UNIT II.SOLAR ENERGY

SOLAR RADIATION

The sun's surface temperature is around 5300° C. The solar radiation from the sun is around 178 TW. The solar rays reach the earth surface through the atmosphere. The radiation above the atmosphere is called as **extra terrestrial radiation** and the radiation below the atmosphere is called as **terrestrial radiation or global radiation**.

Global radiation = Beam or direct radiation + Diffuse or scattered radiation.

The direct radiation reaches the earth from sun directly but diffuse radiation is due to scattered effect of atmosphere and the particles in the air. The reflected rays by the earth surface is called albedo. The solar energy potential or intensity on earth surface is around 0-1 kW/m^2 (night to noon). The solar constant is defined as the solar radiation incidence per m^2 of atmosphere . Its value is 1367 W/m^2.

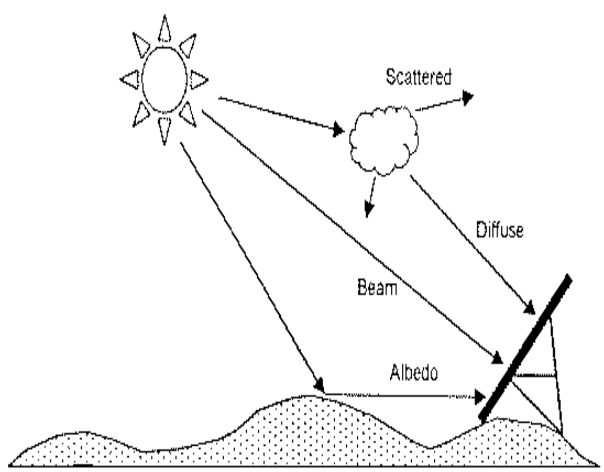

Fig.2.1. Solar radiation components

The angles in solar geometry:

Altitude angle (α): The angle between beam radiation and the ground.

Incidence angle: The angle of incidence of beam radiation from the zenith. In case of Horizontal surface collectors the incidence angle is equal to zenith angle.

Zenith angle: The angle between the beam radiation and Vertical plane.

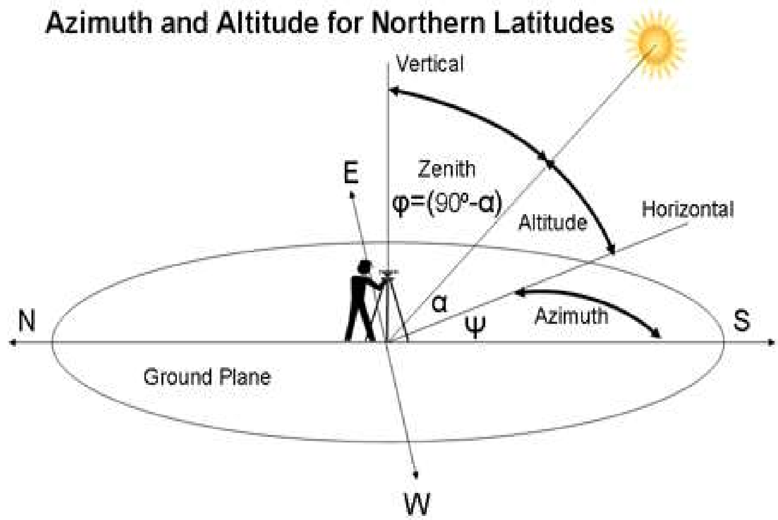

Fig.2.2. Solar Geometry

The **solar azimuth angle** is the azimuth angle of the sun. It defines in which *direction* the sun is, whereas the solar zenith angle or solar elevation defines how high the sun is. (The elevation is the complement of the zenith.) There are several conventions for the solar azimuth; however it is traditionally defined as the angle between a line due south and the shadow cast by a vertical rod on Earth.

SOLAR RADIATION MEASUREMENTS

1. **Pyranometer :** To measure global radiation (both beam and diffuse radiation)

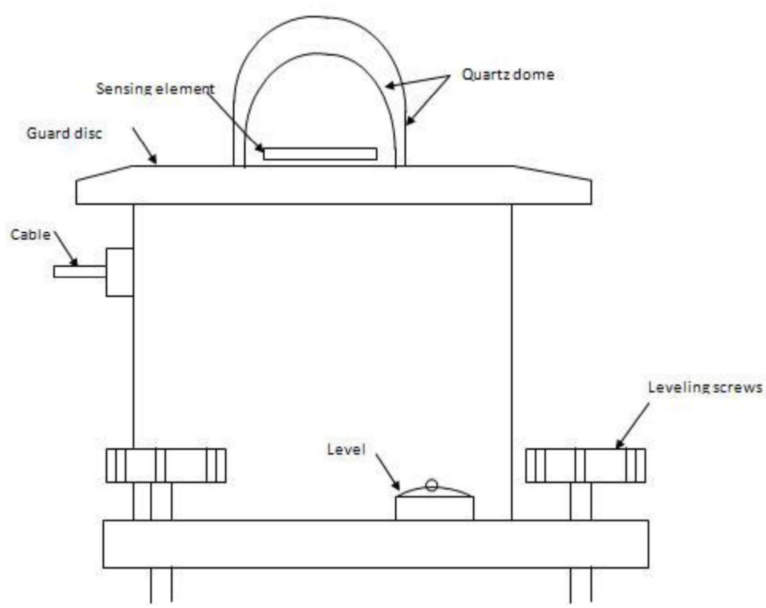

Fig.2.3. Pyranometer

The quartz domes collects the beam and diffuse incident solar radiations. The sensing element is subjected to heating by solar radiation and its thermal resistance is used to measure the global radiation by using the emf generated.

2. **Pyrheliometer :** To measure beam radiation.

Pyrheliometer has a collimator tube to collect the beam radiation component and the thermal resistance of black absorber plate is used to determine the intensity of the beam radiation. This narrow tube allows only beam radiation to reach the sensing element.

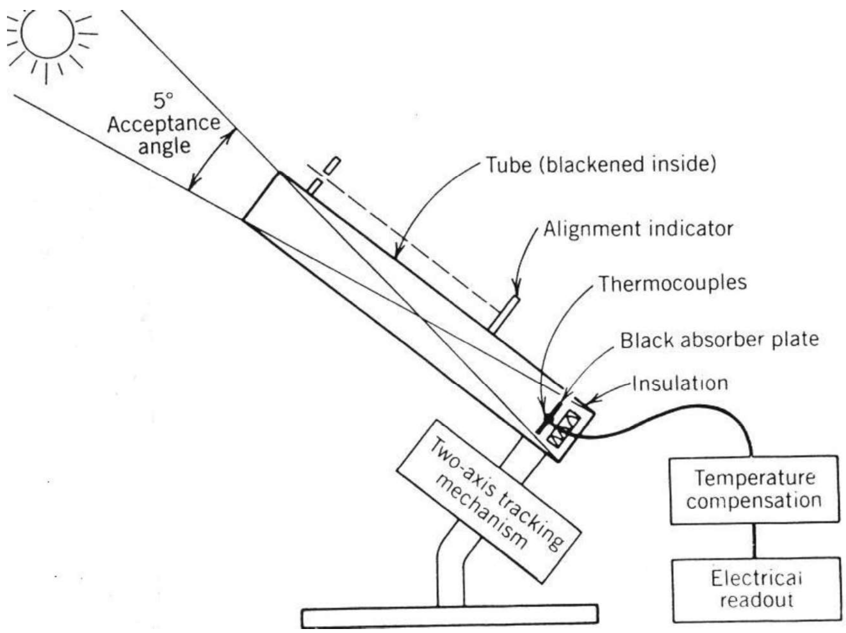

Fig.2.4. Pyrheliometer

3. Pyrgeometer: To measure IR and long wave radiation.

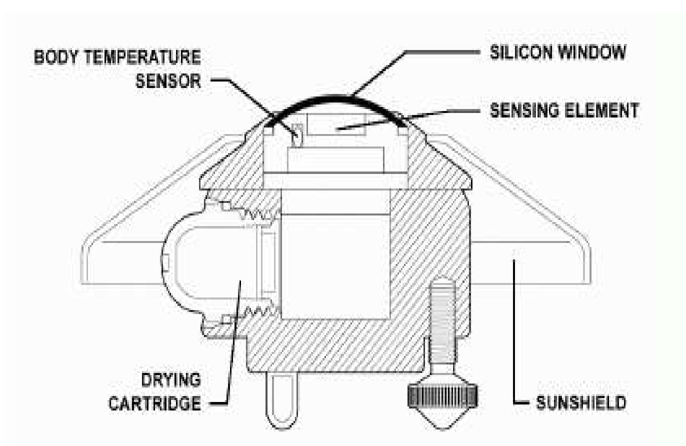

Fig.2.5. Pyrgeometer

4. Sunshine recorder: To measure the actual sunshine daily hours. The working principle is the based on the length of card board paper burnt in the spherical glass. The spherical bowl is calibrated in such a way that the length of paper burnt is directly proportional to the active solar hours.

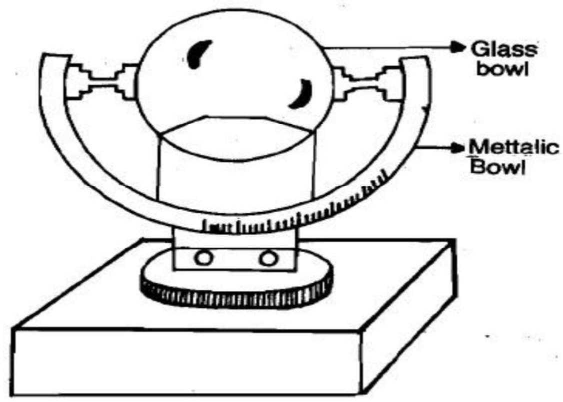

Fig.2.6. Sunshine recorder

SOLAR THERMAL ENERGY TECHNOLOGIES

The solar collectors are broadly classified as solar thermal collectors and photovoltaic cells. Then the thermal collectors are classified as follows:

I. Based on Concentration

- Non-concentrated .. Flat plate collectors
- Concentrated collectors … Parabolic collectors

II. Based on sun-tracking

- Single axis tracking . ….. Parabolic and cylindrical trough collectors
- Two-axis tracking …… Parabolic dish collectors, Heliostat Mirror field

SOLAR FLAT PLATE COLLECTORS

The flat plate collectors contains absorber plate (to increase the heat absorption rate) , absorber tube (to carry the heat transfer fluids), insulation on all sides except aperture area, glass cover (to transmit the incident rays and retain rays inside the collector) etc. The working temperature range of this collector is around 60-120 °C. The major classification is Flat plate collector, Evacuated tube collector, compound parabolic collectors. It’s suitable for mainly domestic thermal applications. The flat plate collectors can be classified further as liquid heaters and air heaters.

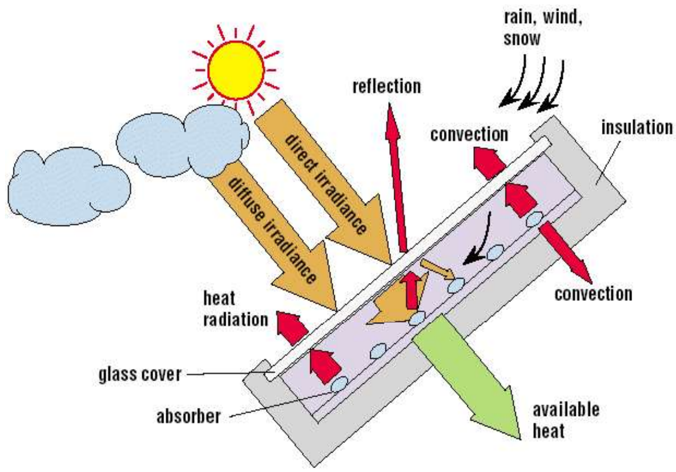

Fig.2.7.Solar flat plate collector

Derivation of collector efficiency and heat loss coefficients (Performance factors) of solar flat plate collector

The energy balance of the absorber can be represented by a mathematical equation:

$$\mathbf{Q_u = A_p\, S - Q_L} \text{ --------------- Eqn. 1}$$

Where,

Q_u = Useful heat delivered by the collector, Watts

A_p = Area of the absorber plate, m^2

S = Solar heat energy absorbed by the absorber plate, W/m^2

Q_L = Rate of heat loss by convection & re-radiation from the top, by conduction & convection from sides and by conduction & convection from the bottom, Watts

The solar flux falling on the top cover is given by

$$\mathbf{I_T = I_b * R_b + I_d * R_d + (I_b + I_d) * R_r} \quad \text{--------------- Eqn. 2}$$

(Suffix "b" , "d" and "r" denote beam, diffused & tilt factor respectively.)

The flux absorbed is obtained in the above equation (2) to be multiplied by the transmittivity-absobvity product ($\tau\alpha$), then the equation (2) becomes,

$$\mathbf{S = I_b * R_b * (\tau * \alpha)_b + I_d * R_d * (\tau * \alpha)_d + (I_b + I_d) * R_r * (\tau * \alpha)_r} \quad \text{--------------- Eqn. 3}$$

Now it is necessary to define the two terms – Instantaneous collector efficiency* and stagnation temperature#, which are required to indicate the performances of the collector and also for comparing the designs of different collectors.

$$\eta_i = Q_u / (A_p * I_T) \quad \text{--------------- Eqn. 4}$$

** "Instantaneous collector efficiency" is defined as the ratio of useful heat gain to radiation falling on the collector.*

 # The maximum temperature that the absorber can attain is called as "Stagnation temperature".

Ac is usually 15-20% more than Ap.

Total loss co-efficient and Heat losses

Heat loss from the collector using he total loss coefficient is given by the equation:

$$Q_L = U_T * A_p * \{T_P - T_a\} \text{ --------------- Eqn. 5}$$

Where,

Q_L = Rate of heat loss by convection & re-radiation from the top (Q_t) + by conduction & convection from sides (Q_s) + by conduction & convection from the bottom (Q_b),Watts

U_T = Total loss coefficient

T_P = Average Mean temperature of the absorber plate, K or C

T_a = Surrounding or ambient temperature of air, K or C

A_p = Area of the absorber plate, m^2

The collector losses are from top, the bottom and the sides.

Total heat loss loss coefficient is given by $U_T = U_t + U_b + U_s$ --------------- Eqn. 6

Total heat loss, $Q_L = Q_t + Q_b + Q_s$ --------------- Eqn. 7

The total heat loss coefficient (U_t) ***normally ranges from 2 to 10 W/m²***^{2}***.***

To find out Q_t, Q_s & Q_b, the following equations can be used:

$Q_t = U_t * A_p * \{T_P - T_a\}$ --------------- Eqn. 8

$Q_b = U_b * A_p * \{T_P - T_a\}$ --------------- Eqn. 10

$Q_s = U_s * A_p * \{T_P - T_a\}$ --------------- Eqn. 11

$U_b = k_i / x$ --------------- Eqn. 12

$U_s = (L_1 + L_2) * L_3 * k_i / (L_1 * L_2 * y)$ --------------- Eqn. 13

Where,

k_i = Thermal conductivity of Insulation, W/m.K

x & y = Thickness of Insulation, m

L_1, L_2 & L_3 = Length, width & height respectively, m

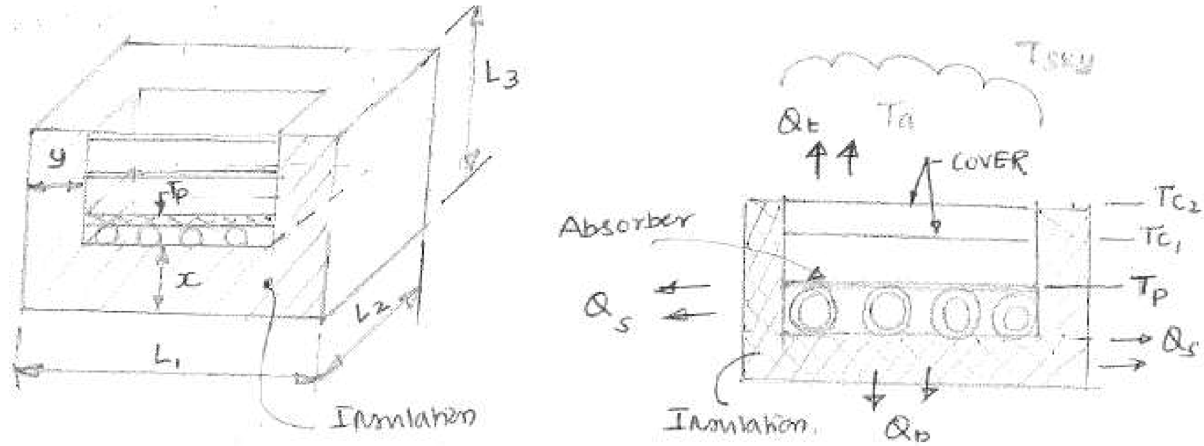

Fig.2.8 Flat plate collector dimensions

Heat loss coefficient ($\mathbf{U_{t1}}$) between absorber plate and top cover 1 is given by

$\mathbf{U_{t1} = h_{p\text{-}c1} * \{ T_P - T_a\} + [\sigma \{ T_P^{\,4} - T_{c1}^{\,4}\} / \{(1/\varepsilon_p + 1/\varepsilon_c) - 1\}]}$ --------------- Eqn. 14

Heat loss coefficient ($\mathbf{U_{t2}}$) between top cover 1 and top cover 2 is given by

$\mathbf{U_{t2} = h_{c1\text{-}c2} * \{ T_{c1} - T_{c2}\} + [\sigma \{ T_{c1}^{\,4} - T_{c2}^{\,4}\} / \{(1/\varepsilon_c + 1/\varepsilon_c) - 1\}]}$ --------------- Eqn. 15

Heat loss coefficient ($\mathbf{U_{t3}}$) between top cover 2 and air is given by

$\mathbf{U_{t3} = h_{c2\text{-}a} * \{ T_{c2} - T_a\} + [\sigma * \varepsilon_c \{ T_{c2}^{\,4} - T_{sky}^{\,4}\}]}$ --------------- Eqn. 15 and

$\mathbf{U_t = U_{t1} + U_{t2} + U_{t3}}$ --------------- Eqn. 16

Where,

h_{p-c1} = Convective heat transfer co-efficient between absorber plate and top cover 1, W/m^2.K ,

h_{c1-c2} = Convective heat transfer co-efficient between top cover 1 and top cover 2, W/m^2.K ,

h_{c2-a} or h_w= Convective heat transfer co-efficient between top cover 2 and surroundings, W/m^2.K

T_{c1} & T_{c2} = Temperature of the top cover 1 and top cover 2 respectively, in K

T_{sky}= Temperature of the sky, in K

$\boldsymbol{\varepsilon_p}$ & $\boldsymbol{\varepsilon_{c1}}$ = Emissivity of absorber plate and cover plate,

h_{c2-a} **or** h_w **= 5.7 + 3.8 *V**, W/m^2.K --------------- Eqn. 17

Where, V = Wind speed, m/s

<u>Collector Heat Removal Factor</u>

$$F_R = [(m * C_p) / (U_L * A_P)] * (1 - e^{\{(-F' * U_L * A_P) / (m * C_p)\}}$$ --------------- Eqn. 18

Where,

F' = Collector efficient factor

m = mass flow rate

C_p = Specific heat

<u>Problem. 2.1</u>

In a solar water heater, the collector plate is at 87 °C and glass cover is at 67 °C. Heat from collector plate is lost to the air by convection and to the glass cover by radiation. If the heat transfer co-efficient by convection is 4.6 W/m^2 K, find the heat loss from the collector plate per hour per m^2 surface area. Also find the equivalent radiation heat transfer co-efficient. Assume emissivity of plate is 0.2 and emissivity of glass is 0.3 and radiation shape factor is 1.

Solution :

Suffix-p for Plate and g for Glass.

Equivalent emissivity, $\varepsilon_{equi} = 1/ \{ [1/\varepsilon_p + 1/ \varepsilon_g] -1 \} =$ 0.136

The radiation heat transfer coefficient

$hr = \sigma\ \varepsilon_{equi} (Tp^4 - Tg^4) / (Tp - Tg) =$ **1.32 W /m^2 –K**

Total heat loss by collector plate, Qt = (hc+hr) As (Tp – Tg) = **118.4 W/m^2.**

<u>Problem 2.2</u>

A solar water heating plant with a FPC has to be designed based on the following data:

Daily solar radiation = 5 kWh/m^2 per day
Hot water consumption = 1000 kg per day
Hot water temperature = 45 C
Cold water temperature = 14 C
Plant mean efficiency = 48 %.

Isobaric specific heat of water = 1.163 W h/kg-K
Determine total collector surface area and the number of solar collector modules required if a single module has an area of 2.2 m^2.

Solution:

Daily heat requirement,

Qhw = m Cp (Th – Tc)

= 1000 x 1.163 x (45-14) = 36053 W h /day

Daily useful heat output by ignoring heat losses,

Q = Incident radiation x Efficiency = 5 x 0.48 = 2.4 kWh/day

Required collector surface area, A = Qhw / Q = **15.02 m2**

No. of collector panels required, N = 15.02 / 2.2 = **7 collectors**

HEAT TRANSFER ANALYSIS OF CYLINDRICAL PARABOLIC COLLECTOR

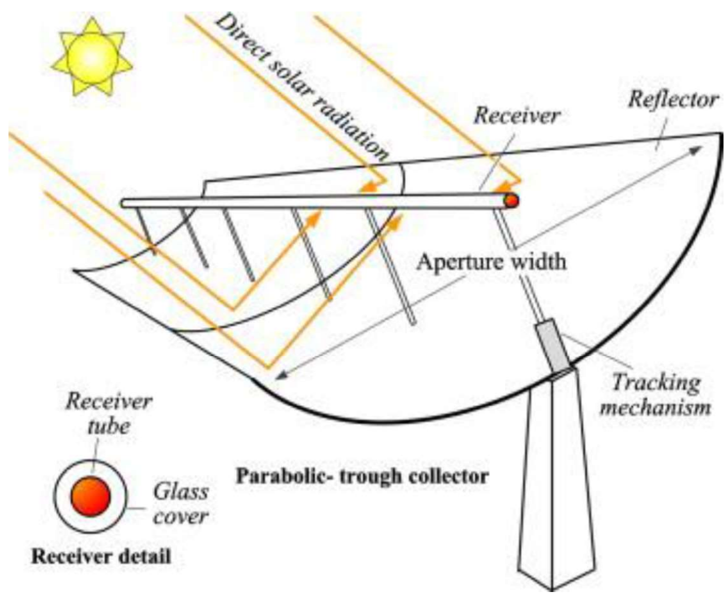

Fig.2.9 Solar Parabolic collector

Let W = Aperture width of the concentrator in m

L1 = Length of the concentrator in m

θ = Rim angle in degrees

d = Diameter of absorber tube in m

D = Diameter of glass tube in m

m = Mass flow rate of HTF in kg/s

Tfi, Tfo = HTF temperature at inlet and outlet respectively

Cp = Specific heat of HTF in kJ/kg-K

C = Concentration Ratio = Effective aperture area / Absorber tube area

I_b = Perpendicular incident solar beam radiation (W/m^2)

R_t= Tilt factor of the reflector

r = Reflectivity of the concentrator surface

F_i = Intercept factor. It is the fraction of the reflected radiation intercepted by the absorber tube.

$\alpha\ \tau$ = Product of absorptivity and transmissivity of absorbing surface for radiation

U = Overall heat transfer coefficient from the absorbing tube surface.

T_p = Local temperature of absorber tube

T_a = Ambient air temperature

T_f = Local temperature of the flowing fluid

Consider **dQu** is the useful heat gain for the length **dy** of the absorber tube

Heat gain by the absorber = Energy absorbed by the absorber tube +

Direct energy falling and absorbed by absorber -

Heat loss from the absorber tube

$dQu = dQ_1 + dQ_2 - dQ_{loss}$

dQ_2 can be neglected if C is very high and It can not be ignored if C is small.

Anyway dQ_2 is less than dQ_1.

$dQu = I_b\ [\ (W\text{-}d)\ dy]\ \ R_t\ r\ F_i\ \ (\alpha\ \tau) + I_b\ (d\ dy)\ R_t\ (\alpha\ \tau) - (\pi d\ dy\ )\ U\ (Tp - Ta)$ ……….1

If S is the solar flux falling on the concentrator and it is completely absorbed by the absorber tube, $dQ_{loss} = 0$,

$S\ (W\text{-}d)\ dy = I_b\ [\ (W\text{-}d)\ dy]\ \ R_t\ r\ F_i\ \ (\alpha\ \tau) + I_b\ (d\ dy)\ R_t\ (\alpha\ \tau)$

$S = I_b\ R_t\ r\ F_i\ \ (\alpha\ \tau) + I_b\ d\ R_t\ (\alpha\ \tau) / (W\text{-}d)$

$I_b\ R_t\ r\ F_i\ \ (\alpha\ \tau) = S - I_b\ d\ R_t\ (\alpha\ \tau) / (W\text{-}d)$

By substituting this in equ(1),

$dQu = (W\text{-}d)\ dy\ [\ S\ - U\ (Tp - Ta) / C\ ]$

The useful heat gain also can be written as

dQu = Heat convected by the tube surface to the fluid = Heat gained by the fluid

$dQu = h_p\ (\pi d\ dy\ )\ (Tp - Tf) = m\ Cp\ dTf = m\ Cp\ (Tfo - Tfi)$

Where h_p : Convective heat transfer co-efficient on the pipe surface ($W/m^2\ K$)

Collector Efficiency Factor, $F' = 1 / [\ 1 + U / h_p\ ]$

$m\ Cp\ dTf\ = F'\ (W\text{-}d)\ dy\ [\ S\ - U\ (Tp - Ta) / C\ ]$

Heat Removal Factor (HRF), $F_R\ = P\ [\ 1\text{-}\exp\ (- F'/P)]$ Where $P = m\ Cp /\ (\pi d\ L_1\ U)$

Instantaneous collector efficiency, $\eta = Qu / [(I_b\ R_b + I_d\ R_d\ )W\ L]$

Problem 2.3

A solar concentrating collector consisting of a PTC and an absorber tube uses thermo-oil as HTF. The beam radiation intensity is 750 W/m^2. The unshaded area is 240 m^2 and the CR is 40. The inlet temperature of thermo-oil is 280 C, its mass flow rate is 0.6 kg/s and Cp is 3200 J/kg-K. The ambient is at 30 C. The optical efficiency is 0.74, heat loss coefficient of the absorber is 7 W / m^2-K and the HRF is 0.96. Determine the useful heat output of the collector and outlet temperature of the HTF?

Solution:

Solar concentrating collector:

$Q = F_R$ x A [I_b x Opt. Efficiency – (U_{loss}/ CR) (Ti – Ta) = **117792 W**

To = Ti + Q / (m Cp) = **341.35 C**

Problem.2.4

A cylindrical parabolic collector having 2.5 m width and 10 m long is used to heat fluid entering at 150 C with a flow rate of 7.5 kg/min (Cp = 1.25 kJ/kg.C). The diameter of the absorber tube is 6.5 cm which is covered with glass tube. Take the following data: Ib = 700 W /m2, Ta = 30 C, Optical properties $(\alpha\tau)_{ab} = 0.8$, $r_r = 0.93$ and $\tau_g = 0.85$. Also take collector efficiency factor, F' = 0.85, heat loss co-efficient = 8 W /m2-C, Tilt and intercept factor is 1. Find the useful heat gain, exit temperature of fluid and collector efficiency.

Solution:

Solar energy absorbed by the absorber,

$S = Ib\ Rt\ (\alpha\tau)_{ab}\ [r_r\ \tau_g\ Fi + (d / (W\text{-}d))]$ = **442.4 W/m2**

Heat removal factor, HRF , $F_R = P\ [\ 1 - \exp(- F'/ P\ ]$ = 0.813

(Where $P = m\ Cp / \pi\ d\ L\ U = 9.56$)

Concentration Ratio, $CR = (W\text{-}d) / \pi d = 11.93$

Useful heat gain, $Qu = F_R\ (W\text{-}d)\ L\ [\ S - U /CR\ (Ti - Ta)$ = **7167.6 W**

Exit temperature, $Qu = m\ Cp\ (To - Ti)$, **To = 196 °C**

Collector efficiency, $\eta = Qu / [Ib\ Rt\ W\ L]$ **= 0.41 %**

SOLAR PARABOLIC TROUGH POWER GENERATION

An array of parabolic trough collectors are used to achieve high temperature around 400 °C of water and an additional firing involved to run during non-solar times as well as lean solar time. The working principle is simple steam power cycle (Rankine cycle). The steam power cycle has the components like turbine, condenser, cooling tower and pump. This power cycle can employ a direct HTF from the collector to turbine or binary fluid as one HTF in the solar collector field and another HTF in turbine through a heat exchanger.

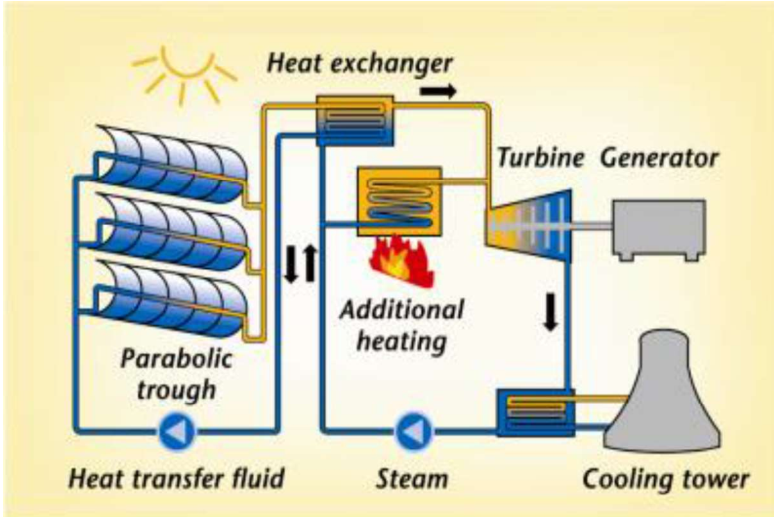

Fig.2.10.Parabolic trough power plant

SOLAR CENTRAL RECEIVER POWER PLANT

The boiler is placed centrally in the large mirrors field. Array of heliostat mirrors are used to focus the solar rays towards the central receiver to produce high temperature more than 500 °C in order to produce steam out of feed water. The generated steam is used to run a steam turbine and then the exhausted low pressure water is condensed in condenser and pumped back to the boiler.

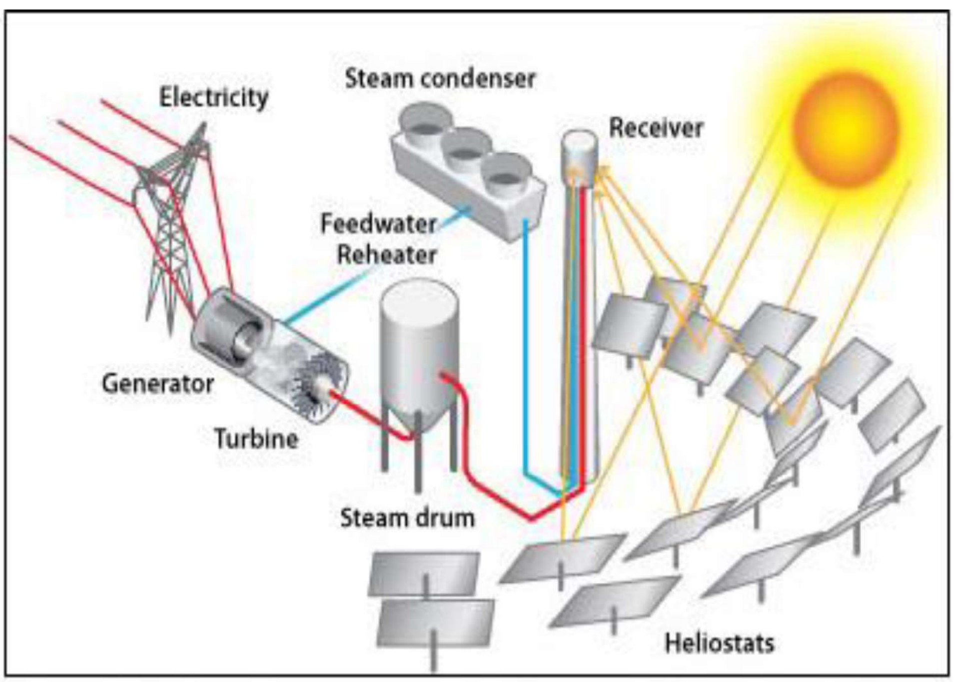

Fig.2.11.Solar tower (central receiver) power plant

SOLAR STILLS (SOLAR DESALINATION)

The working principle of solar stills is similar to rainfall. The evaporation and condensation of saline or sea water is used in the solar stills to produce potable water.

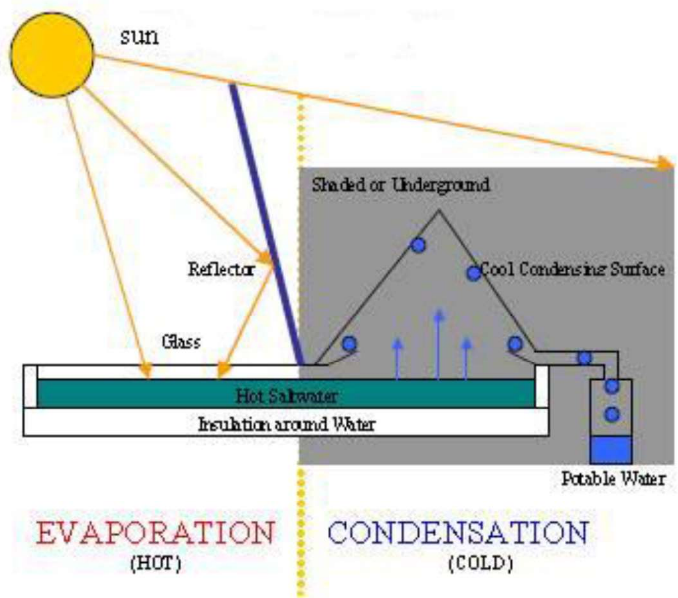

Fig.2.12. Solar Still

The solar energy is used to evaporate the salt water using the focused solar radiation and the condensation of that vapour takes place in the shaded or underground place. The shaded or cold surface is used as condensing surface. The condensed water is collected.

SOLAR COOLING AND REFRIGERATION

The solar cooling and refrigeration system operates based on vapour absorption refrigeration principle or vapour compression refrigeration principle.

The solar vapour absorption refrigerator has the following components:

1. Generator
2. Absorber
3. Condenser
4. Evaporator
5. Heat exchanger
6. Pump and throttle valves

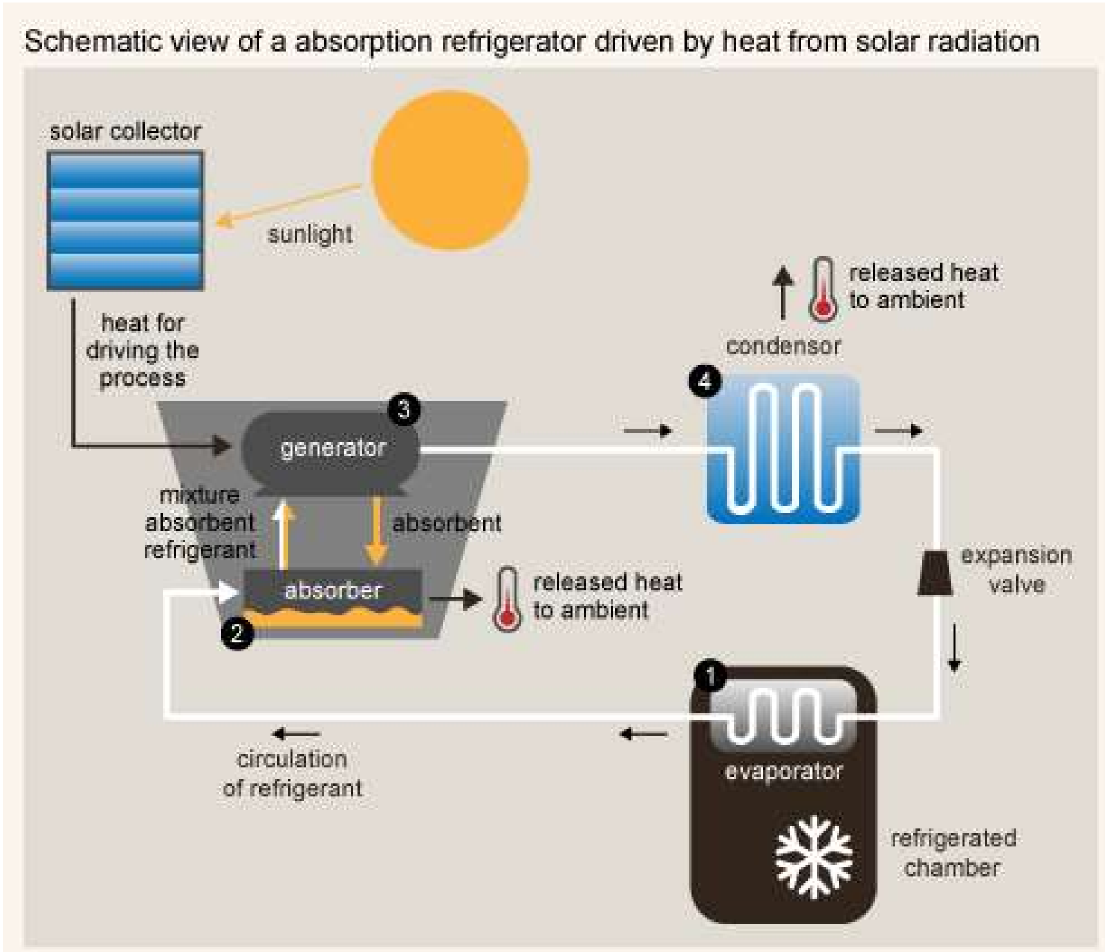

Fig.2.13. Solar Vapour absorption Refrigeration

Solar energy is used to run the vapour generator of the system. The high pressure hot water around 120°C is used in the generator to separate the refrigerant and absorbent. The absorbent material is having great affinity towards the refrigerant vapour. The strong mixture (rich refrigerant in the absorbent liquid) is pumped to the generator and then the refrigent vapour goes to the condenser and then its expanded to low pressure and temperature liquid in a throttle valve. This refrigerant liquid is absorbs the heat in the evaporator section and the refrigerant vapour is absorbed by the absorbent in the absorber and the cycle is repeated.

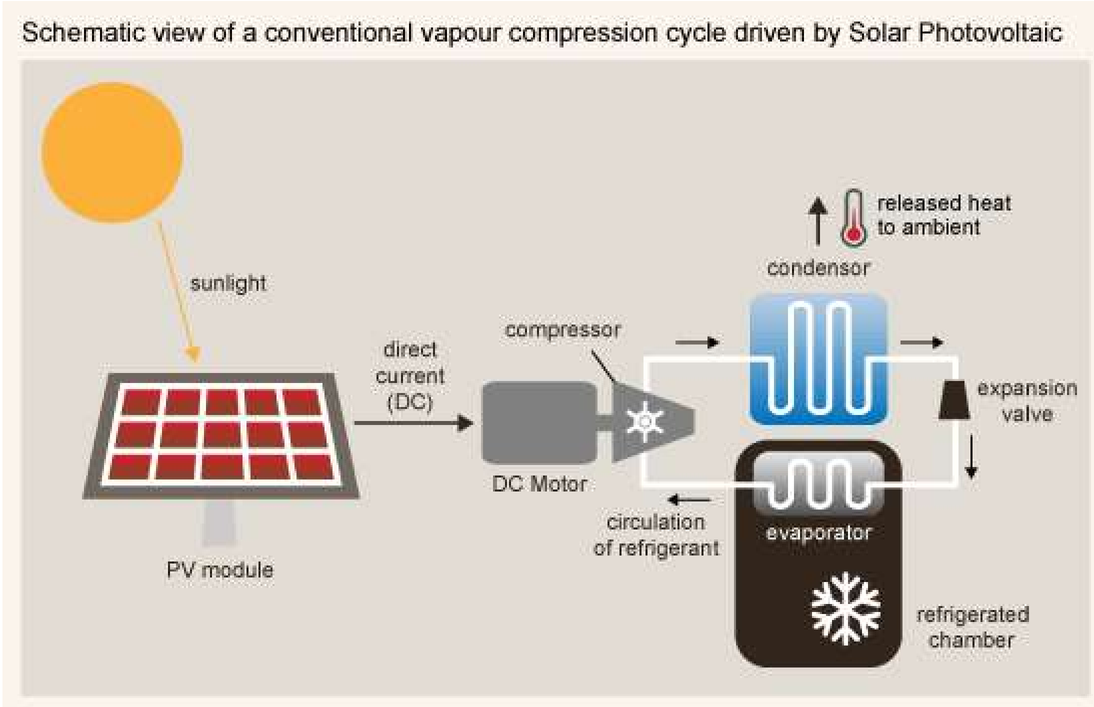

Fig.2.14 SPV operated vapour compression refrigeration system

The solar vapour compression refrigeration can be run by DC/AC motor (using solar photovoltaics) or using solar operated vapor turbine. The first case requires solar PV panels and or a battery. The second case requires a solar thermal steam generation systems with parabolic trough or dish system and the turbine is connected with the vapour compressor of the vapour compression refrigeration system.

SOLAR AIR-CONDITIONING SYSTEM

This solar HVAC consists of heat supply system, chilled water supply system, air-conditioned space. The chiller operates on vapour absorption refrigeration principle. The vapour absorption refrigeration based chiller is used to provide cold energy. The water passed to the chiller gets cooled and the cold water supplied to the room and the blower flows air over the cold water coils and the chilled air supplied to the room. The return air from the room exhausted to the atmosphere.

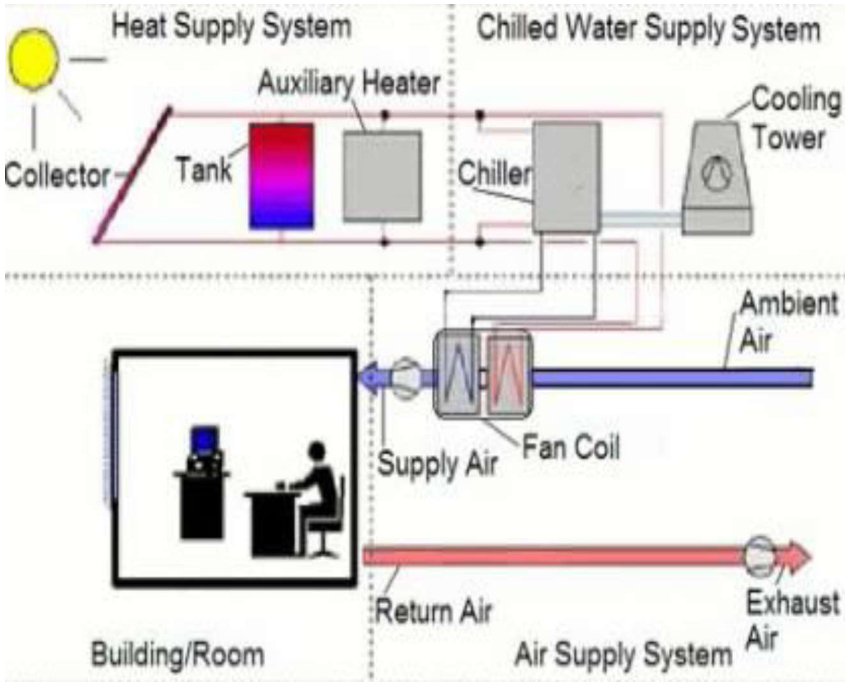

Fig 2.15. Solar A/C system

In case of solar combined heating and cooling, the vapour absorption chiller and a hot water coils are used. The hot water circuit used for the heating needs and the chiller provides the cooling needs.

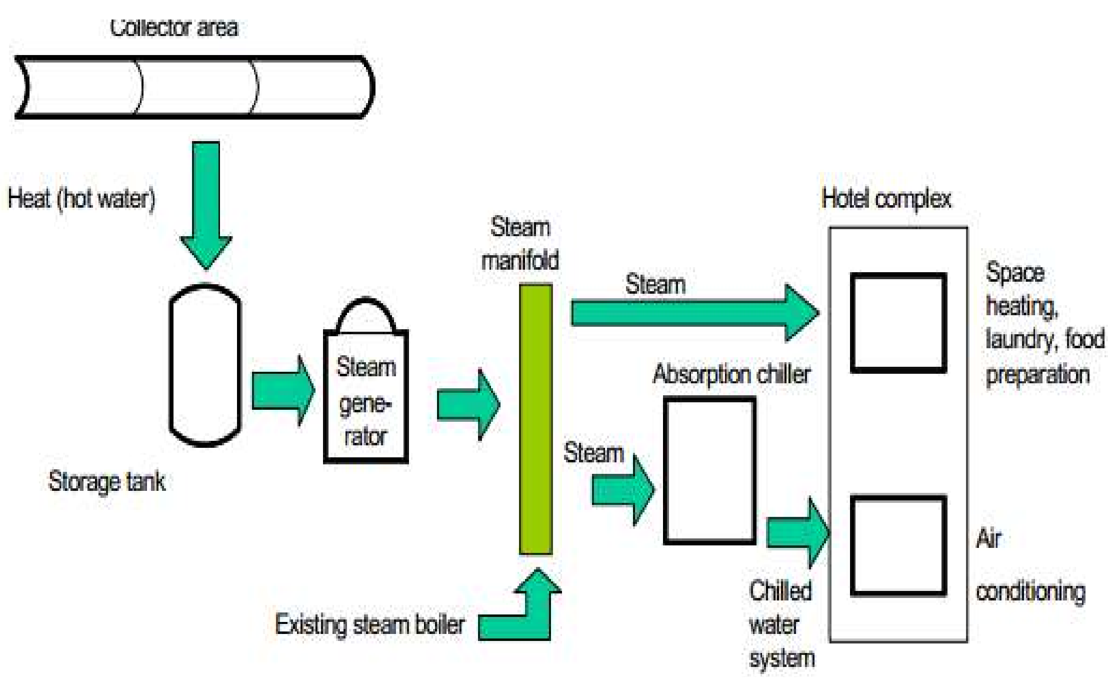

Fig.2.16. Solar heating and cooling in hotels (combined heating and cooling)

SOLAR PHOTOVOLTAIC SYSTEMS (SPV)

Semiconductor materials (Si) are capable of conducting electricity if the more than 1.12 eV is supplied. The semiconductors are doped with some impurities to make n (excess electron) or p (excess hole) type semiconductor. Doping materials Boron, Cadmium etc.

SPV Cells uses semi-conductor materials which is capable of free the electrons by use of light energy (Photon-light or sun rays into Electrons – electricity). The p-n type semiconductors are arranged and the n-type has mobile electrons and p-type has mobile holes and the photons (more than 2 eV) produces the DC electricity from the SPV panels. The arrangement of solar panels (multiple solar cells) will give the desired electric power.

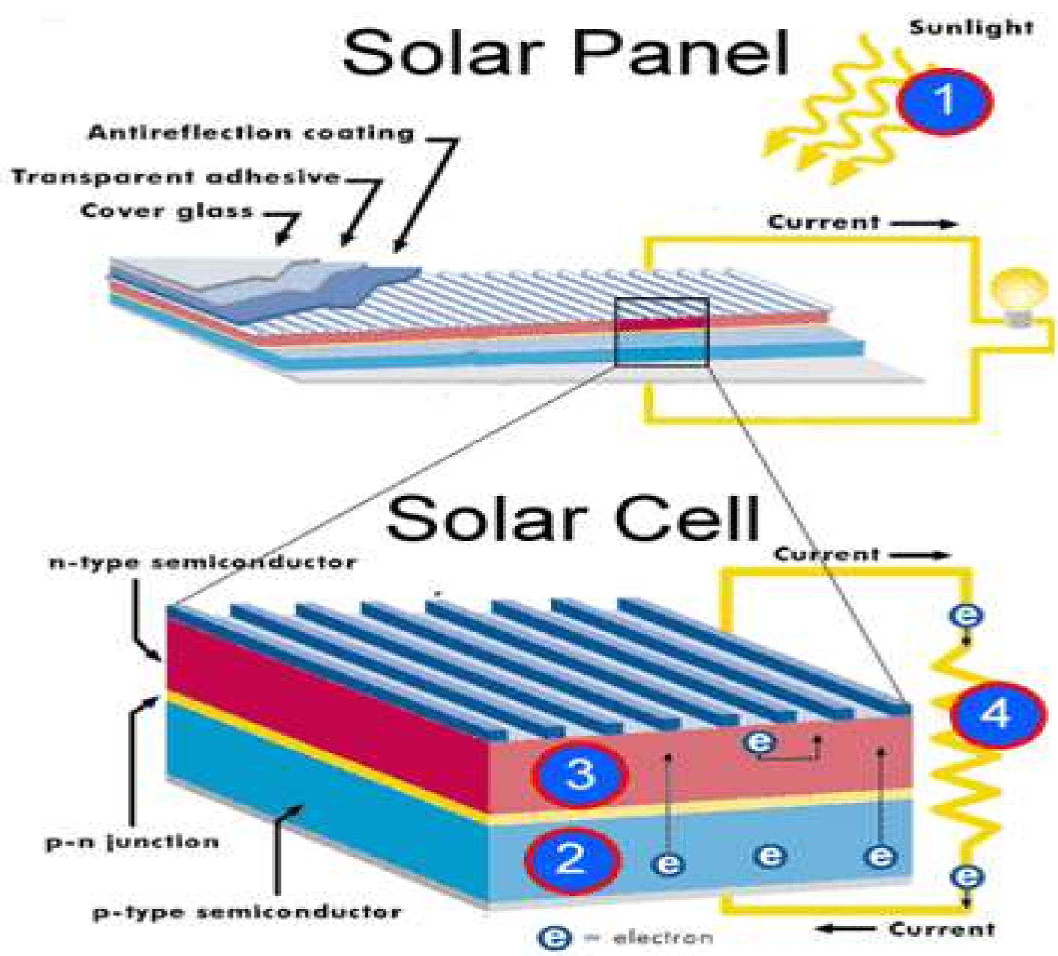

Fig.2.17. Solar Cell construction

Solar PV Modules, Panels and Array

Cells require protection from the environment and are usually packaged tightly behind a glass sheet. When more power is required than a single cell can deliver, cells are electrically connected together to form photovoltaic modules, or solar panels. A single module is enough to power an emergency telephone, but for a house or a power plant the modules must be arranged in multiples as arrays.

Cell : A single SPV cell.
Module: No. of interconnected encapsulated solar cells. A photovoltaic module is a packaged, connected assembly of solar cells.
Panel: Collection of modules. A solar panel is a set of solar photovoltaic modules electrically connected and mounted on a supporting structure.

Array: Collection of panels

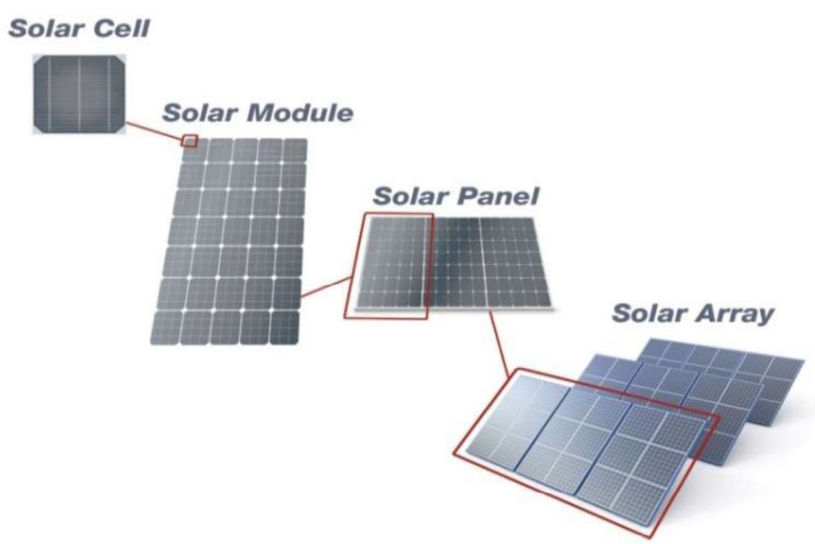

Fig. 2.18. SPV Construction

Photovoltaic power capacity is measured as maximum power output under standardized test conditions (STC) in "Wp" (Watts peak). The actual power output at a particular point in time may be less than or greater than this standardized, or "rated," value, depending on geographical location, time of day, weather conditions, and other factors. Solar photovoltaic array capacity factors are typically under 25%, which is lower than many other industrial sources of electricity. A photovoltaic system typically includes a panel or an array of solar modules, an inverter, and sometimes a battery and or solar tracker and interconnection wiring.

Types of SPV Cell technology

1. Crystalline Silicon solar cells - Single (Mono), Multi (Poly), Ribbon
2. Thin Film solar cells - Silicon, a-Si, m-Si, CdTe, CIGS
3. Concentrating solar cells - Si, GaAs
4. Dye, Organic, nano materials & other emerging solar cells

Characteristics of SPV

SC Current: The short-circuit current is the current through the solar cell when the voltage across the solar cell is zero (i.e., when the solar cell is short circuited). The short-circuit current is due to the generation and collection of light-generated carriers.The short-circuit current is the largest current which may be drawn from the solar cell.

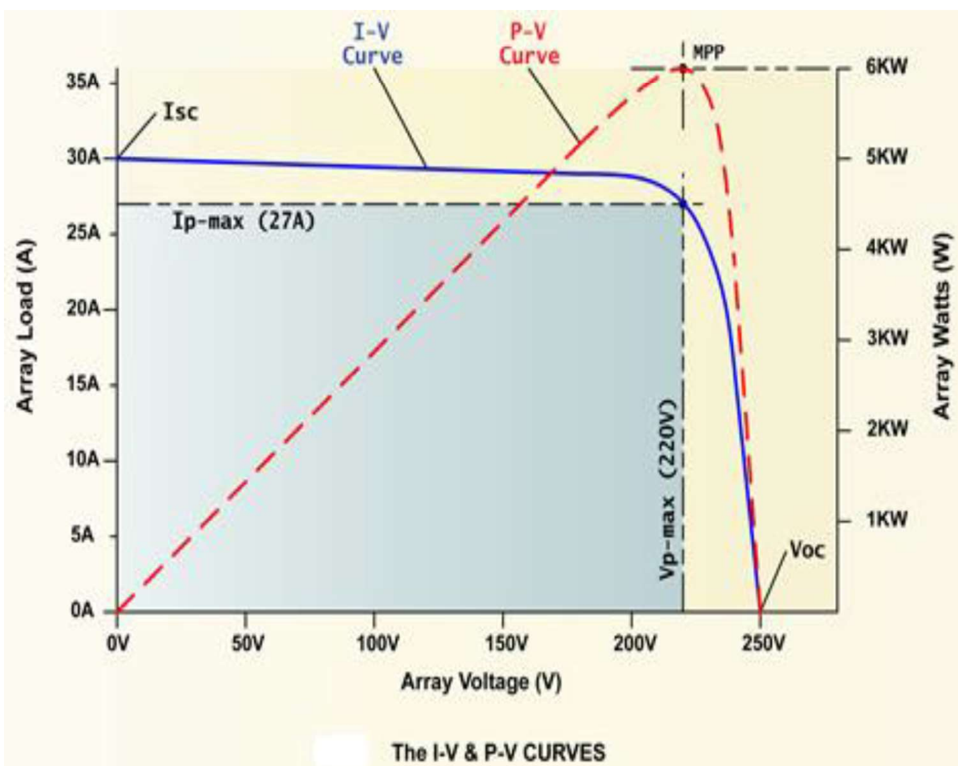

Fig.2.19 SPV I-V Curve and Power Curve

OC Voltage: The open-circuit voltage, Voc, is the maximum voltage available from a solar cell, and this occurs at zero current. The open-circuit voltage corresponds to the amount of forward bias on the solar cell junction due to illumination.

Maximum Power: Power out of a solar cell increases with voltage, reaches a maximum (Pm) and then decreases again.

Fill factor: The FF is defined as the ratio of the maximum power from the actual solar cell to the maximum power from a ideal solar cell.

FF = Im Vm / (Isc Voc)

PV Efficiency: Efficiency is defined as the ratio of energy output from the solar cell to input energy from the sun. Efficiency of a cell also depends on the solar spectrum, intensity of sunlight and the temperature of the solar cell.

Efficiency = Max cell power / Incident light energy

= Vm Im / Pi

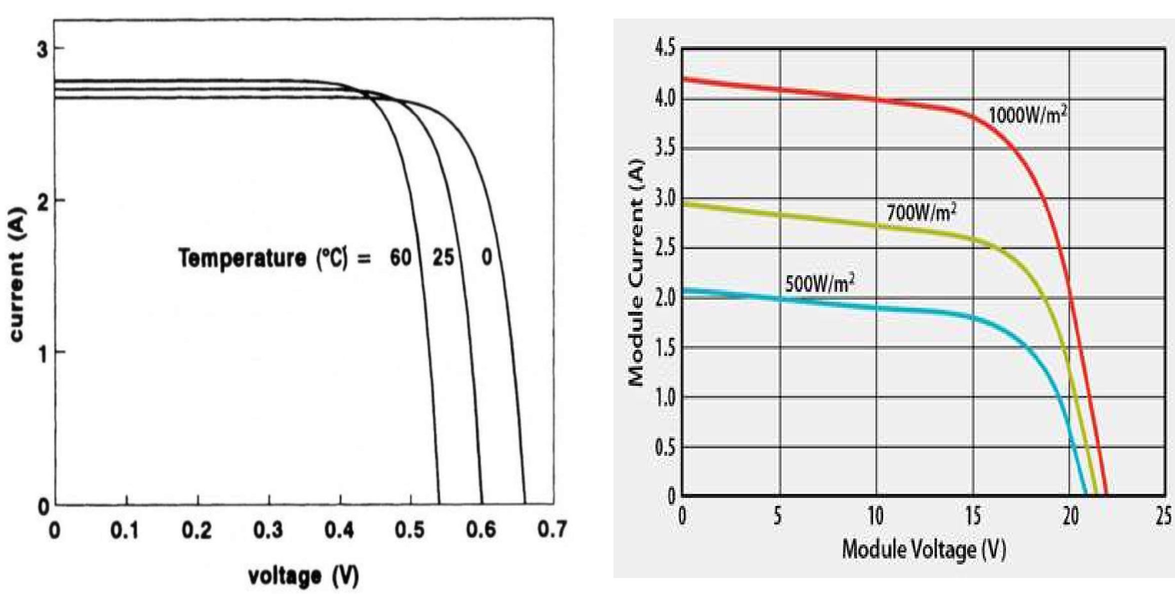

Fig.2.20 I-V characteristics for cell temperature and solar insolation

Effect of solar irradiance : PV power output increases with increase in Solar irradiance.
Effect of Cell temperature : Cell temperature increases means SC current increases and the power decreases.

The practical application of photovoltaic:

- To power orbiting satellites and other spacecraft,
- Used for grid connected power generation. (An inverter used to convert the DC to AC).
- For off-grid power for remote dwellings, boats, recreational vehicles, electric cars, roadside emergency telephones, remote sensing, and cathodic protection of pipelines.

PV CELLS/MODULES CONNECTIONS

Series connections: Adds Voltage

Parallel connections: Adds current

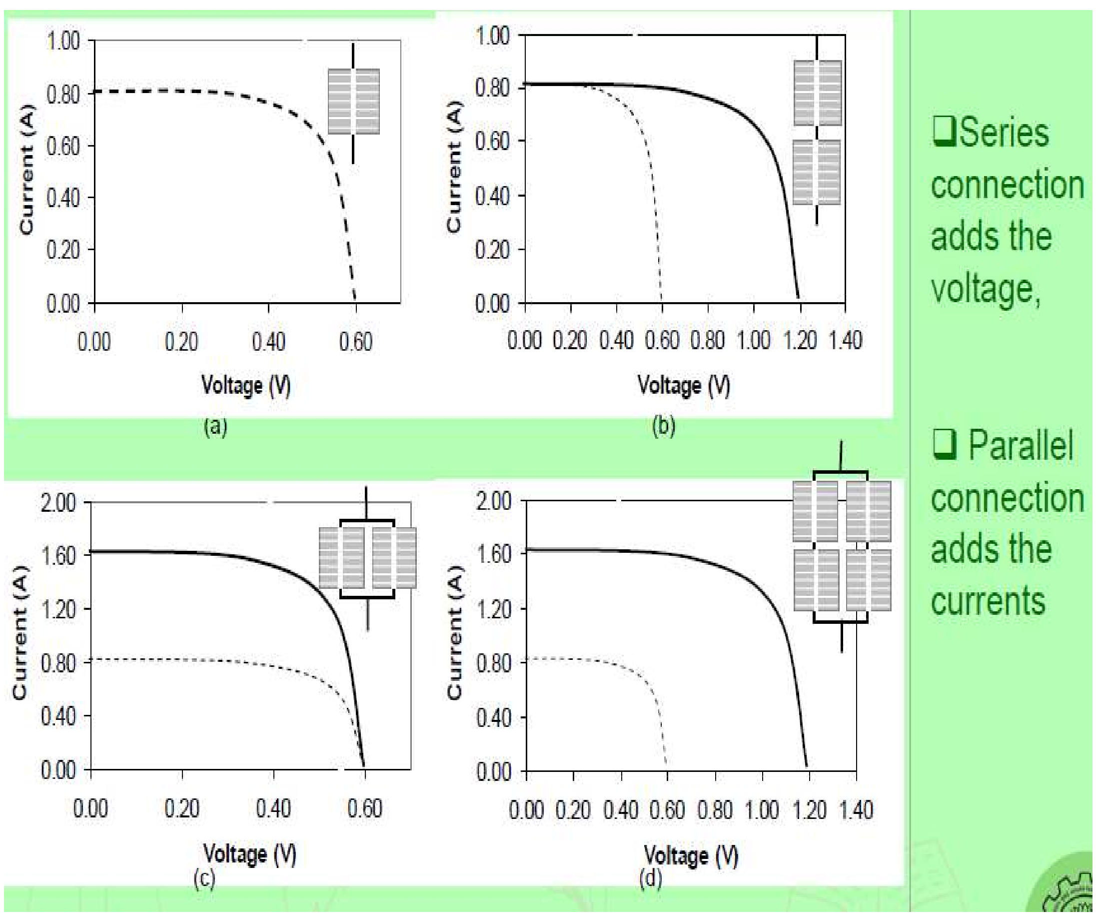

Fig. 2.21. Series and Parallel connections of SPV cell/module

Power electronic circuits of SPV system

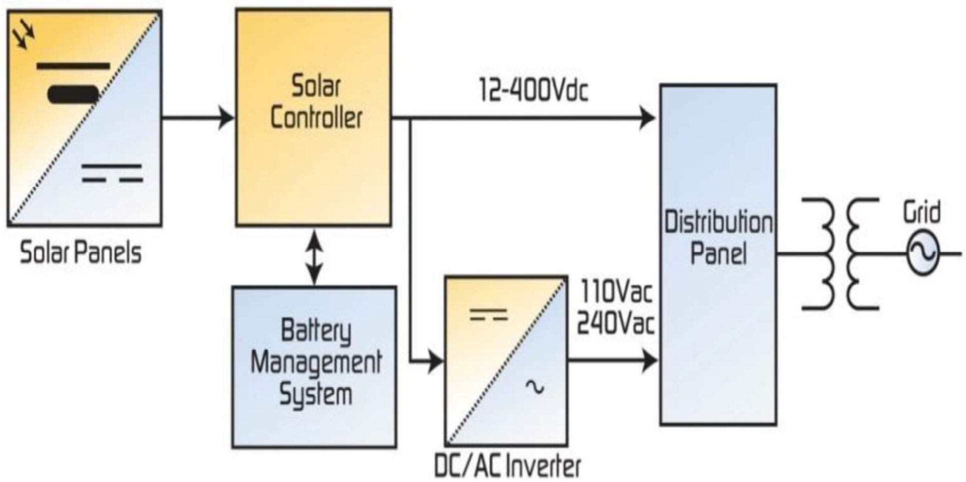

Fig.2.22 Solar PV system with battery / grid-tied

A photovoltaic (PV) system may be a combination of several components such as a battery system, DC/AC conversion circuits, and other power conditioning devices in addition to the solar panels themselves.

DC/DC converters are also useful in circuitry designed to draw maximum power from solar panels in what are called maximum power point trackers (MPPT). In the absence of a MPPT and depending on the load connected directly to solar panels, a great deal of the solar panel's electrical power may be dissipated in the form of heat. In the interest of maximizing energy efficiency, MPPTs are connected between the solar panels and load to ensure that the solar panels are producing their maximum power despite variations in light intensity and/or other factors that may vary within the system. MPPTs may be used in the presence or absence of battery charging systems but are more often used in grid-connected systems that have no batteries.

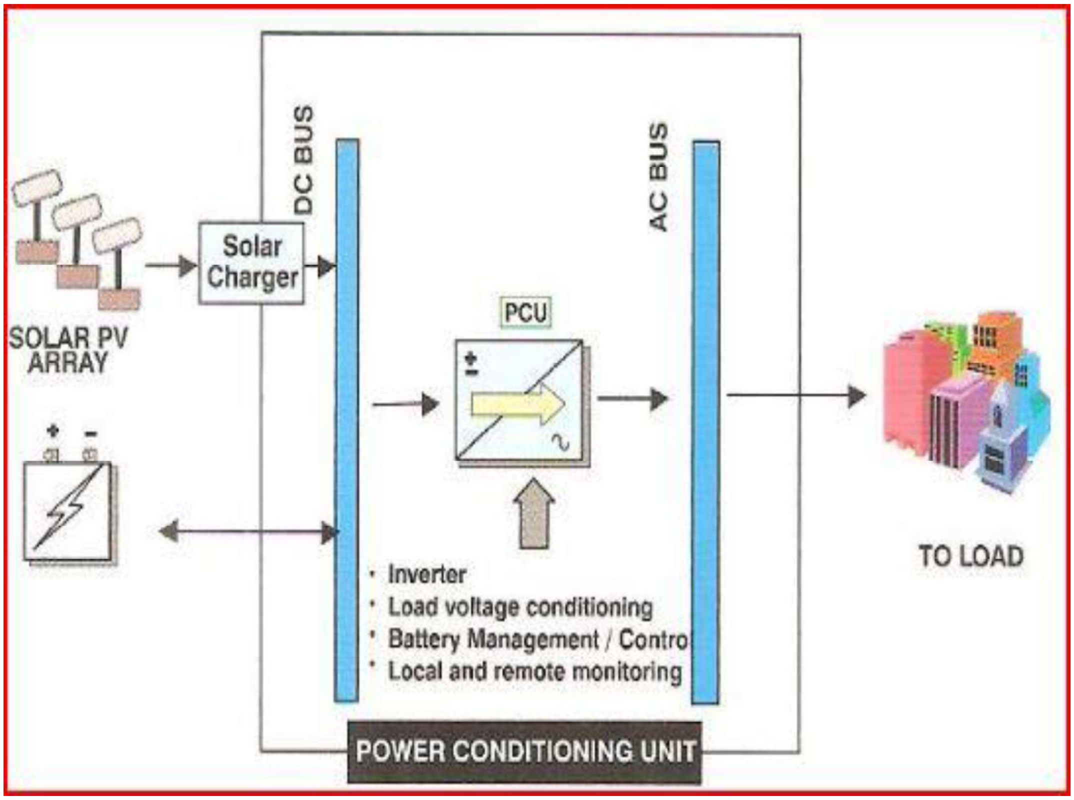

Fig.2.23. Solar PV Power conditioning Unit

Challenges in SPV technology

1. High cost per unit watt (high cost of material)
2. Moderate efficiencies ,
3. Availability of material ,
4. Long term stability,
5. Long energy payback period (high processing cost) & long money payback period etc.

SPV Applications: Power generation, Home lighting systems, Street and garden lighting system, Traffic control system, Railway signaling equipment, Battery charging e.g. Mobile, telephones.

Advantages of Solar Energy

1. Non-depleting sources of energy
2. Free of energy cost
3. No air pollution

4. No water pollution
5. No soil pollution
6. No fuel transport
7. No ash/waste disposal
8. Abundant sources of energy
9. Reduces the fossil fuel dependency
10. Useful for thermal and electricity need in remote places
11. Useful in space shuttles and ships
12. Cooling and heating possibility with solar energy
13. Useful in refinery processes
14. Used for power generation as well as process heating applications
15. Creates wind energy.

Limitations of solar energy

1. Availability – intermittent, available during day time
2. Dilute source – very low concentration of solar energy
3. Susceptible to climatic changes – clouds, rain etc.
4. Variable intensity throughout the day
5. Energy storage is required based on the demand
6. Conversion efficiency is very low (SPV < 15 %)
7. Costlier energy conversion equipment cost
8. Occupies larger area per kWh
9. Special coated solar grade mirrors required
10. Suitable corrosion resistant materials to be used