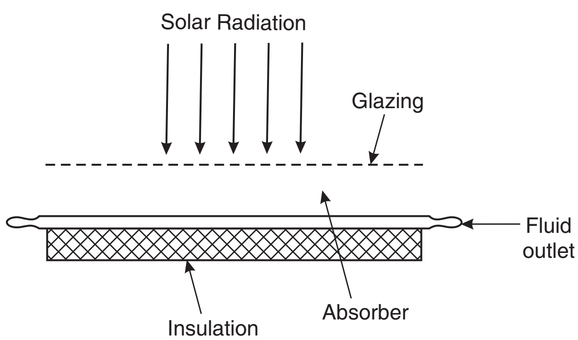


Fig. 1

A typical flat plate collector is shown in figure.

It has five important parts :

1. Dark flat plate absorber of solar

Energy : The absorber consists of a thin absorber sheet because of the metal is a good heat conductor.

This is normally metallic or with a black surface, although a wide variety of other materials can be used with air heaters.

2. Transparent cover : Which may be one or more sheets of glass (or) radiation transmitting plastic film or sheet but reduces heat losses.

3. Heat transport fluid : To remove heat from the absorber fluid is usually circulated through tubing or channels to transfer heat from the absorber to an insulated water tank.

4. Heat insulation backing : Often backed by a grid or coil of fluid tubing to minimise the heat losses.

5. Insulating casing : The casing or container which enclose the other components and protects them from the weather.

FPC may be divided into two main classifications based on the type of heat transfer fluid.

(1) Liquid flat plate collectors.

(2) Air flat plate collectors.

LIQUID HEATING TYPE FPC

A flat-plate collector is placed at a location in a position such that its length aligns with the line of longitude and is suitably tilted towards south to have maximum collection. The positioning of the collector is shown in fig. The constructional details of a simple flate plate collector are shown in fig. The basic elements in a majority of these collectors are :

(i) Transparent cover (one or two sheets) of glass or plastic).

(ii) Blackened absorber plate usually of copper, aluminium or steel.

(iii) Tubes, channels or passages in thermal contact with the absorber plate. In some designs, the tubes form an integral part of absorber plate.

(iv) Weather tight insulated container to enclose the above components.

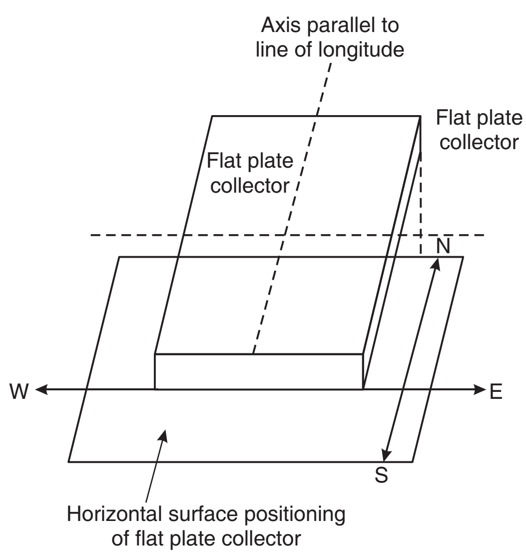


Fig. 2 : Horizontal surface positioning of flot-plate collector

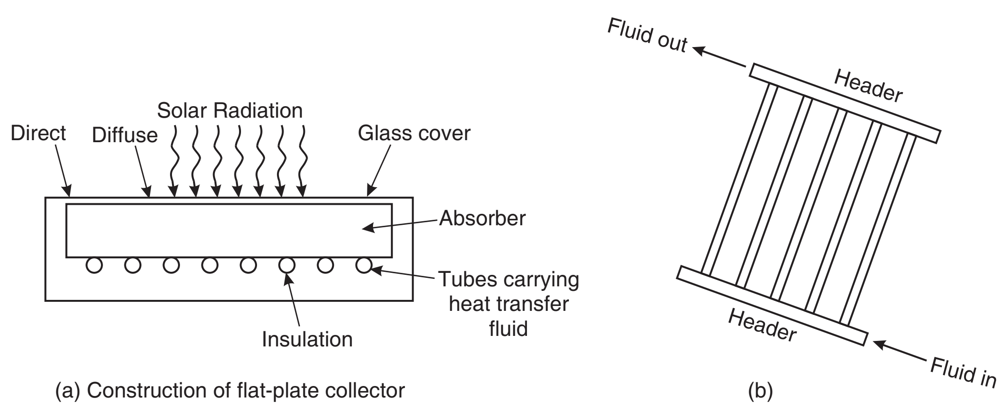
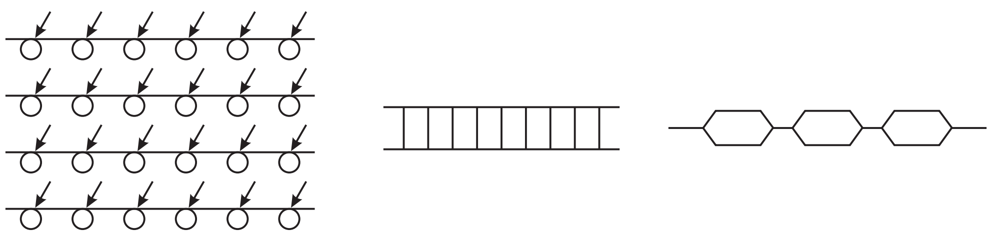


Fig. 3 : Construction of flop plate collection

A liquid most commonly water is used as the heat transport medium from the collector to the next stage of the system. However, some times a minture of water and ethylene glycol (antifreeze mixture) is also used if the ambient temperatures are likely to drop below 0°C during nights. The absorber plate is usually made from a metal sheet ranging in thickness from 0.2 to 1 mm. The metallic tubes range in diameter from 1 to 1.5 cm. In some designs. The tubes are bonded to the top or in line. Header pipes, which are of slightly larger diameter of typically 2 to 2.5 cm, lead the water in and out of the collector and distribute to tubes. In the bottom and along the side walls, thermal in solution provided by a 2.5 to 8 cm thick layer of glass wool prevents heat loss from the rear surface and sides of the collector. The glass cover also prevents heat loss due to convection by keeping the air stagnant. The glass cover may reflect some 15% of incoming solar radiation, which can be reduced by applying anti-reflective coating on the outer surface of the glass. The usual practice is to have one or two covers with specing ranging from 1.5 to 3 cm. Transparent plastics may also be used in place of glass but they offer in ferior performance as compared to glass.



(a) Pipe and fin type (b) Water sandwich type (c) Semi-water sandwich type

Fig. 4

A variety of absorber-plates designs have been developed as shown in fig.

(i) Pipe-and-fin type : Here the liquid flows only in the pipe and hence they have a comparatively low wetted area and liquid capacity.

(ii) Rectangular or cylindrical full sandwich type :

In this, both the wetted area and water capacity are high.

(iii) Roll-bond or semi-sandwich type : It is an intermediate between the above two types.

FLATE PLATE COLLECTORS

Flate Plate collectors

In concentration type solar collectors, solar rediation is converged from a large area into a smaller area using optical means.

A flat-plate capacitor is simple in construction and does not require sun tracking. The principal advantage of a flat-plate collector is that because of the absence of optical concentration, the area from which heat is cost is large. Also, due to the same region high temperature cannot be attained.

The main advantage of concentration type collectors is that high temperatures can be attained due to concentration of radiation this also fields high temperature thermal energy.

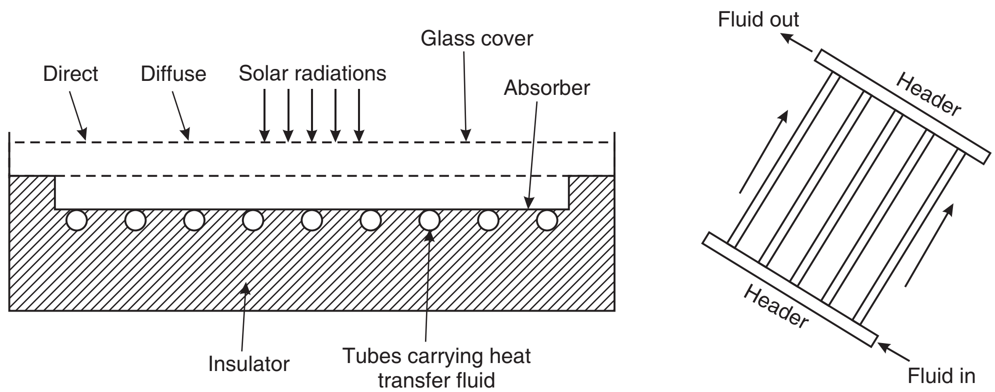


Fig. 5

Liquid flat-plate collector :

A flat-plate collector is placed at a location in a position such that its length aligns with the line of longitude and is suitably titled towards south to have maximum collection. The basic elements in a majority of these collectors are :

(i) Transparent cover of glass or plastic.

(ii) Blackened absorber plate usually of copper, aluminium or steel.

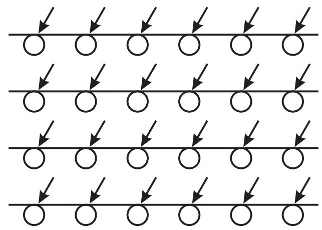
(iii) Tubes, channels or passages in thermal contact with the absorber plate.

(iv) Weather tight-insulated container to enclose the above components.

A liquid, most commonly water, is used as the heat transport medium from the collector to the next stage of the system. However, sometimes a mixture of water and ethylene glycol is also used in the ambient temperatures are likely to drop below 0°C during nights. As solar radiation strikes on a specially treated metallic absorber plate, it is absorbed and raises the plates temperature. The absorber plate is usually made from a metal sheet ranging in thickness from 0.2 to 1 mm. The heat is transfered to the heat transfer liquid circulating in the tube. The metallic tubes range in diameter from 1 to 1.5 cm. These are soldered, brazed, welded or pressure bonded to the absorber plate with a pitch ranging from 5 to 12 cm. Header pipes, which are of slightly larger diameter of typically 2 to 2.5 cm, lead the water in and out of the collector and distribute to tubes. The header pipes, is copper, but other metals and plastics have also been tried. In the bottom and along the side walls thermal insulation procided by a 2.5 to 8 cm thick layer of glass wool prevents heat loss from the rear surface and sides of the collector. The glass cover also prevents heat loss due to convection by keeping the air stagnant. Transparent plastics may also be used in place of glass but they often offer inferior performance as compared of glass. Most plastics are not as opaque to infrared radiation as glass. The life of a plastic material is short when exposed to sun rays.

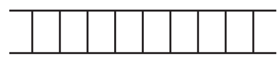
A variety of absorber plate designs have been developed as shown in fig. these absorber plates can be broadly divided into three basic types of depending on the extent of wetted area relative to the absorbing surface area.

(i) Pipe-and-fin type : Here, the liquid flows only in the pipe and hence they have a comparatevely low wetted area and liquid capacity.



(a) Pipe and fin type

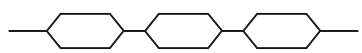
(ii) Rectangular (or) cylindrical full-sandwich :



(b) Water sandwich type

In this both the wetted area and water capacity are high.

(iii) Roll-bond (or) semi sandwich type :



(c) Semi-water sandwich type

It is an intermediate between the above two types :

TIN EFFICIENCY

The heat transfer takes place from a rod/fin of uniform cross-section area prettending from a flat wall in practical application.

Fin may have varying cross sectional area and may be attached to the circular surfaces. In side to indicate the effectiveness of a fin in transfering a given quantity of heat a new parameter called fin efficiency. It is defined as

***F* = actual heat transfered**

Heat transfer for entere fin area at base temperature.

The temperature distribution between two tubes can be divided. If it temperaly assumes the temeprature gradient in the flow direction is negligible.

Collector efficiency : The solar energy collection efficiency, ncol of both thrmal collectors and photovolatic collectors is defined as the ratio of the rate of aseful thermal energy leaving the collector to the useable solar irradeance falling on the aperture area.

Simply stated, collector efficiency is

$$\eta_{\text{col}} = \frac{Q_{\text{usefull}}}{A_a I_a}$$

Where Q_{usefull} = rate of (usefull) energy output (ω)

A_a = Aperture area of the collector (cm^2)

I_a = Solar irradiance falling on collector aperture (w/m^2)

The incoming solar irradiance falling on the collector aperture, I_a, multipliced by the collector aperture area represents the maximum amount of solar energy that could be captured by that collector.

Evacuated tube collector

The performance of a flat-plate collector can be improved by suppressing or reducing the heat lost from the collector by convection and conduction. This is done by having vaccum around the absorber. As a consequence, it becomes essential to use a glass tube as a cover because only a tubelar surface is able to withstand the stresses introduced by the pressure differences as a result of vacuum. The collector consits of a number of long tubular modules stacked together.

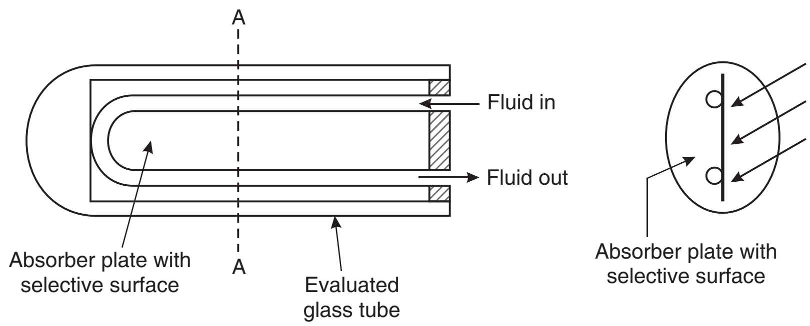


Fig. 6

Evacuated tube collectors are very expensive compared to conventional flate-plate collectors. Thus, it is possible to consider them only for high fluid temperature in a range 100 to 130°C.

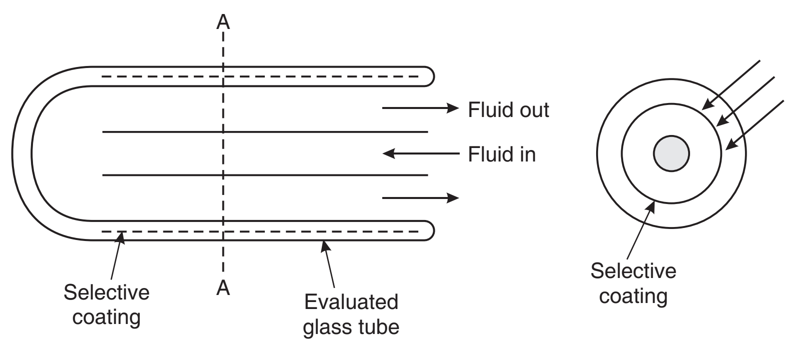


Fig. 7

Temperature distribution in FPC

A liquid heating collector shown in fig.

Fig. (a) shows region between two tubes. Some of the solar energy absorbed by the plate must be conducted along the plate to the region of the tubes. Thus the temperature midway between the tubes will be hihger than the temperature in the vicinity of the tubes. The temperature above the tubes will be nearly uniform because of the presence of the tube and cued metal.

The energy transferred to the fluid will heat the fluid, causing a temperature gradient to exist in the direction of flow since in any region of the collector the general temperature level is governed by the local temperature level of the fluid as shown in fig. (b) is expected. At any location y, the general temperature distribution to the x-direction is as shown in fig. (1) and at any location x_1 the temperature distribution in the y-direction will look like fig. (d).

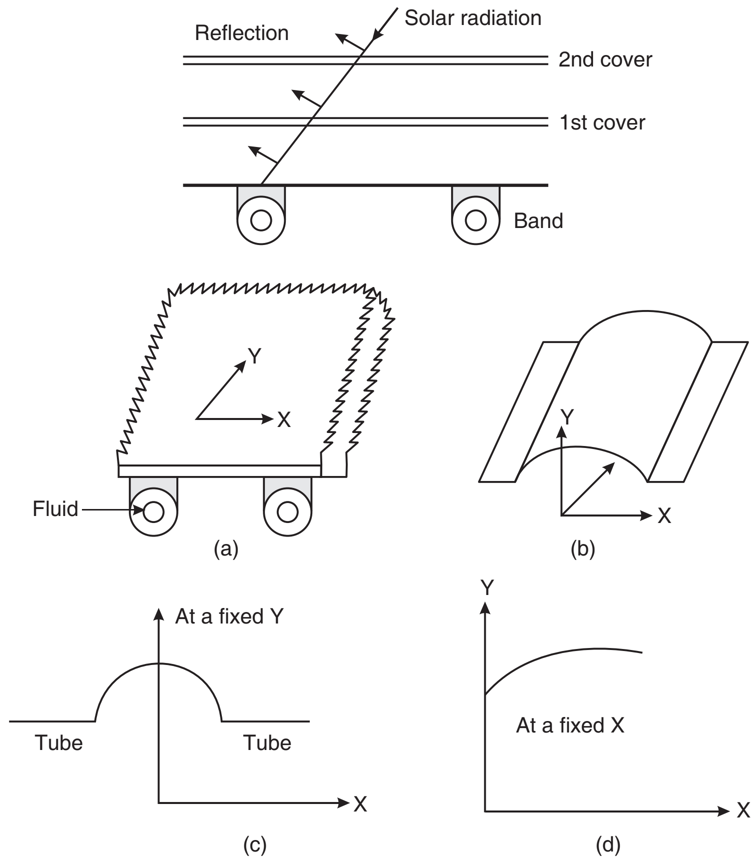


Fig. 8

Energy balance equation

The performance of solar collector is described by an energy balance that indicates the distribution of incident solar radiation into useful energy gain and various losses.

The thermal losses can be separated into three components.

1. Conductive losses : An overall heat transfer coefficient value of less than 0.69 w/m^2°K is suggested to minimize back losses.

2. Convective losses : Sizing the air gap between the collector covers at 1.25 to 2.5 cm reduces internal convective losses to the minimum possible level.

3. Radiative losses : Radiative losses from the absorber can be reduced by the use of spectrally selective absorber coating.

Under steady conditions the useful heat delivered by a solar collector is equal to the energy absorbed in the metal surface minus the heat losses from the surfaces directly and indirectly to the surroundings.

This principle can be stated in the following relationship.

$$Q_u = A_c\,[HR\,(\tau \propto)_e - U_L(t_P - t_a)]$$

where

Q_u = is the useful energy delivered by collector watts or kcal/hour

A_c = is the collector area, m^2

HR = is the solar energy received on the upper

Surface of the slopping collector structure. w/m^2 or $k.cal/hrm^2$

H = is the rate of incident beam (or) diffuse radiation on unit area of surface of any orientation.

R = is the factor to convert beam or diffuse radiation to that on the plane of collector.

The symbol HR is used to represent the sum of $H_b R_b$ and $H_d R_d$.

τ = is the fraction of incoming solar radiation that reaches the asborbing surface transmissivity (dimension less)

$\propto$= is the fraction of solar energy reaching the surface that is absorbed, absorptivity (dimension less)

$(\tau, \propto)_e$ is the effective transmittance absorptance product of cover system for beam and diffuse radiation.

U_L = is the overall heat less coefficient.

t_P = is the average temperature of the upper surface of the absorber plate

t_a = is the atmosphere temeprature.

The diagrammatic representation of terms in this relation ship as shown in figure. In order that the performance of solar collector be as high that to increase the value of $HR(\tau, \propto)$ in the above equation and reduce the value of $U_L(t_p - t_a)$ are selected.

Where as the other factors in the equation depend on collector design, operating conditions, solar energy input and the atmospheric temperature.

∴ The energy balance equation on the whole collector can be written as

$$A_c[(HR(\tau, \propto)_b + HR(\tau, \propto)_d)] = Q_u + Q_e + Q_s$$

Q_u = rate of useful heat transfer to a working fluid in the solar heat exchanger

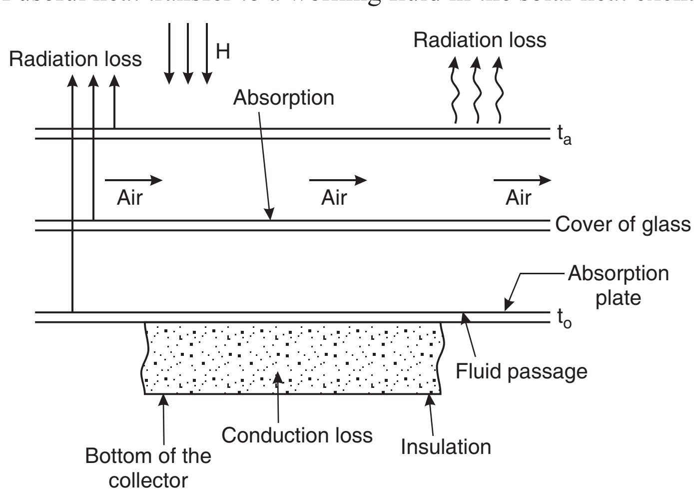


Fig. 9

Q_e = rate of energy losses from the collector to the surroundings by re-radiation, convectional by conduction

Q_u = rate of energy storage in the collector.

Collector efficiency "η_c" : Is the collector performance and is defined as the ratio of the useful gain over any time period to the incident solar energy over the same time period.

$$\boxed{\eta_c = \frac{\int Q_u dT}{\int HR\, dT}}$$

EXERCISE

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CONCENTRATING COLLECTORS

CLASSIFICATION OF CONCENTRATING COLLECTORS :

The concentrating collectors are used at high temperature. In this type the solar radiation is converged from a large area into smaller area using optical mean. This can be divided as two categories

(i) Focus type

(ii) Non-focus type

Focus type are further classified as :

1. Line focus type
2. Point focus type

Non focus-type can be classified into :

1. Modified flate plate collector
2. Compound parabolic concentrating

Line focus are of three types :

(a) Cylindrical parabolic concentrator

(b) Fixed mirror solar concentrator

(c) Linear fresnel lens collector

Point focus are of 4 types :

(a) Parabolic dish collector

(b) Hemispherical bowl mirror concentrator

(c) Circular fresnel lens concentrator

(d) Central tower receiver

Types of point focus

1. Parabolic dish collector : When a parabola is rotated about its optical axis, a parabolic shape is produced. Beam radiation is focused at a point in the paraboloid. This requires to axis tracking. It can have a concentration ratio ranging from 10 to few thousands and can field a temperature upto 3000°C.

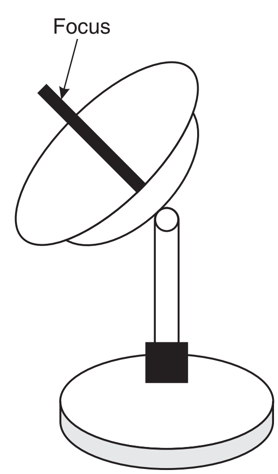


Fig. 1 : Parabolic dish collector

Hemi spherical bowel mirror concentrator :

It consits of hemi spherical fixed mirror at tracking absorber and a supporting structure is shown in fig. All rays entering into the hemisphere after reflection cross section. The paraoxial line at some point between the focus and the mirror surface.

Linear absorber pivoted about the centre of the hemisphere intrepts all reflected rays.

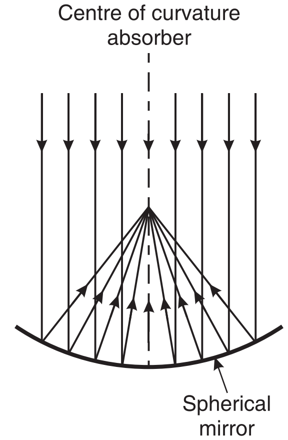


Fig. 2

Circular fresnel lens concentration :

These lens are generally used where high flux is desired such as with sillicon solar cells with gallium orsanoid solar cell as a receiver. As shown in figure. The concentration of circular fresnel lens. It is divided into no of thin circular zones.

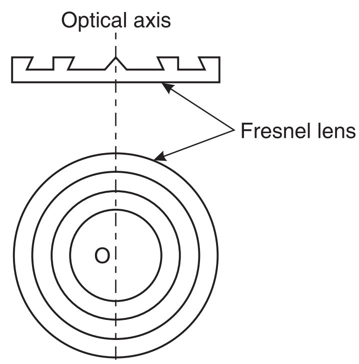


Fig. 3

The till of each zone is so adjusted that optically, the concentration ratio may be as high as 2000 but is less than that obtained from a parolodial reflector.

Central tower receiver :

In a central tower receiver collector the receiver is located at the top of a tower. Beam radiation is reflected on it from a large no of independently controlled, almost flat mirrors known as beliostats, spread over a large area on the ground, surrounding the tower. The heliostats together act like a dilute paraboloid of very big size.

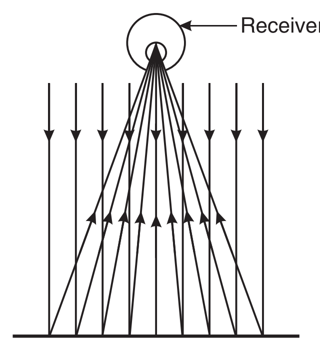


Fig. 4

Parabolic tough collector :

The incoming solar radiation is collected over the reflecting surface and is concentrate at the focus of the parabola The absorber is placed at the focus of the parabola. It contains highly polished aluminium, of silver glass. The sun direction must be along the focal line and vector. They are generally siented along east-west or north south direction. The north-south orientation permits more solar energy to be collected than east-west direction.

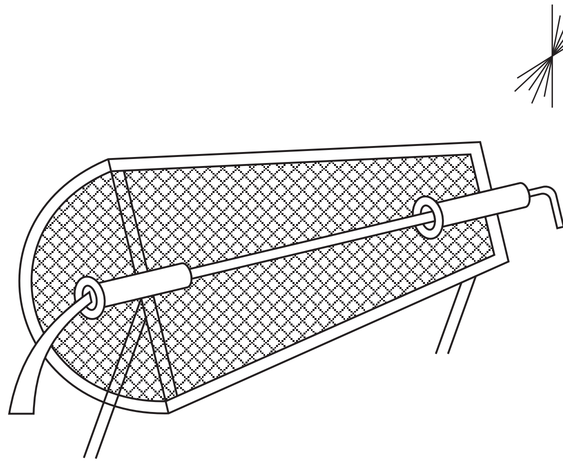


Fig. 6

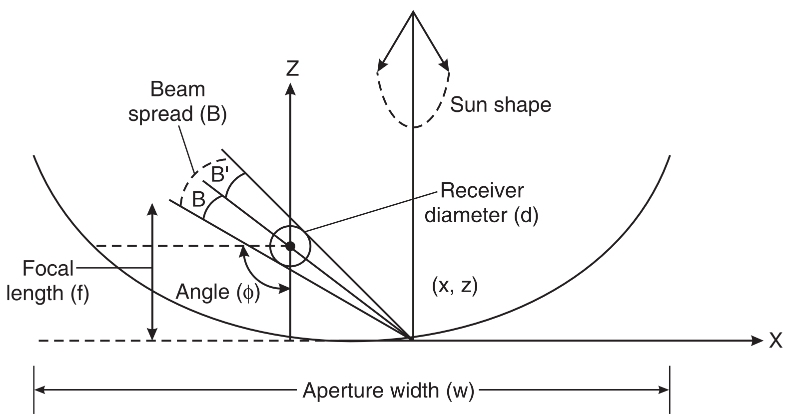
Design parameter

Concentration ratio $= \omega\text{-dg}/\pi dg = \sin\phi R / \pi \sin\theta°C$

Concentrating ratio :

Geometral concentration ratio (C_{geo})

$$C_{geo} = \frac{A_r}{A_a}$$



A_r = Receiver area, A_a = Absorber area

Optical concentration ratio (C_{opt})

$$C_{opt} = \frac{1/A_r \int I_r . dA_r}{I_0}$$

$I_r \rightarrow$ Flux emitted from the receiver

$I_0 \rightarrow$ Flux incident on the aperture

$A_r \rightarrow$ Receiver area

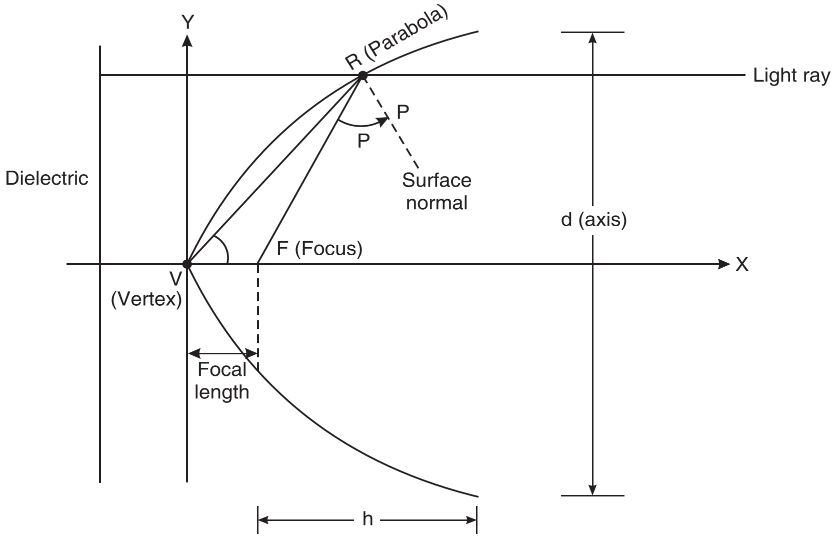


Fig. 7

Rim angle :

It is defined graphically.

In a cross section of the parabolic concentrator the angle between the aperture plane normal and the line coating the focus and the edge of the parabola.

Aperture : Entry plane eleminated by the board of the collector in general perpendicular to the optic axis.

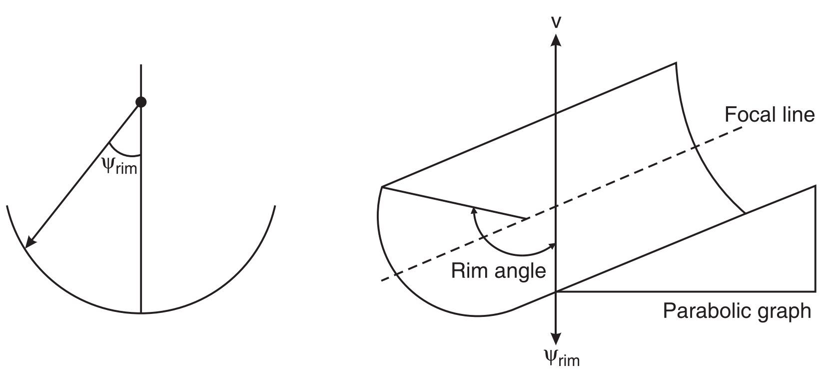


Fig. 8

Acceptance angle :

It is the maximum angle at which incoming sunlight can be caplered by a solar concentrator.

$\alpha < \theta \rightarrow$ all light in captured

$\alpha > \theta \rightarrow$ all light in lost

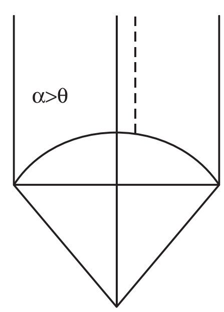


Fig. 9

EXERCISE

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Unit : III

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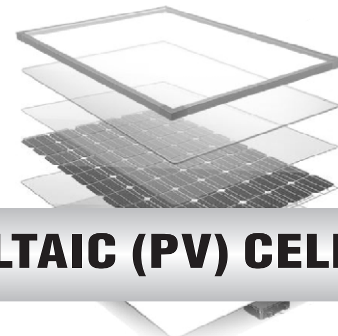

SOLAR PHOTOVOLTAIC (PV) CELL

PHYSICS OF A SOLAR CELL

The solar cell photo voltaic system converts solar energy into electrical energy. The basic conversion devised used in known as a solar photovoltaic cell or a solar cell.

Major advantage or PV system

- It converts solar energy directly into electrical energy without going through the thermal mechanical line.
- Solar PV system are reliable, modular and durable and generally maintainance free.
- These systems are quite compatible with almost all environments.
- A solar PV system can be located at the place of the use enhance no or minimum distribution network is required.
- It is universally available.

Disadvantages :

- At present the cost of solar cell is high, the efficiency of solar cell is low.
- Solar cell is intermittent.

Description of solar cell

Depending the type of material used for fabrication junction.

1. Single crystal silicon cell
2. Amorphous silicon cell
3. Gallium assenoid cell (GaAs)
4. Copper Indium (Cuon) disellinide-cell (CIS)
5. Cadmium telluride cell (CdTe)
6. Organic PV cell.

2. Types of interfaces : The interfaces are three types :

1. Homo *P-N* junction
2. Hetero *P-N* junction
3. Metal semiconductor (schottky)

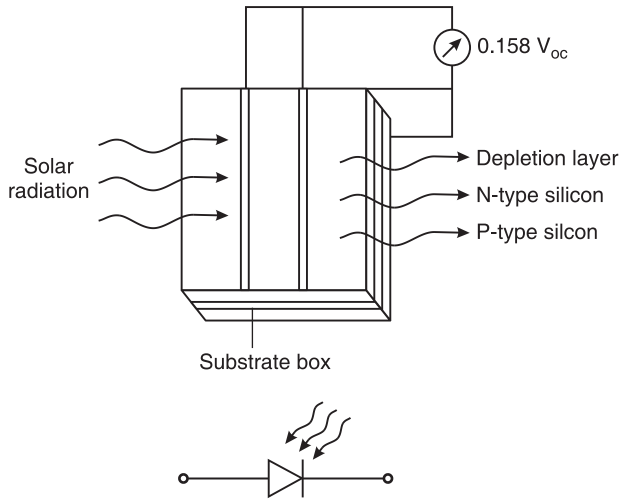

Fig. 1

Homo *P-N* junction

Modern cells make use of semiconductor materials usually based on a single crystal when doped with phosphorous, Arsenic or antimony then the silicon becomes *N*-type semiconductor on the other hand doped with boron aluminium, Indium or Gallium. The semiconductor material have equal hand Gaps. *P*-type & *N*-type gets sandwich together forming the source of built in voltage smooth band transition observe across a *P*-*N* junction in a standard solar cell.

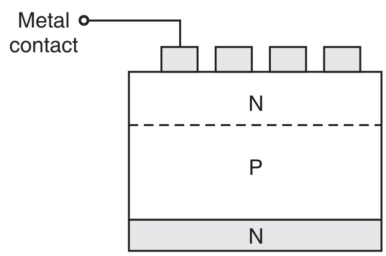

Fig. 2

P-N Hetero junction

It is also provide for a *P*-*N* or *N*-*P* junction to be formed two different semiconductor materials such as cadmium sulphide (cds) and cuprous sulphide (Cu_2S). This is known as hetero junction. In heterogenous *P*-*N* junction two dissimilar semiconductor materials such as group III and group IV or group II and VI compound semiconductor with closely matching crystal lattice are used to form the junction. The band gap of the top material exposed to sunlight is wider than the band gap of the material ledow the junction as a result the higher band gap region will appear transport to photons with lower energies, so they can penetrate to the junction where the band gap is less than the incident photon energy.

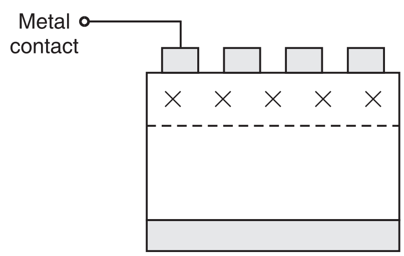

Fig. 3

Metal semiconductor or schottky :

In a basic schottky junction solar cell on interphase between metal and a semi-conductor provides the band bonding necessary for

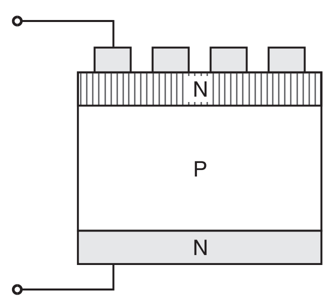

Fig. 4

charge separation due differing energy levels between formy level of the metal and the conduction band of the semiconductor in about potential diffract is create and this is called as schottky height barrier.

3. Photo voltaic cell : When a solar cell is illuminated electron whole (P-N junction) pairs are generated and the electric current obtained (I). It is the difference between the solar light generated circuit I_c and diode current I_j.

$$I = I_c - I_j$$

$$I = I_c - I_0 \left[\exp\left(\frac{ev}{KT} - 1\right)\right]$$

Maximum or saturation current this phenomenon is known as photovotaic effect.

4. Equivalent circuit of a solar cell : In analysing the cell performance photo voltaic process of solar cell can be modelled as a maeroscopic of solar cell can be equivalent circuit as shown in fig. This circuit consist a light dependent current source supplying current (I_1) to a network of resistance including.

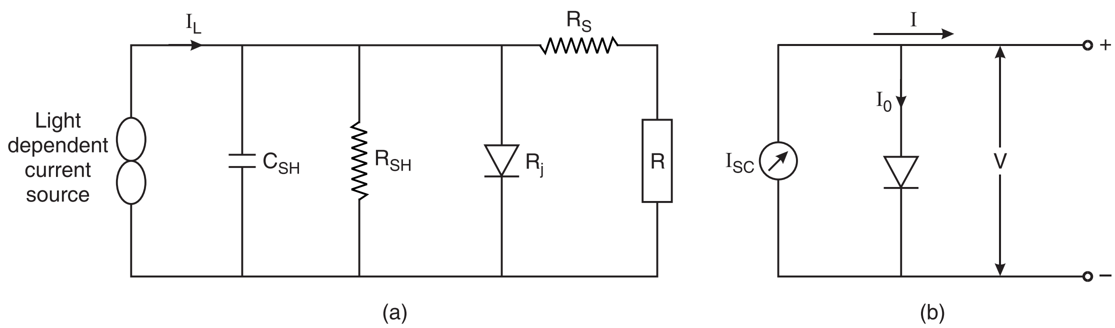

Fig. 4

1. Junction resistance
2. Internal shunt resistance (RSH)
3. Internal series resistance (RS)
4. Internal shunt capacitance (CSH)
5. External load resistance (R)

The external shunt resistance is much larger than the external load resistance so that most of the available current can be delivered to the load and the internal series resistance so less power is dissipated internalley within the cells.

Now the relativistic model can be derived without introducing considerable errors in the analysis resulting equivalent circuit is as shown in fig. B so the load current is obtained as

$$I = I_1 - I_j$$

where $$I_j = I_0 \left[\exp\left(\left(\frac{ev}{KT}\right) - 1\right)\right]$$

junction current from the current voltage relationship of P-N junction diode here $= V =$ voltage

$K =$ Boltzmann constant

$I_0 =$ Saturation current

The light flux causes the flow of load current may be taken as the difference of the generated current and junction current. The short circuit is always less than the idealised value because of the properties of the material and procedure used for the fabrication of devise. For the ideal case the equivalent circuit is as shown in figure B.

Under short circuit condition,

$$V = 0,\ I = I_{sc}$$

Which is the short circuit current generated by the light dependent current source under open circuit

$$I = 0$$

Maximum open circuit voltage becomes 'V_{oc}'.

Now substituting this $I = I_L - I_0\left[\exp\left(\left(\frac{ev}{KT}\right) - 1\right)\right]$

Now apply open circuit condition;

$$I = 0,\ V = V_{oc}$$

$$0 = I_L - I_0\left(\exp\left(\frac{ev_{oc}}{KT}\right) - 1\right)$$

$$\frac{I_L}{I_0} = \left(\exp\left(\frac{ev_{oc}}{KT}\right) - 1\right)$$

$$\log\frac{I_L}{I_0} = \left[\frac{ev_0}{KT} - 1\right]$$

$$\left[\log\frac{I_L}{I_0} + 1\right] = \frac{ev_{oc}}{KT}$$

$$v_{oc} = \frac{KT}{e}\left[\log\frac{I_L}{I_0} + 1\right]$$

This is the expression for the equivalent cell circuit.

5. Parameters of solar cell

I-Y Characteristics :

A solar cell converts the sunlight into electricity flow nicely a solar cell does the conversion of sunlight into electricity is determined the parameters of solar cells. The list of solar cell parameters :

- Short circuit current (I_{sc})
- Open circuit voltage (V_{oc})
- Maximum power point

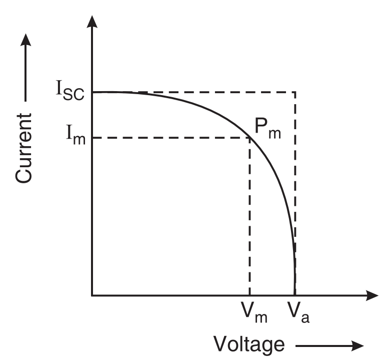

Fig. 5

- Current at max power point (I_m)
- Voltage at max power point (V_m)
- Fill factor (FF)
- Efficiency (η)

The parameters can be best understood by current voltage curve (I-V curve) of a solar cell. I-V curve plotted Y-axis is normally plotted as a current axis and X-axis is plotted as voltage axis.

Normally the value of the cell parameters are given by a manufacture or scientist at standard test conditions. (STC) which is corresponding to 1000 w/m^2 of input solar condition and 25°C cell operating temperature.

Short circuit current (I_{sc}) : It is the max current a solar cell can produce the higher the I_{sc} better is the cell. It is measured in ampere (A) or milli ampere (MA).

Open circuit voltage (V_{oc}) : It is the max voltage that a solar cell produce the higher the V_{oc} the better is the cell. Its measured in volts (V) or sometimes millivolts (mv)

Max power point (P_m) : It is the max power that a solar cell producers under STC. The higher the P_m, the better is the cell. Its given in terms of watt (w)

$$P_m \text{ (or) } P_{\max} = I_m \times V_m$$

Current at maximum power point : This is the current which solar cell will produce when operating at max power point the V_m is will always be lower than the V_{oc} its given in terms of volt (V) or milli volt (v).

Fill factor (FF) : Its the ratio of areas covered by $I_m\ V_m$ rectangle with the area covered $I_{sc} - V_{oc}$ rectangle

$$FF = \frac{PM}{I_{sc} \times V_{oc}}$$

$$P_m = I_{sc} \times V_{oc} \times FF$$

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SOLAR CELL FABRICATION

PRODUCTION OF SINGLE CRYSTAL SILICON

There are two main techniques for converting poly crystalline (*EGS*) is to a single crystal (in got) which are used to obtain the final wafers.

1. Czochralski technique (*Cz*)
2. Float zone technique (*Fz*)

1. Cz technique : J. Czokralski determine the crystallisation velocity of metals by pulling mono-polyerystals against gravity out of a melt which is held in a crucible puller consests of three main components.

1. Frequency
2. Crystal pulling mechanism
3. Ambient control
4. Control system

1. Frequency : In which it includes a fused silica crucible a graphite suspector and a rotation mechanism a heating element and power supply.

2. A crystal pulling mechanism : In which it includes a seed holder and a rotation mechanism (in anticlockwise direction).

3. An ambient control : An ambient control which includes a gas source (such as organ) a flow control and on a exhaust system in this czokralski process crucible is placed in a graphite suspector which loaded the silicon is melted by in duction heating.

4. Control system : This control system is the control high temperature and the inner lines of the crucible also starts melting as follows.

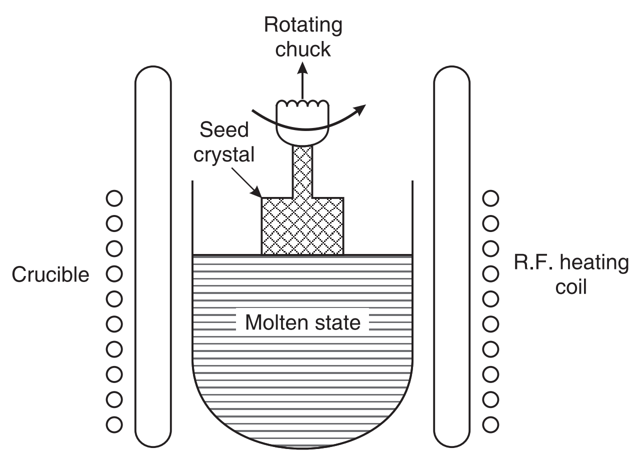


Fig. 1

2. Float zone technique :

This float zone techniques is suited for small wafer production with low oxygen impurities. Single crystalline used for desired orientation this is taken in an inert gas furnaces and then melted along the length of the rod by travelling radio frequency coil. This coil starts from fuel region. *i.e.*, containing seed or travelled up then the molten region satisfies it has the some orientation as the sad. This furnace is filled with an inert gas like argon to reduce gaseous impurities and also the ionisation takes place.

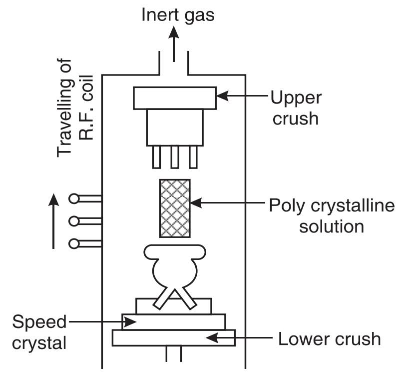


Fig. 2

7. Effect of variation of (Bandgap) insolation and temperature

As the insolation keeps on varying throughout the day, it is important to observe is effect on *PV* characteristics. If the spectral content of the radiation remains unaltered and temperature and all factors remain same, both I_{sc} and V_{oc} increase with increasing the intensity of radiation the photo generated current depends directly on insolation. Therefore the short circuit current depends linearly while the open circuit current depneds linearly while the open circuit voltage depends logarithmically on the insolation. This is shown in fig :

If I_{sc} is known under standard test conditions *i.e.*, radiation of $G_0 = 1\,\text{K}\,\omega/\text{m}^2$ AM 1.5, thenthe short circuit curent I'sc at any other insolation level G canbe calculated at a very good approximation, as

$$I'_m = \frac{G}{G_0} \times I_{sc}$$

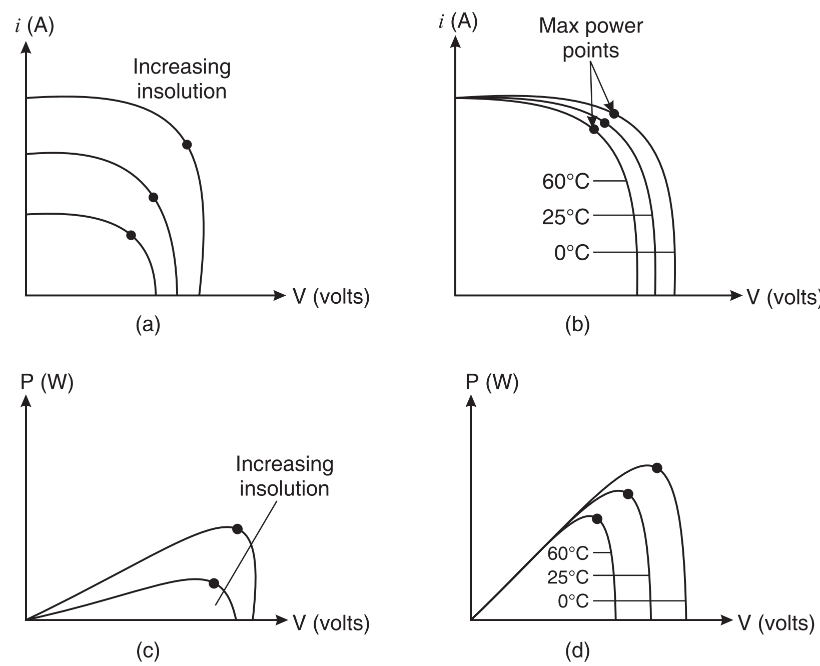
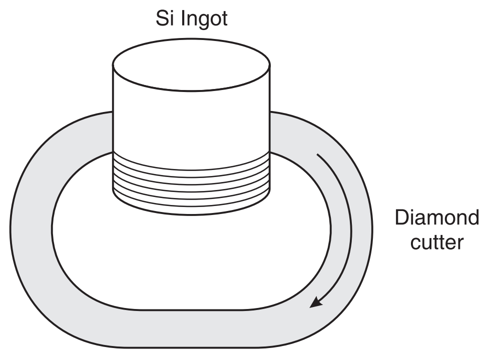


Fig. 1

An illuminated *PV* cell converts only a small fraction of irradiance into electrical energy. The balance is converted into heat, resulting into heating the cell. As a result, the cell can be expected to operate above the ambient temperature, keeping insolation level as a constant, if the temperature increased, there is a marginal increase in the cell current but a marked reduction in the band gap. This in turn increase in photo generation rate and thus a marginal increase in current.

I-V characteristics is generally provided by the manufacture of standard conditions.

8. Wafer manufacturing or silicon wafer fabrications : After is a single crystal is obtained this need to be further processed to produce wafers. For this, the wafers need to be shaped and cut. Usually, industrial grade diamond tipped saws are used for this process. The shaping operations consists of *Q* steps. The seed and tang ends of the ingot are remove. The surface of the ingot is ground to get an uniform diameter across the length of the ingot.



Preparation of wafer

Fig. 3

9. Solar cell manufacturing process or wafer to cell formation : In solar cell manufacturing there are 6 steps it will works.

1. Making single crystalline '*si*'
2. Making '*si*' wafer
3. Doping
4. Placing electrical contacts
5. Anti reflecting costs
6. Encapsulating cells.

Making single crystalling '*si*'

In this single crystal '*si*' ingots are prepared by using *CZ* and *FZ* techniques then a cylinderical ingot of '*si*' is formed.

Making '*si*' wafers

In this wafer method a 5 mm thick using diamond point cutter from a solar cell the wafer's then polished to remove saw marks.

Doping :

Boron and phosphorous are introduced in a small amounts into malt silicon during *CZ* and *FZ* process.

Placing electrical contacts :

The contacts must be very thin sunlight to the cell metals such as silver, nickel or copper or vaccum evaporated through a photo resist silk screens are nearly deposited on the exposed portion of cells that have partially covered with wax. After the contacts are in place thin strips are placed in between the cells. This is the most commonly used strips and are tin coated copper.

Anti-reflecting coating :

Because pure silicon is shiny it can reflect upto 35% of the sunlight to reduce this amound of the sunlight loss as a anti-reflective coating is put on the silicon vapours. The most commonly used coating are helium dioxide (HeO_2) and silicon dioxide (SiO_2) are used as a anti reflective coats.

Encapsulating the cells : This is the finished solar cell are sealed into the silicon rubber or ethylene vinyl acelate the encapsulated solar cells are now placed into a aluminium frame that as a mylar or tedler leak sheet and a glass or a plastic cover.

10. Thin solar cells : Thin film solar panels are made with solar cells that have light absorbing layers. Most sandwich active material between two panels of a glass. Because of their narrow design and the efficient semiconductor built into their cells, thin film solar cells are the lighest PV cell and strong durability.

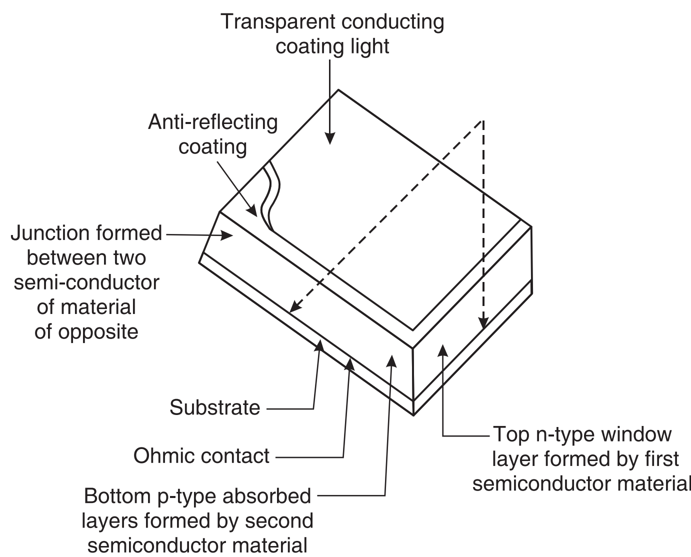


Fig. 4

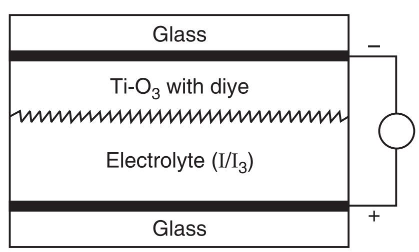


Fig. 5

Thin film solar panel technologies :

Cadmiuim telluride (CdTe) : The most widely used TF technology, is CdTe thin film solar panels. CdTe contains significant amounts of cadmium an element with relative toxicity :

So this is a factor of consideration. These are favourable direct band gap of 1.44 ev. This is a thin film junction its efficiency is about 10%.

Copper indium gallium selenide (CIGS) : A copper indium Gallium selenide solar cell or CIGS cell uses an alesorber made of copper, indium, gallium, selenide (CIGS), while gallium free variants of the semiconductor material are alebreviate CIS.

11. Multi junction solar cells : Multi junction solar cells are the solar cells with multiple *P*-*N* junction made of different semiconductor materials. Each materials *P*-*N* junction will produce electric current. So the use of multiple semiconductor materials allows the absorbeney range of wavelength improving the cells sunlight to electrical energy conversion efficiency. Traditional single junction cells have maximum theoritical efficiency of 86.8 under highly concentrated sunlight but the cells made from multiple layers can have multiple land gap and therefore, respond to multiple wavelengths capturing and converting some of the energy the could otherwise be lost to relaxation as described above.

12. Basic concepts of dye sensitized solar cell : It is a low cost solar cell belonging to the group of thin film solar cells. It is leased on a semiconductor formed between a photo sensitized anode and a electrolyte a photoelectro chemical system. Dye sensitized solar cells separate the two functions provided by silicon in a traditional cell design. Normally the silicon acts as both the source of photo electrons as well as providing the electric field to separate the charge and create a current. In the dye, sensitized solar cell, the bulk of the semiconductor for charge transport, the photo electrons are provided from a separate photo sensitive dye charge separation occurs at the surface between the dye, semiconductor and electrolyte.

13. Quantum dot solar cell : Quantum dots acts as the absorbing photovottaic material. It attempts to replace bulk materials such as silicon, copper indices gallium selenide (CIGS) or (CdTe). Band goes are tunable by changing the dots size. In bulk materials the bandgap is fixed by the choice of material (s).

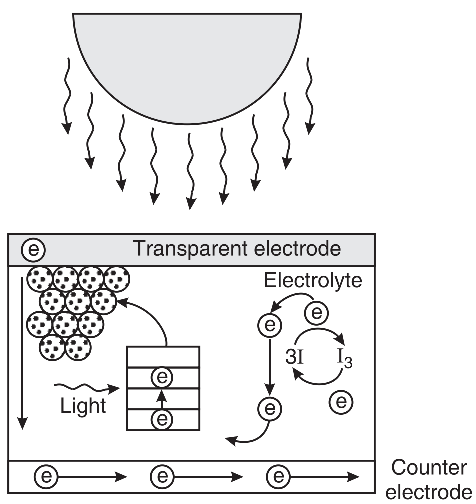


Fig. 6

This property makes quantum dot attractive for the multi junction solar cells. The small silicon monocrystals showing the increases band gap due to the quantum confinement are known as the quantum dot when the size of a semiconductor silicon crystal is reduced below the bore execution radius. This is the quantum dot.

14. Thin film solar cells advantages : Thin film solar cells are the new generation solar cells that contain multiple thin layers of PV materials. The thickness of thin film layers are very less as compared to *PN* solar cells.

According to the type of *PV* material used, the thin film solar cells are Classified into 4 type. They are :

(i) Amorphous silicon and other thin film silicon (TF-Si)

(ii) CdTe

(iii) (CIS) or (CIGs) Cu indium gallium deselenide.

(iv) Dye-sensitized solar cell (DSC) and other organic solar cells.

Advantages :

(i) Low material consumption : The amount of material consumed per unit solar cell given area is lower than solar cell.

(ii) Shorter energy payback period : It refers to the time of cell operation is the field during which it will generate the amount of energy equivalent to the energy required for its production. The energy pay back period of thin film is better by a factor of 2.

(iii) Monolithic integration : It refers to a process in which the solar cells are connected in series during their fabrication to make a moduce. Most thin films technologies offer the possibilities of monolithic integration.

(iv) Large area modules : The area of thin film depends on the size of the equipment used for deposition. Large area fabrication capability also gives cost advantages.

(v) Tuneable material properties : The optical and electrical properties of their films depends on the structure and the composition thin film parameters can be controlled by of deposition by controlling the deposition parameters.

(vi) Low temperature processes : Most of the processes used in fabricating a thin film solar cell can be at low temperatur (< 200°C-500°C).

(vii) Transport modules can be made : Thin film material can be deposited on the glass substrate and the thickness of the films can be controlled.

Disadvantages :

(i) Low solar cell efficiency :

15. CdTe/CDs cell formation : CdTe (cadmium telluride cell) has a favourable street leavel gap of 1.5 ev. Thin film heterogenous junction with *N*-type Cds and *P*-type CdTe is fabricated as shown below its lower cost crystaline silicon.

It is used world's largest photo voltaic stations. Here a transport conducting oxide layer is used instead of metallic contact at the top on *N*-side. Ethylene vinyl acetate (EVA) is used for encapsulation.

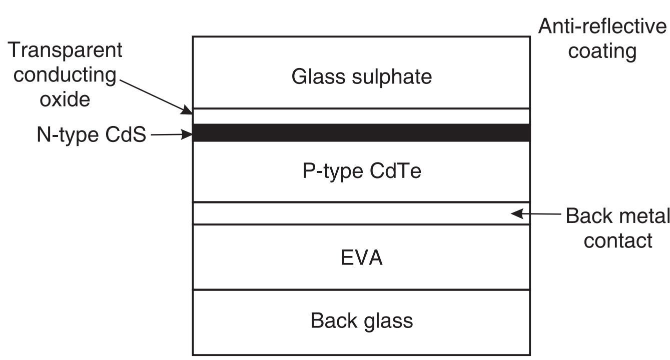


Fig. 7

No instability problem has been reported in atrial of few years of outdoor applications. Its efficeincy is about 10% and open circuit cell voltage is around 0.8 V.

16. Advantage of Cz process : (i) One advantage is Cz technique allows big crystal diameter from 75 to 200 mm.

(ii) Cz silicon is often used in the electronic in industry to make semiconductor devices such as integrated circuits.

Disadvantages of Cz process :

(i) Impurities such as oxygen and carbon form the quanta and graphite crucible which lower the minority carrier diffusion length in the finished 'si' wafer.

(ii) It is comparably low homogenity of axial and radial dopaut concentration in the crystal caused by oscillations in the melt during crystal grown.

Advantages of float cell zone technique

- The main advantage of the *Fz* process is low impurity concentration in the 'si' crystal.
- In particular the 'O_2' and 'C' concentration are much lower as compound to *Cz* silicon, since the most does not come into contact with quant execible and no graphite container is used.
- They are typically used for power devices and detector applications.

Disadvantages of float zone

Fz silicon is that their wafers are generally not greater than 150 mm due to the surface tensions limitations during growth.

Fz process is more expensive than *Cz* process.

EXERCISE

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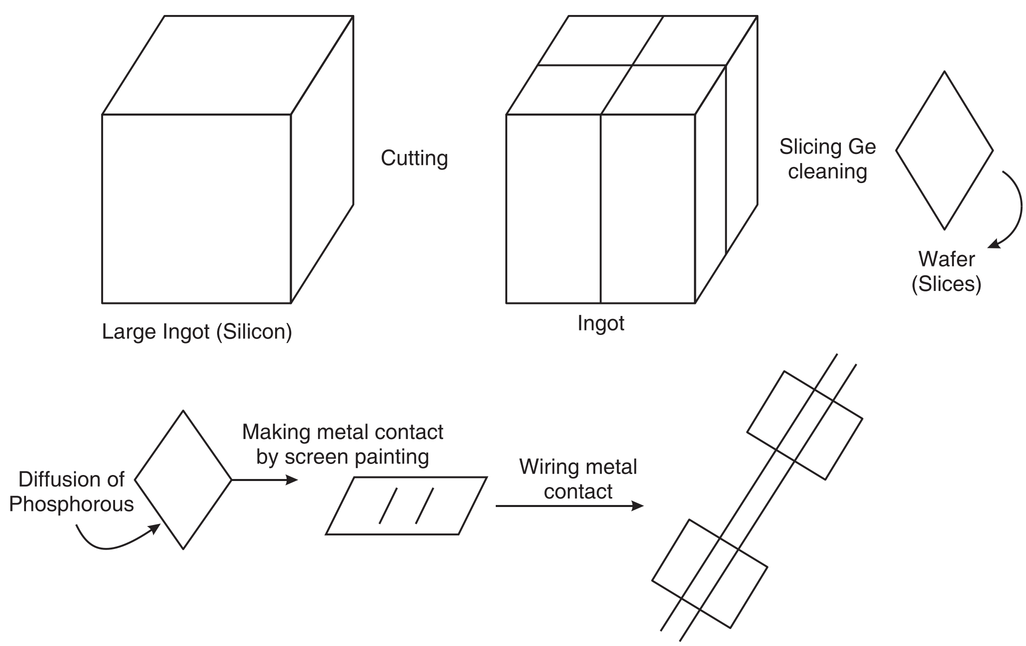
Unit : IV

7 SOLAR PV SYSTEM

SOLAR CELL MODULE ASSEMBLY

A bar single cell can not be used for outdoor energy generation by it self. It is because (i) The out put of single is very small and (2) It requires protection (capsulation) against but, moisiture, mechanical shocks and out door barsh conditions workable voltage and reasonable power is obtained by interconnecting an appropriate number of cells. The unit is fixed on a durable back cover of several square feet, with a transparent cover on the top and hermetically sealed to make it suitable for outdoor applications. This assembly is known as solar module a basic building block of a PV system.

The most common commerical modules have a scries connection of 3208136 silicon cells to make it capable of charging-12v stage battery. However, larger and smaller capacity modules are also available in the international marked.



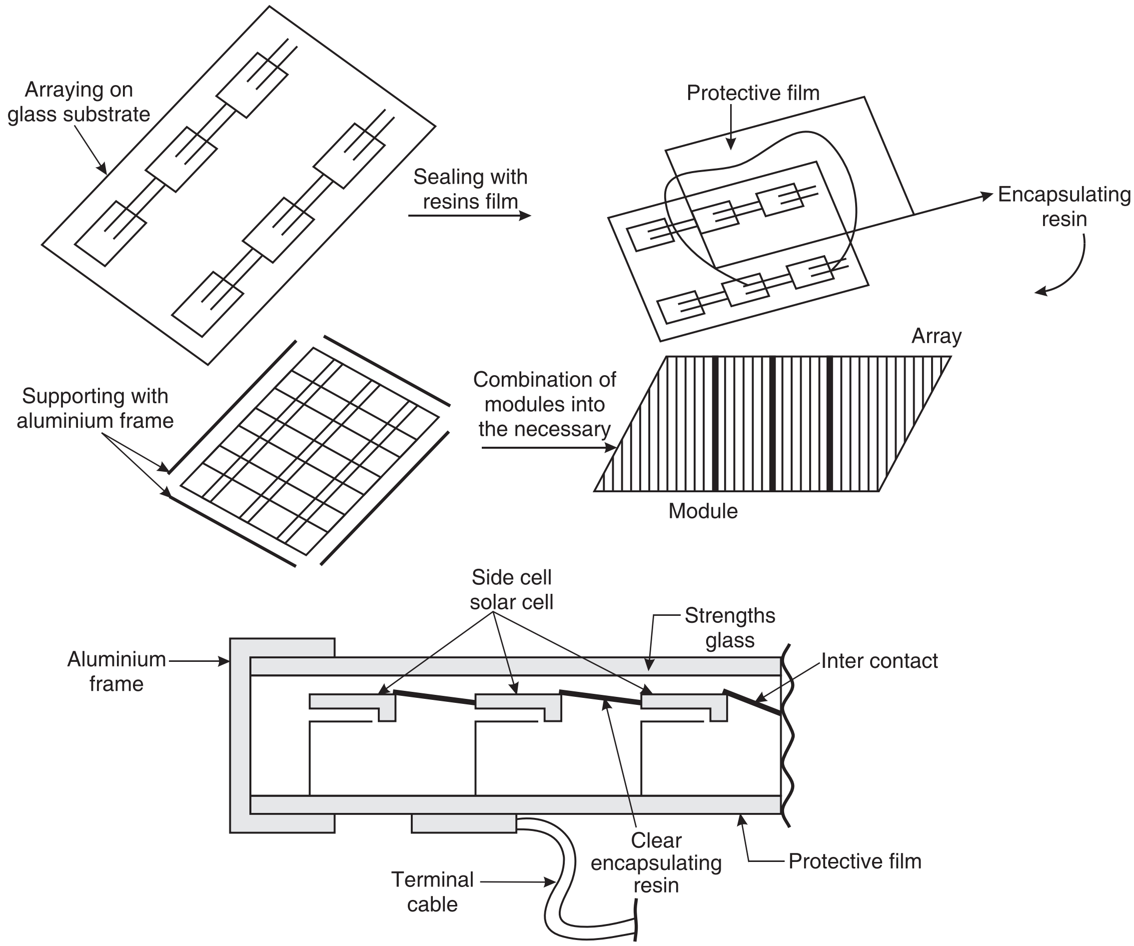


Fig. 1. Section View of PV module

Solar module performance

A PV module is made up of many cells connected together. The electrical behaviour of *PV* module is similar to cells parameters.

Which are as follows :

1. Open circuit voltage (V_{oc})
2. Short circuit current (I_{sc})
3. Maximum power point (P_m)
4. Voltage-maximum power point (V_m)
5. Current at maximum power point (I_m)
6. Fill factor (FF)
7. Efficiency (η)

These electrical parameters of the *PV* modules are explained as follows :

1. Open circuit voltage (V_{oc}) : It is the maximum voltage that solar *PV* module produce. It happens when two terminals of the module left open and hence it is open circuit voltage.

For a given number cells in series in a *PV* module higher the 'V_{oc}' better is the *PV* module.

2. Short circuit current (I_{sc}) : It is the maximum current a solar *PV* module can produce. It happens when two terminals of a *PV* module is shorted hence the name is short circuit current. For a given solar cell area used in the module the higher the (I_{sc}) the better is the *PV* module. The value of this maximum current depends on *PV* module technologies; *PV* module area, the amount of solar radiation falling on *PV* module, angle of *PV* module with respect to sun's rays.

3. Maximum power point (P_m or P_{max}) : It is the maximum power that a solar *PV* module produces under (*STC*) for given *PV* module dimension. The higher the P_m the better is *PV* module. It is given in term of watt (W). A solar *PV* module can operate at many current and voltage combinations. But a solar *PV* module will produce maximum power only. when operating at certain current and voltage. This can be seen from the *P-V* curve of a *PV* module as shown in figure.

4. Voltage at maximum power point (V_m) : This the voltage which solar *PV* module will produce when operating at maximum power point. The V_m will always be lower than (V_{oc}). Normally 'V_m' is equal to about 80% to 85 % of the V_{oc} of the *PV* module.

5. Current at maximum power (I_m) : This is the current which solar *PV* module will produce when operating at maximum power point. The I_m will always be lower than I_{sc}. Normally I_m is equal to about 90% to 95% of the I_{sc} of the module.

6. Fill factor (*FF*) : The *FF* is the ratio of the area covered by $I_m - V_m$ rectangle with area covered by $I_{sc} - V_{sc}$. rectangle. It indicates the squareness of the *I-V* curve.

The higher the *FF*, the better is the *PV* module.

The *FF* of *PV* module is given in terms of percentage (%).

$$FF = \frac{I_m \times V_m}{I_{sc} \times V_{oc}} \text{ or } FF = \frac{P_m}{I_{sc} \times V_{oc}}$$

$$\therefore \qquad P_m = I_{sc} \times V_{oc} \times FF$$

7. Efficiency (η) : The efficiency of a solar *PV* module is defined as the maximum output power (P_m) divided by input power (P_{in}). The efficiency of a *PV* module is given interms of percentage (%).

That this percentage of radiation input power is converted into electrical power P_{in} for STC is consider as 1000 W/m^2. This input power is power density.

$$\therefore \qquad \eta = \frac{P_{max}}{P_{in}} = \frac{I_{sc} \times V_{oc} \times FF}{P_{in} \times A}$$

A module manufacture provides most of the above module parameters in the form of data sheets.

I-V AND *P-V* CHARACTERISTIC OF

SPV module : The *I-V* characteristic of SPV module is graph of current (I) and voltage (V) in which values of different current for different voltage is plated on y-axis and x-axises respectively. A typical *I-V* curve of *PV* module is as shown in figure (a).

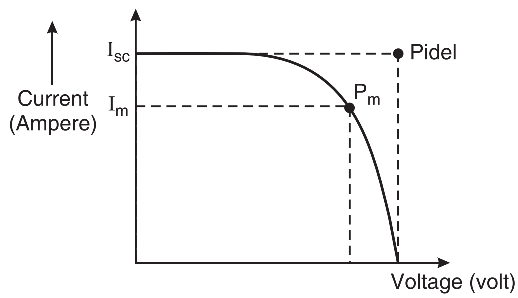


Fig. 2

When a solar *PV* system is deployed for practical applications. The *I-V* characteristic keep on changing insolation and temperature. In solar to receive maximum power, the load most adjust it self accordingly to track the maximum power point. The *I-V* characteristics of *PV* system along with some common loads as shown in figure (b).

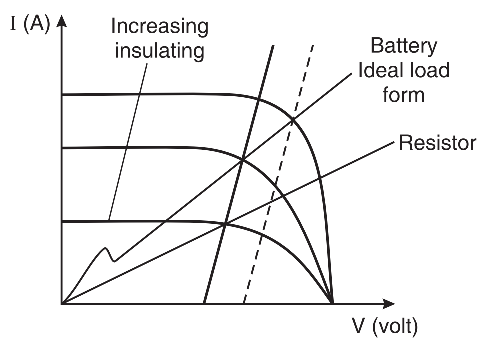


Fig. 3

MODULES IN SERIES AND PARALLEL

Series : Series combination of the *PV* modules is achieved by connecting the opposite polarity terminals of modules together as shown below in figure. The negative terminal of one module is connected with the positive terminal of the other module. When two modules with open circuit voltage of V_{oc_1} and V_{oc_2} are connected in series the voltage of series combination is the addition of two voltages which is $V_{oc_1} + V_{oc_2}$ as shown in figure. When *PV* modules are connected in series the voltages of the series connected *PV* module is the sum of the voltage of individual *PV* module.

The voltage of series combination will be $= V_{oc_1} + V_{oc_2} + V_{oc_3} + ...$

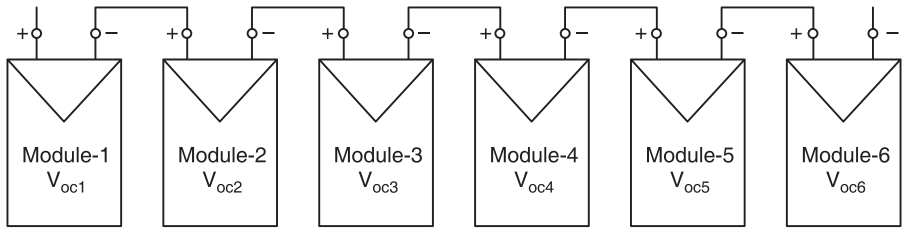


Fig. 4

Modules in parallel

When solar *PV* system power requirement is higher than the avaliable single module power. Then the solar *PV* modules are connected in series or parallel.

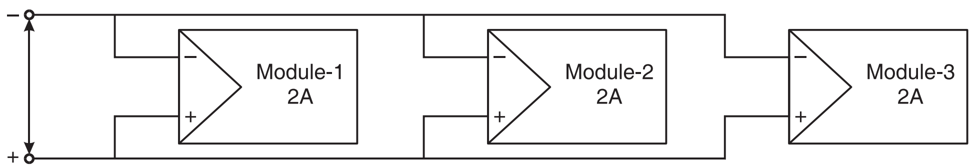


Fig. 5

In parallel combination of *PV* module, the voltage of the combination remain the same as that of individual module voltage where as the current of the parallel combination is the sum of the currents of all *PV* module.

The parallel configuration is achieved by connecting same polarity terminals together. In this way the positive terminal of one module is connected to the positive terminal of the other module and similar, negative terminal of one module connected to the negative terminal of other *PV* module. The parallel combination of the *PV* module as shown in figure.

Thus if current at maximum power point of two module is I_{m_1} and I_{m_2}. Then the total current at maximum power point at parallel connection will be $I_{m_1} + I_{m_2}$.

e.g. : The total current of combination will be $= I_{\text{module}_1} + I_{\text{module}_2} + I_{\text{module}_3}$

i.e., $= 2 + 2 + 2 = 6A$

MODULE PROTECTION

Use of by pass : In solar *PV* modules in all most all cases all the solar cells, identical in nature are connected in series when light falls on a *PV* module, same current is generated in all solar cells which flow through *PV* module same current is generated in all solar cells which flow through *PV* module.

Now due to some reason if one of the solar cell gets shaded, then the current generated by that cell will be lower than the rest of the solar cells. Since the cell are connected in series, the shaded solar cell will resist the current flow generated by non-shaded solar cells generating full current. In this cuse, the shaded solar cell becomes a load for the other cells and the power generated by other solar cells may get dissipatted in the shaded solar cell. Due to this, the shaded solar cell can become very hot, forming hot spots in the *PV* module. The hot spots sometimes can give rise to breaking of glass cover in *PV* module. Or it can cause fire.

Therefore, load heating of solar cell in a *PV* module due to shading should be avoided for that by pass diode is used to avoid the distructive effect of hot spots or local heating in series connected cells in *PV* modules. A diode called by pass diode is connected in parallel with solar cell with opposite polarity to that of solar cell as shown in figure (a). By by passing the current the solar cell gets protected by heating and causing permanent damage to *PV* module.

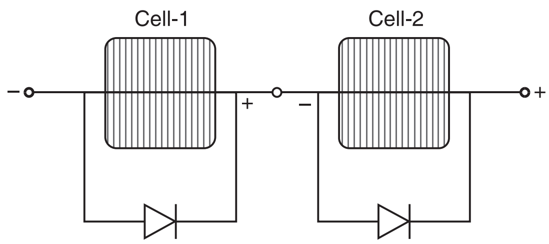


Fig. 6

Ideally, there should be each diode for the each solar cell in the solar *PV* module, but practically due to cost reason there are few bypass diode which are connected in *PV* module. It is recommended that practically, there should beat least one diode for each series combination of 10-15 cells this connection as shown in figure.

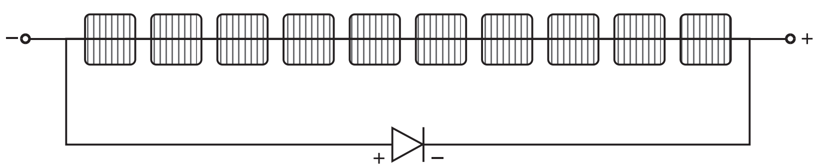


Fig. 7

Blocking diode

In stand alone *PV* system *PV* modules are used to either supply the load during day time or to charge battery. In day time energy is generated by *PV* module and supplied to battery. When there is no sunlight like in the night. The spv modules stop producing the energy and become idle. During night, charged batteries start supplying to the SPV modules. This is loss of energy and should be avoided. In solar to avoide the flow of current from battery to solar *PV* module, adiode called blocking diode is used to block the current flow. Thus the blocking diode prevents the discharging of battery into the SPV module. The connection of blocking diode with a solar *PV* module as shown in figure.

Blocking diodes are added in *PV* system to avoid reverse flow of current into the *PV* module.

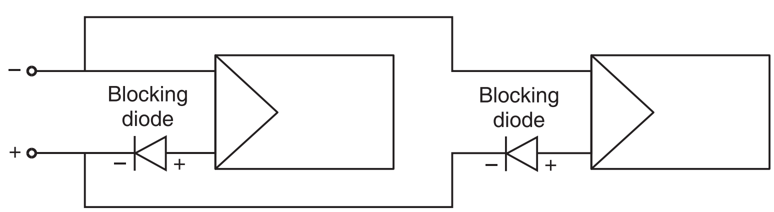


Fig. 8

Steps involved in the fabrication of solar module :

To fabricate a solar module from a cell in plants are of 7 stages which are as follows :

1. Cell sorting
2. Tabbing
3. Stringing
4. Lamination
5. Curing
6. Module forming
7. Module *I-V* characterisation

The block diagram of fabrication of solar modules as shown in fig.

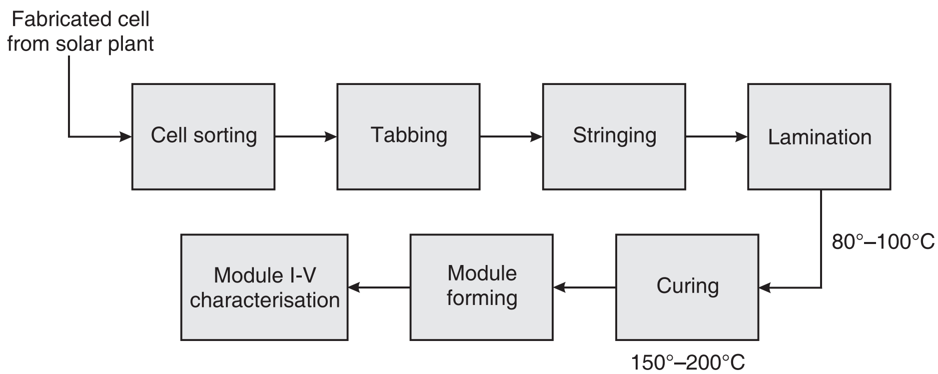


Fig. 9

1. *Cell sorting* : In this stage the solar cells are sorting to fabricate solar cells into modules.

2. *Tabbing* : After the sorting of the cells, metal contacts are used in form of metal strips and soldered at the front side of the cells. This process is known as tabbing.

3. *Stringing* : In this stage the no of solar cells are interconnected in series (Typically 36 cells) then this process is known as stringing.

4. *Lamination* : After following the stringing stack of connected cells, glass laminates and *PVF* (polymer (or) tedler) is prepared as per the structure shown in below figure.

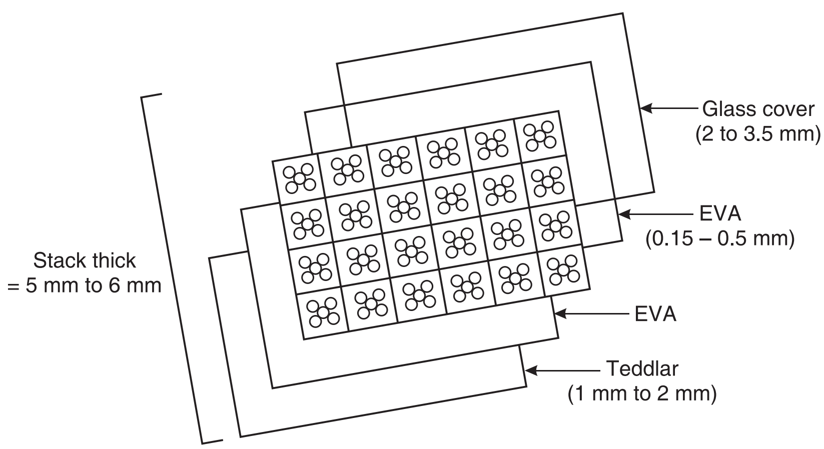


Fig. 10

The total thickness of the stag is about 5 mm to 6 mm. This is kept in a machine which is called laminator. It consists of a chamber equipped with heater, vaccume pump and air pressure unit.

The air inside the chamber of the laminator is removed, pressure applied by using vaccume pump and drive out the residual air and moisture present in the laminator now the module is heated to a temperature about 80 to 100°C. During which EVA melts and surrounds the electrical circuit forming seals to the glass front and back tedler sheet of the module. EVA extra EVA. [ethylene venyl Acetate] sheet is added at the module perimeter to ensure complete sealing of the module edge. This process is called lamination.

5. Curing : Curing is done in which the module is heated. The curing is done at a temperature between 150°C to 200°C. During the curing process, the polymerization of EVA occurs. The polymerization makes the EVA sheet compact and provides strength and durability for long term.

Both two process (Lamination and curing) have completed in less than 1 hour.

6. Module forming : After lamination process is completed, modules are framed using aluminium frames. Also plastic box containing electrical points for external electrical connection is added at the rear side of the module. This box also contains bypass and blocking diodes.

7. Module I-V Characterization : At the end modules are characterized for their *I-V* and power out put.

A sticker is put at the rear side of the module giving the voltage, current and peak power of the module.

SOLAR *PV* SYSTEM AND ITS COMPONENTS

A basic photovoltaic system integrated with the utility grid is as shown figure.

It consists of following components :

1. Photovoltaic cell : Thin squares, discs or films of semiconductor material that generate voltage and current when exposed to sunlight.

2. Module : A photovoltaic cell wired together and laminated between a clear start glazing and encapsulating substrate.

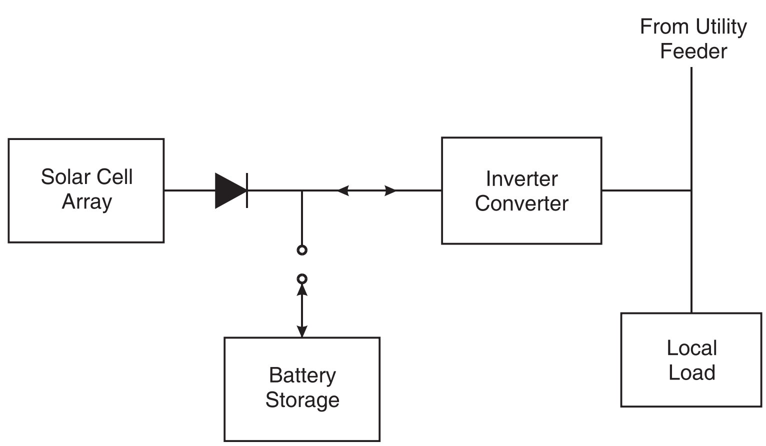


Fig. 11

3. Solar array : Large or small which converts the insolation to useful DC electrical power.

One of more modules with mounting hardware and wired together at specific voltage.

4. A blocking diode : Which lets the array generated power flow only toward the battery or grid.

5. Battery storage : In which the solar generated electric energy may be storied.

6. Inverter/converter : An electric device which converts the battery bus voltage to AC of frequency and phase to match that needed to integrate with the utility grid. Thus it is typically a DC, AC inverter.

7. Charge controller : Power conditioning equipment to regulate battery voltage.

8. Load : The appliances, motors and equipment powered by DC the appliances, motors and equipment powered by AC.

SOLAR PV ARRAY

In general large number of interconnected solar panels known as solar *PV* array are installed in an array field. These panels may be installed as stationary or with sun tracking mechansion.

Important points

1. It is important to ensure that an installed panel does not cast its shadow on the surface of its neighbouring panels during a whole year.
2. The layout and mechanical design of the array such as till angle panels, height of panels clearance among the panels taking into consideration.
3. Local climatic conditions.
4. Its case of maintenance.

Inverter

These are the devices usually solid state which. Change the array DC output to AC suitable voltage, frequency and phase to feed photovoltaically generated power into the power grid or local load as shown in figure. These functional blocks are sometimes referred to as power conditioning.

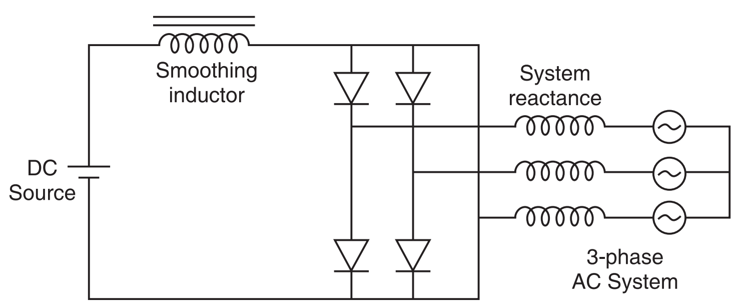


Fig. 12

Battery storage

The simplest means of storage on smallar moderate scale is in electric storage batteries especially as solar cells produce the direct electric current required for battery charging. The stored energy can then be delivered as electricity upon discharge. The common lead acid storage batteries are not ideal for this purpose.

Extensive research in progress should lead to the developement of more suitable batteries.

EXERCISE

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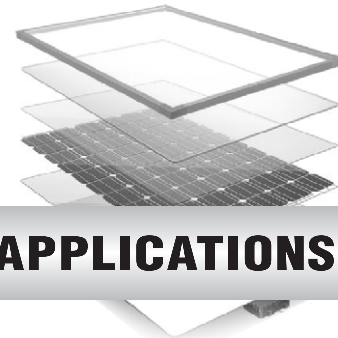

8 SOLAR THERMAL APPLICATIONS

SOLAR HOT WATER SYSTEM (SHWS)

The most common type of solar hot water system are as shown in figure. Which converts sunlight into heat. It consists two main parts *i.e.,* A titled flat-plate solar collector with water as heat transfer fluid and the other A thermally insulated hot-water storage tank is mounted above the collector on the roof of building or home. The heated water of the collector rises up to the hot water tank and replaces an equal quantity of cold water, which enters the collector. The cycle repreates, resulting in all their water of the hot water tank getting heated up.

Solar water heating system can be either active or passive (forced).

1. Active : The active system, which are most common, rely on pumps to move the liquid between the collector and Storage tank.

2. Passive : The passive system rely on gravity and the (convection driven) tendency for water to naturally circulate as it is heated.

An auxiliary electrical emersion heater may be used as back-up for use during the cloudy periods.

TYPES OF SHWS :

1. Active solar hot water systems.
2. Passive solar hot water systems.

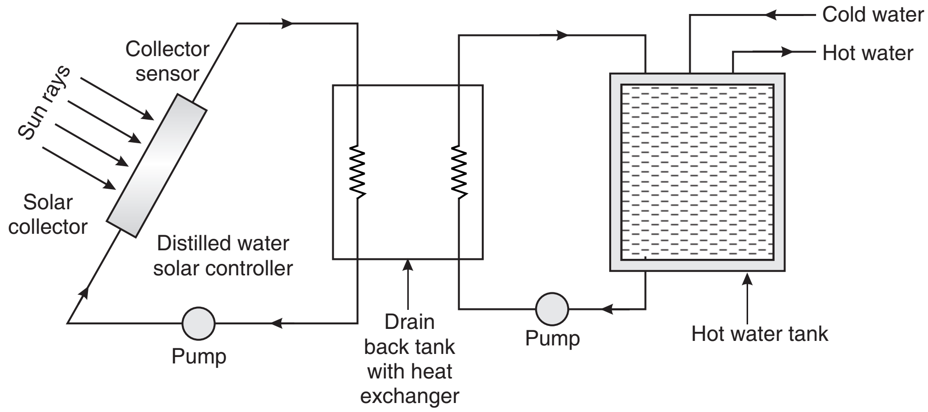

Fig. 1

1. Active solar water heating system : The active water system that can be used to heat domestic hot water are the same as the one that provide space heat.

Parts of water heating system :

There are five major components in active solar water heating system :

1. Collector
2. Circulation system
3. Storage tank
4. Back up heating system
5. Control system to regulate the overall system operation.

1. Collector : It is a big black panel on the roof. Which capture solar energy. Generally used FPC (or) evacuated tubes.

2. Circulation : A solar panels works by transfering heat from the collector to the tank through. A heat exchanger is used to transfer the heat from the fluids circulating through the collector to the water used.

3. Storage tank : This is a insulated hot water tank can be used to storage the hot water from the collector.

4. Back up heating system : An auxiliary electrical emersion heater may be used as a back up for use during cloudy periods.

5. Control system : This is used to regulate the overall system operation. In this system it will activate the pumps to the collector and heat exchanger when design temperature differences are reached.

A typical active water heating system that exhibits effective ness, reliability and low maintenance as shown in figure.

It uses destilled water as the circulating fluid. The system that use antifreeze fluids need regular inspection of the antifreeze solution. A refrigerant system is generally more costly and must be handled with care to prevent leaking any refrigeant.

This hot water system can be used for heating swimming pools and spas.

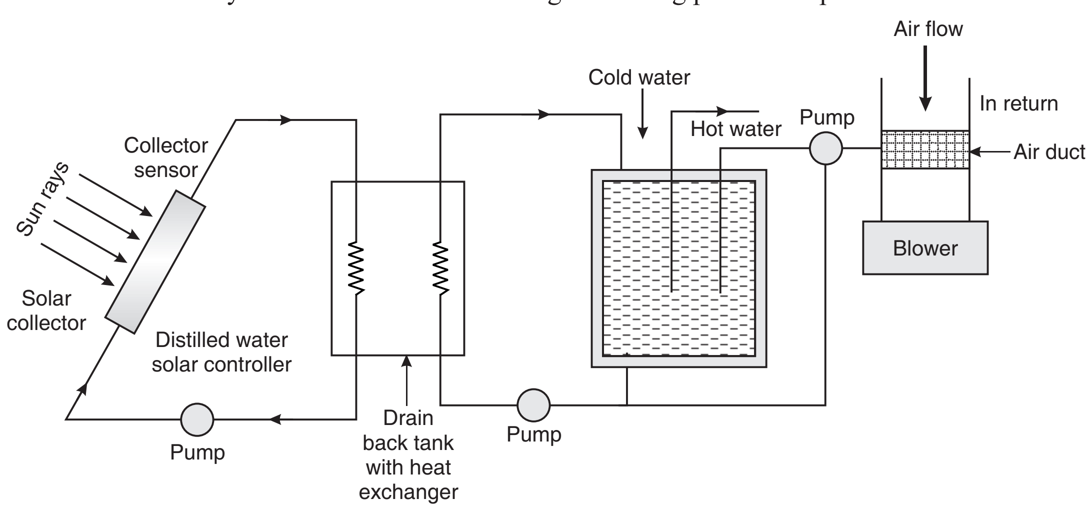

Fig. 2

Passive solar water heating systems :

A passive solar water heating system uses natural convection or household water pressure to circulate water through a solar collector to a storage tank or the point of use. The passive system is generally less efficient than the active system. The passive approach is simple and economical.

The passive water heating system have the same parameters for installations as that of active system south facing non-shaded location with the collector tilted at the angle of our latitude. Since the storage tank and collector are combined or in very close proximity, roof structural capacities must accommodate the extra weight of passive system. The passive solar water heating system are of two types :

1. Batch system
2. Thermosiphon system.

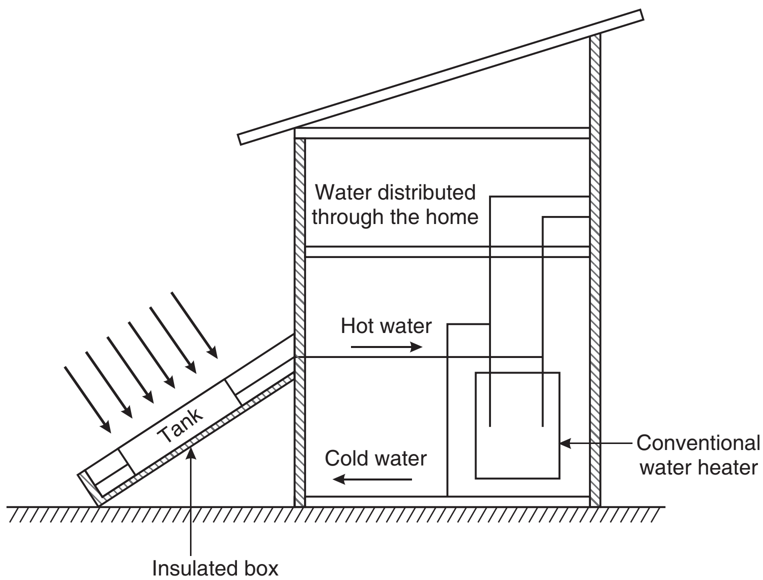

Fig. 3

1. Batch system : The batch system is the simplest of all solar water heating systems. It consists of one or more metal water tanks pointed with a heat absorbing black coating and placed in an insulating box or container with a glass or plastic cover that admits sunlight to strike the tank directly.

In this system tank is the collector as well these system will use the existing house pressure to move water through the system. Each time a hot water tap is opend, heated water from the batch system tank is removed and replaced by incoming cold water the piping that connects to and from the batch heater needs to be highly insulated. In many applications insulated poly butylene piping is used because the pipe can expand if frozen. The water in the batch heater it self will not freeze because there is adequate mass to keep it from freezing.

A typical schematic of batch domestic water heating system are as shown in figure.

THERMOSIPHON SYSTEM

The thermosiphon system uses flat plate collector and a separate storage tank must be located higher than the collector as shownin figure.

The storage tank located above the collector receives heated water coming from the top of the collector into the top of the storage tank cold water from the bottom of the storage tank will be drawn into the lower entry of the solar collector to replace the heated water that was thermosiphoned upward. This system is more costly and complex than the batch system. This system as shown in figure. Anti freeze can be used in this system.

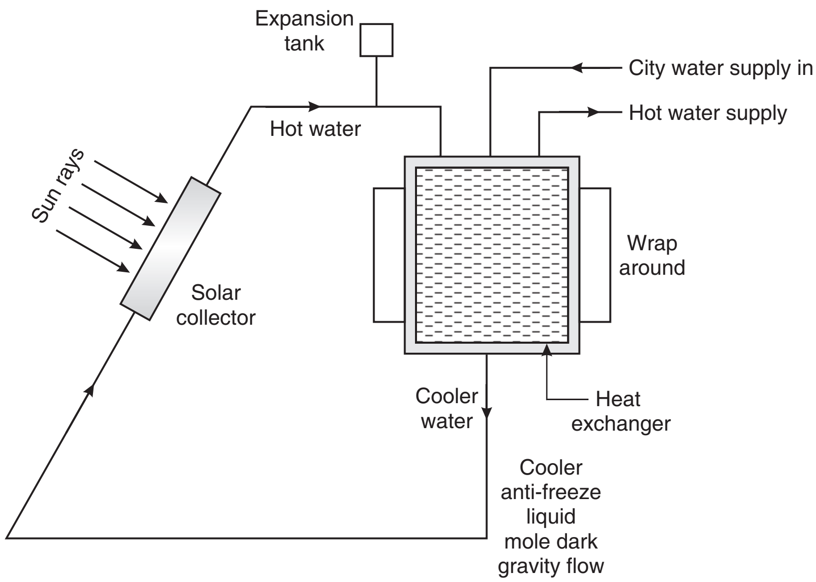

Fig. 4

STANDARD METHODS OF TESTING EFFICIENCY OF SHWS

Standard testing and rating procedure provides a basis for comparing the efficiency of different types of collector functions of collector testing are as follows :

1. To get requisite data for predicting the performance of solar collector system in given meteorlogical condition.
2. To get requisite data to study and develop the design of solar water heater collector.
3. To compare performance of different design solar collector for their better commercial use.
4. The main parts are a liquid pump, a heat exchanger with cooling and a storage tank with an electric immersion heater. A bypass is provided for control mass flow rate.
5. On any given day data is recorded under steady state conditions for fixed value of 'm' and T_i *i.e.* the principle measurement the fluid flow rate 'm'. The fluid inlet and outlet temperature of collector (T_i & T_o) the solar radiation incident an the collector plate (h) the ambient temperature (T_a) and wind speed (V). The efficiency of solar collector is given by the evacuated tube collector have lower thermal losses as compared to flat plate collector.

Solar passive space heating & cooling system :

Solar energy is also used for heating or cooling a building to maintain a comfortable temperature inside passive system do not require any mechanical device and make use of the natural process of convection, radiation and conduction for transport of heat.

Use of passive heating/cooling system puts restrictions on the building design to make possible the flow of heat naturally, such a specially designed building is called a solar house.

The technology for passive cooling is much less developed than that for passive space heating. Natural passive cooling may not always be sufficient to meet the requirement and at peak load, auxiliary means may also be needed.

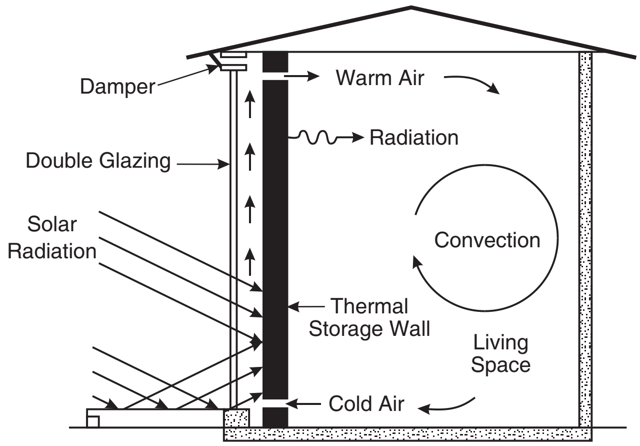

Fig. 5

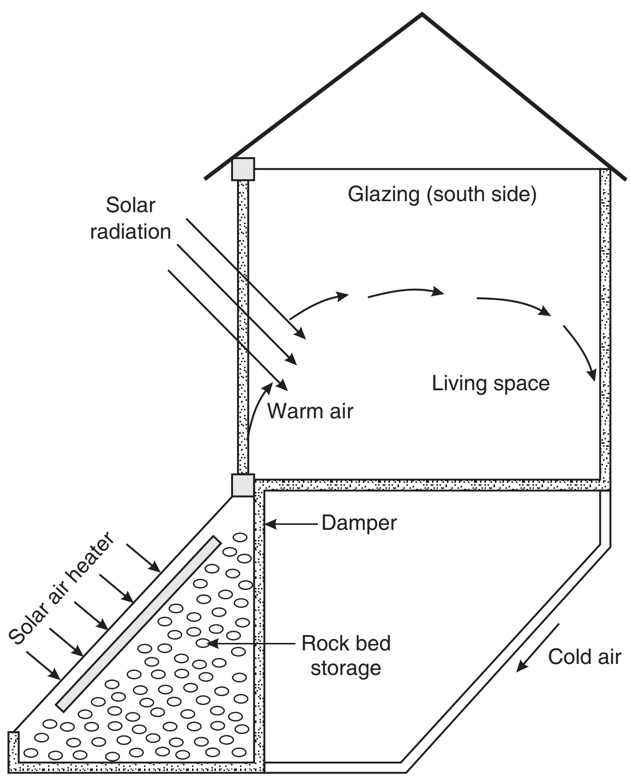

Fig. 6

Space heating : In the case of passive heating careful building design and insulation is desirable and will be less expensive than additional heating/cooling load due to poor design.

A solar passive space-heating system is as shown in figure. The south facing thick wall called trombe wall is made of concrete adobe, stone or composities of brick blocks and sand, designed for thermal storage. In solar to increase the absorption, the outer surface is pointed black. The entire south wall is covered by one or two sheets of glass or plastic with some air gape between the wall and inner glazing as shown in figure (a) thus the thermal wall collects stores and transfer the heat to the room. Heating can be adjusted by controlling the air flow through the inlet and outlet verts by shutters. Opening the damper at the top of the glazing allows the excess heat to escape outside when the heating is not required.

The another variation of solar is space-heating system is shown in figure (b). Sometimes, a reflective horizontal surface is also provided to make available the additional radiation for thermal storage. A movable insulation cover is also used to cover the glaze to reduce heat loss from the storage. Here a collector cum-rock-bed storage system is integrated with the apartment.

Space cooling : For natural cooling the first and best approach is to reduce unnecessary thermal loads entering building. As shown in figure (c) the scheme for solar passive cooling through vertilation. This scheme utilizes a solar ‘‘chimney effect’’ and is effective where outside temperatures are moderate solar radiation is allowed to heat up the air between the glazing and the interior south wall. The heated air riscsup is ducted outside and the warm air from the room is drawn into this space due to natural draught thus produced. As a result cool outside air enters the roo from the bottom air vent on the otherside of the room.

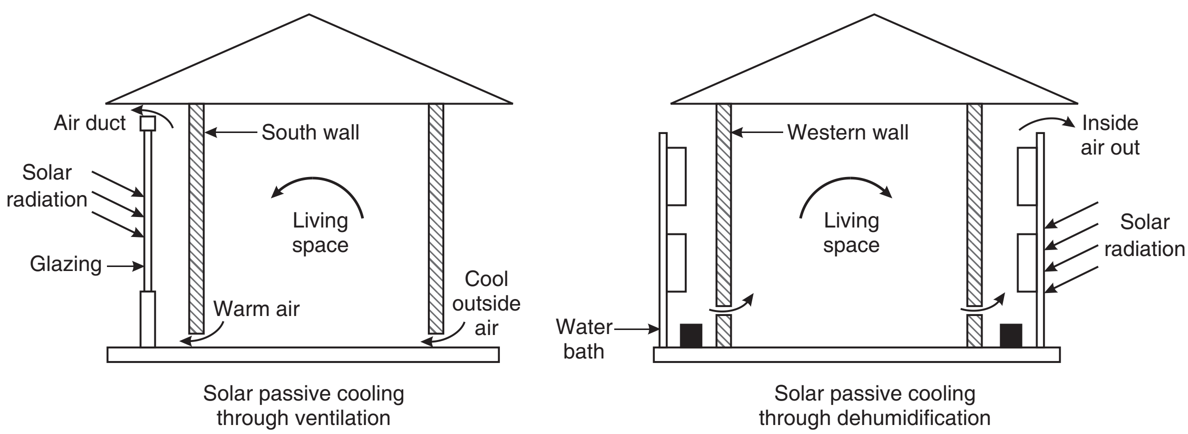

Fig. 7

Solar distilation (desalimator) :

In many small communities the natural supply of fresh water is inadequate in comparison to the availability of brackish or saline water solar distillation can prove to be an effective way of supplying drinking water to such communities. This idea was first applied in 1872 by USA, Greece, Australia and several other countries.

The modren developments in solar distillation have been directed to the use of materials and design for economic and durable construction with increased output in order to reduce the product cost. Several types is there but only the basin-type has been tried commercially on a large scale.

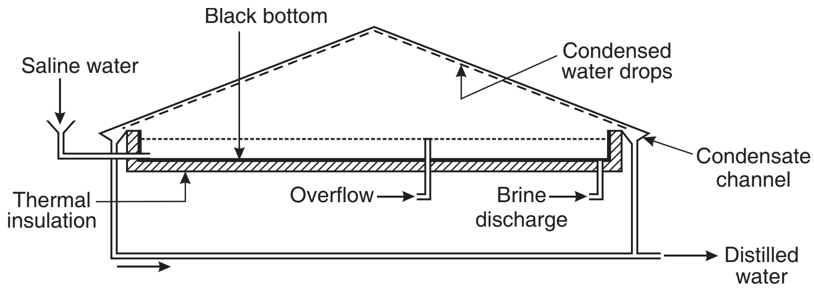

Fig. 8

A simple basin type solar still consists of a shallow blackoned basin filled with saline or backish water to be distilled. It covered with a slopey transparent roof solar radiation after passing through the roof is absorbed by the blackened surface of the basin thus increases the temperature of water. The evaporated water increases the moisture content, which gets condensed on the cooler under neath the glass. The condensed water slips down the slope and is collected through the condensate channel attached to the glass. The construction is schematically as shown in figure.

The still created in an open area with its long axis facing the east-west direction.The still can be fed with saline water either continuously or intermittently. The supply is generally kept at twice the rate which the fresh water is produced but may vary depending on the initial salinity of input water. The output of a solar still in India varies from 5.31/m^2 day (in summer) to 0.91/m^2 day (in winter).

Solar dryer

The drying process removes moisture and helps in the preservation of any product.

A simple cabinet type solar dryer is shown in figure. It has an enclosure with transparent cover. The material to be dried is placed on perforated trays. Solar radiation enters the enclosure and is obserbed by the product as well as the surrounding internal surfaces of the enclosure it raises its temperature inside air heates upto 50°C to 80°C and rises even above. Natural circulation of air is ensured by providing suitable openings at the bottom and top it removes the moisture from product. For large scale drying forced circulation of air may be used by blower. In case of green lumber, where direct exposure to the sun tends to produce curling and wrapping. For products where direct sunlight is not adequate, controlled temperature drying known as kiln drying may be used such dryers are also suitable for food grains and products like tea & tobacco.

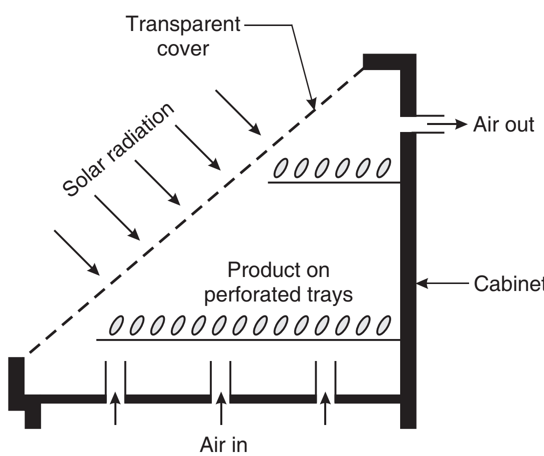

Fig. 9

Solar thermal power generation :

The generation of electrical power is one of the most important applications of an energy source.

Solar thermal power cycles can be classified as follows :

1. Low temperature cycle
2. Medium temperature cycle
3 High temperature cycle

The low temperature cycle work at maximum temperature of about 100°C medium temperature cycles work at maximum temperature upto 400°C while high temperatures above 400°C.

In low temperatuare system use flat plate collectors (or) solar ponds for collecting solar energy.

Medium temperature system use the line-focussing parabolic collector technology.

High temperature system use either paraboloidal dish collector (or) control receivers.

High temperature system : Two concepts have been experimented with in the case of high temperature systems These are the paraboloid dish concept and the central receiver concept.

CONTROL TOWER RECEIVER POWER PLANT

This power plant uses a centeral tower receiver as shown in figure to collect solar radiation from a large area on the ground.

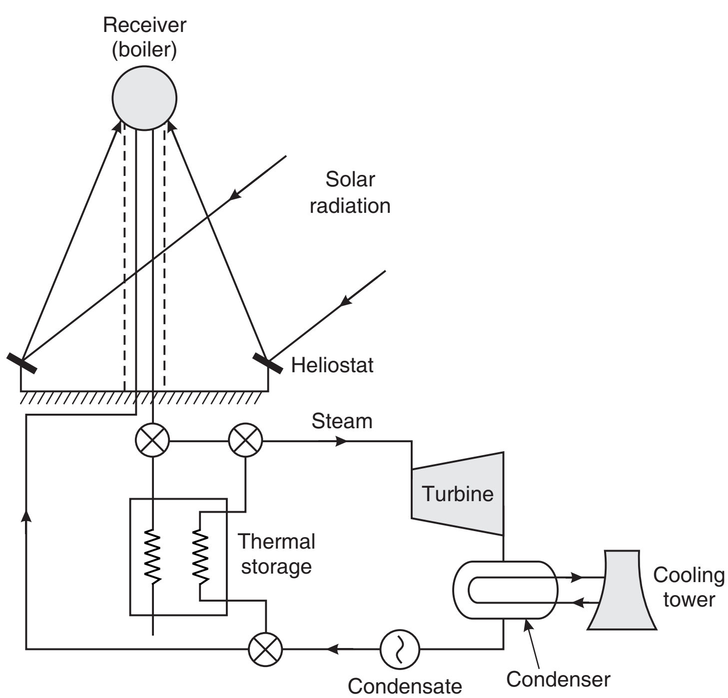

Fig. 10

The receiver mounted at the top of the tower, converts water into high-pressure stream at around 500°C. This high pressure steam is expanded in a turbine coupled with an alternator. The electric power produced is fed to a grid. Thermal buffer storage is provided to continue operating the plant for some time during cloud cover and a bypass is used for starting and shut-down operation. The schamatic diagram as shown in figure.

Low temperature system

A solar chimney is much simpler but works with much lower efficiency as compared to a central tower receiver power plant.

The circular field of heliostats is replaced by circular area of land covered with glazing (a circular green house) the central receiver tower is replaced by a tall chimney that houses a wind turbine at the base of the chimney as shown in figure. Sun light passing through the transparent cover causes the air trapped in the green house to heat up a convection system is set up in which the air drawn up through the chimney drives the turbine coupled with generator. The hot air is continuously replenished by fresh air drawn in the periphery of the green house.

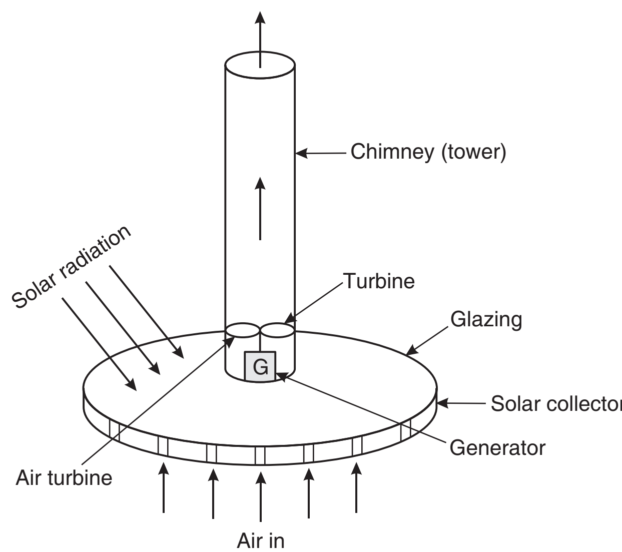

Fig. 12

Medium temperature system

Among solar thermal-electric power plants those operating on medium temperature cycles and using the line-focussing parabolic collector technology at a temperature close to 400°C have proved to be the most cost effective and successful so for. A schematic diagram of a typical plant as shown in figure.

The cylinderical parabolic collectory used have their axes oriented in respective direction. The absorber tube used is made of stainless steel and has a specially developed solective coating. It is surrounded by glass cover with a vacuum. The collectors heat a synethetic or (dow therm A) to a temperature of 390°C with collector efficiency of about 0.7 for beam radiation. The synthetic oil is used for generating super heated high pressure steam which execute a rankine cycle with on efficiency of 38 percent. The plant generally produces electricity for about eight hours a day and is coupled with natural gas for continuous operation. The installed cost of this type of plants has reduced over the years because of the increasing installed capacity.

There is significant advances have been made in parabolic collector technology as well as organic rankine cycle technology. This has resulted in making smaller capacity plants more economically feasible.

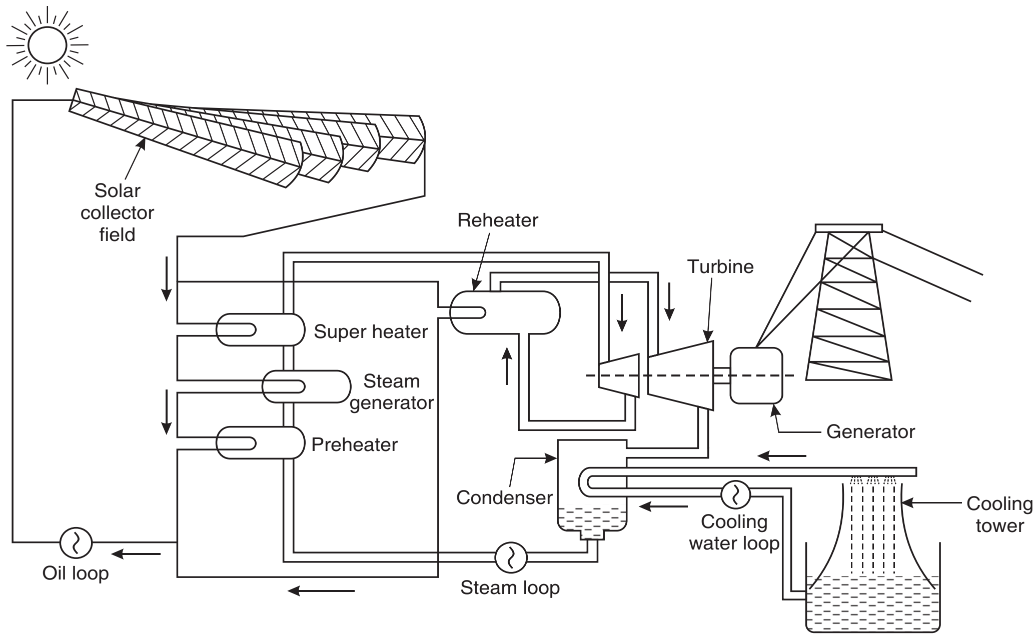

Fig. 13

The Indian experience with the line focussing parabolic collector technology has been restricted so for to a small 50 KW capacity experimental plant at the solar energy centre of the ministry of new and renewable energy.

1. Preheater
2. Steam generator
3. Super heater
4. Reheater
5. Turbine
6. Generator
7. Condenser
8. Coding tower

EXERCISE

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SOLAR PV APPLICATION

SPV SYSTEMS

Solar *PV* systems are broadly classified as follows :

1. Central power station system
2. Distributed systems

1. Central power station system : Central *PV* power stations are conceptually similar to any other conventional central power station. They feed power to grid.These are being proposed in few MW range to meet day time peak loads only.

2. Distributed system : Distributed from of energy use is unique and much more successful with solar and most other renewable energy sources.These system can be divided into three groups :

1. Stand alone systems
2. Grid-interactive systems
3. Small systems for consumer applications

1. Stand-alone systems : It is located at the load centre and dedicated to meet all the electrical loads of a village/community or a specific set of loads. Energy storage is essential. It is quite useful in remote areas.

2. Grid-interactive system : This system is connected to the utility grid with two-way meeting system. It may be a small roof top system awned and operated by the house owner or relatively bigger system. It meets day time requirements of the house without any battery backup and surplus power is feed to the grid.

3. Small systems for consumer applications : These systems are meant for low energy consumer devices requiring power in the range of microwatts to low and mostly designed for indoor applications. *e.g.*, calculator, watches, electronic games etc.

STAND-ALONE SOLAR *PV* SYSTEM

The stand alone *PV* system are as shown in figure. The maximum power point tracker (MPPT) sense the voltage and current outputs of the array and adjusts the operating point to extract maximum power under the given climatic conditions. The output of the array after converting to AC is fed to load. The array output in excess of load requirement is used to charge the battery. After fully charging the battery the excess power may be shunted to dump heaters. When the sun is not available, the battery supplies the load through an inverter.

The battery discharge diode (D_B) prevents the battery from being over charged after the charger is opend the array diode (D_A) is to isolate the array from the battery to prevent battery discharge through array during nights. A mode controller is a control controller for the system.

Examples : Solar street lights,

Home lighting systems,

SPV water pumping system.

Grid-Interactive solar PV systems :

The schematic diagram of a general grid-interactive solar PV system is as shown in figure.

In this system all excess power is fed to a grid. During absence or inadequate sunshine supply of power is maintained from the grid and thus battery is eliminated, dump heater are not required.

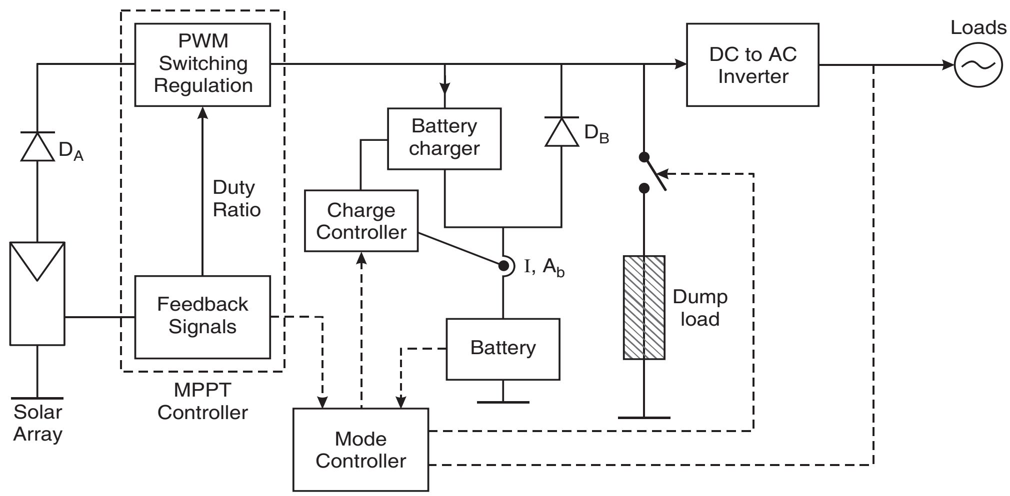

Fig. 1

The mechanism for synchronized operation is in corporated. The dc power is first converted to AC by inverter harmonics are filtered and then only the filtered power is fed into the grid after adjusting the voltage level.

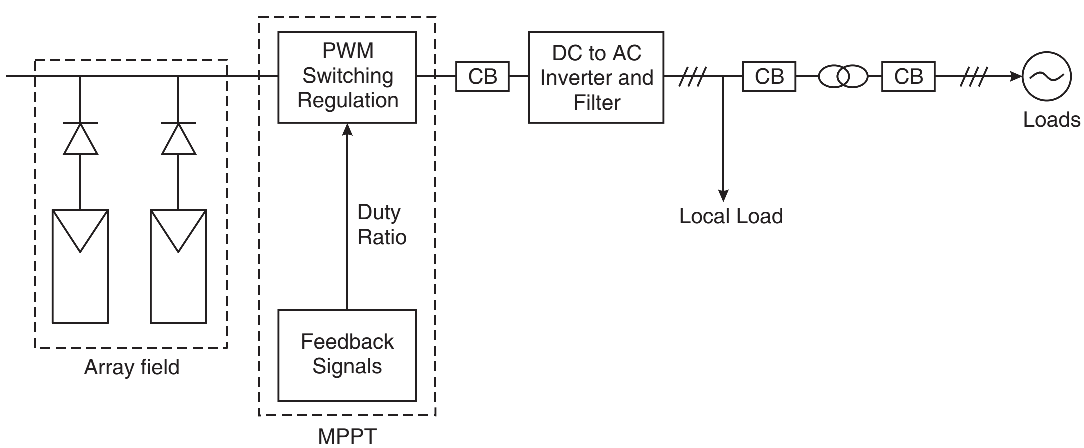

Fig. 2

Recently PV modules are being made with inverters. Which are known as AC PV modules.

Hybrid solar PV system :

A dedicated PV power supply system is insufficient to maintain continuity of supply even with storage batteries. Standalone *PV* systems have a scasonal dependence and are not reliable during periods of low solar inadiance cloudy days and nights. Thus a hybrid energy system has been evolved to meet the load requirements without constraint.

The most effective and economic solution is to install a PV system with a diesel generator along with storage batteries. (or) gasoline generator (or) any other non-conventional source like wind (or) fuel cells such a system is called a hybrid system.

SYSTEM INSTALLATION; OPERATION AND MAINTENANCES

1. System installation :

1. Site survey and planing : The first step of installation of SPV system is to visit the site and finalize the layout then after the equipment.

2. Safety assessment : To identify all the possible risks and make sure to take safety masures of electrical fire, earthing, short circuit ... etc.

3. Solar arrays location : For this arrays should locate a shadow free location for placement of array there is no shading between the hours of best insolation usually from 8 am to 4 pm.

4. Site between two rows : It is also very important the saperation between two rows make sure without any shadow.

5. Other equipment location : Control and inverter should be placed in such a way that occurs is controlled switches are need to be locate in a place which is easily accessable and batteries should be installed in a separate room closed to the inverter (or) control room and access to the room. Batteries to be located in cool and dry and well ventilated place.

6. Installation in mounting structure : To mount the module on stands there are different structure are as shown in figure.

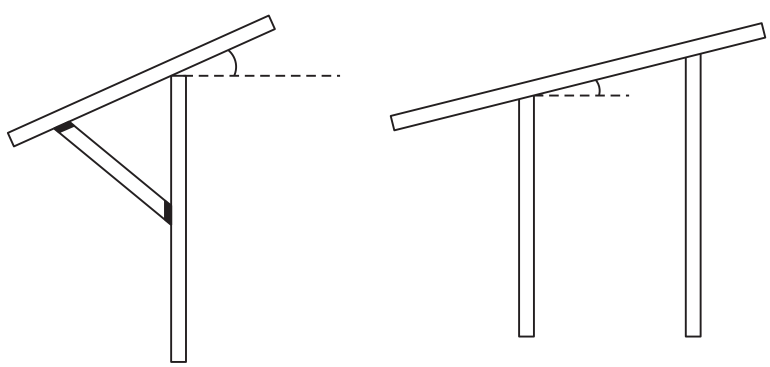

Fig. 3

7. Foundation and structure alignment : The types of foundation for mounting structure are as shown below.

8. Array installation : Solar modules are arranged in array form.

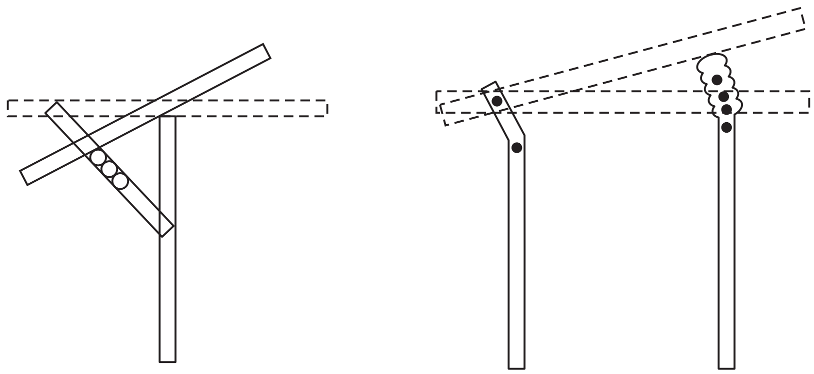

Fig. 4

9. Volt array wiring :

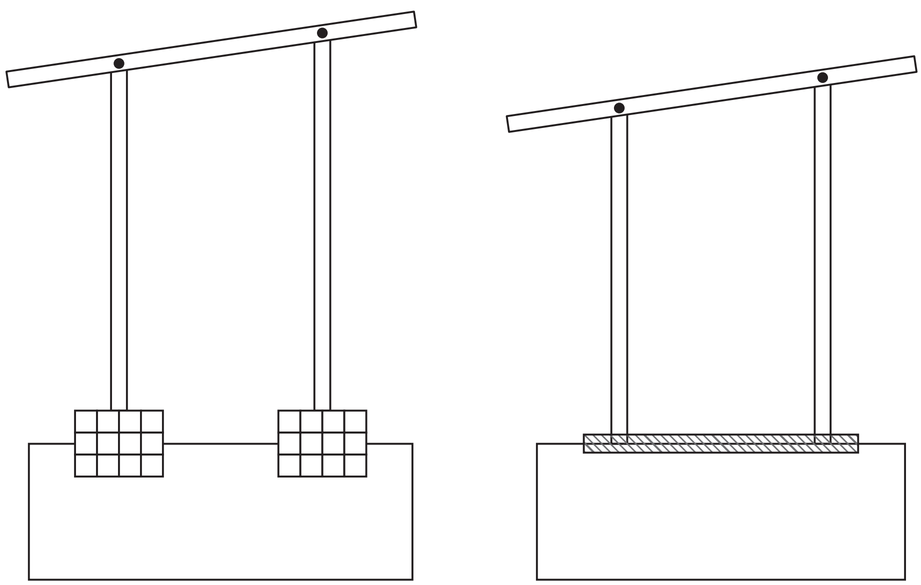

Fig. 5

OPERATION AND MAINTAINANCE :

Recommended materials and supplies list for repair or maintenance

Distilled water

Baking soda

Wire nuts

Crimp connector

Ring, spads and lag terminals

Load, inverter and charge controller fuses.

Rosin core electrical solder

Cables ties

Rags (or) paper towels

Dish soap or pulling grease

Red and black electrical tape

Assorted screws and mails

Preventive maintainance

Clean PV array from dust, brids drop, use clean water avoid hard water.

Monthly : If led acid batteries are use check electrolyte level and top up if required wipe electrolyte residue from the top of the battery, inspect all terminals, clean and fighter as necessary inspect array for broken modlus if any replace it with appriciable module verify out put from the array.

EXERCISE

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