Solar cooker

SOLAR COOKER

A Solar cooker is a cooking derive that utilizes the energy of direct sunlight to cook or heat food and liquids.
Solar cookers concentrate sunlight onto a receiver such as a cooking pan.
The interaction between the light energy and the receiver material converts light to heat and this is called absorption. The conversion is maximized by using materials that absorb, conduct, and retain heat.

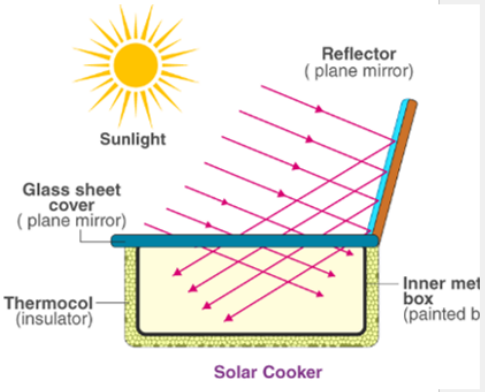
The device consists of

Black Box – The box is an insulated metal or wooden box which is painted black from the inside to absorb more heat.

Glass Cover – A cover made of two sheets of toughened glass held together in an aluminium frame is used.

Plane Mirror reflector – The plane mirror reflector is fixe with the help of hinges. The mirror reflector can be positioned at any desired angle to the box. The mirror is positioned so as to allow the reflected sunlight to fall on the glass cover of the box.

Cooking Containers – A set of aluminium containers blackened from the outside are used.



WORKING PRINCIPLE

- A mirror surface with high specular reflection is used to concentrate and channelize light from the sun into a small cooking space.
- The interaction between the light energy and the receiver material helps to convert light into heat by a process called conduction.
- The conversion is maximized by making use of materials that conduct and retain heat. Pots and pans used in solar cookers are painted with black color to maximize absorption.
- The sunlight can be concentrated by several orders of magnitude, producing magnitudes high enough to melt salt and metal. For household solar cooking applications, such high temperatures are not required.
- Solar cookers available in the market are designed to achieve temperatures of 65ºC to 400ºC.

ADVANTAGES

- **Solar cookers use no fuel. This saves cost as well as the environment by not contributing to pollution.**
- **Reduces carbon footprint by cooking without carbon dioxide-based fuels.**

DISADVANTAGES

- **Solar cookers are less useful in cloudy weather.**
- **Some solar cookers take longer to cook food than a conventional stove or an oven.**
- **Some solar cookers are affected by strong winds which can slow the cooking process.**
- **It might get difficult to cook some thick foods such as large roasts and loaves of bread.**

Define (i) Declination Angle (ii) Latitude angle (iii) Zenith Angle (iv) Solar Azimuth Angle (v) Surface Azimuth Angle (vii) Angle of Incidence (vii) Tilt Angle (viii) Hour Angle with respect to solar radiation.

1. Declination Angle (δ)

It is the angle between a line extending from the center of the Sun and center of the earth and projection of this on earth's equatorial plane.

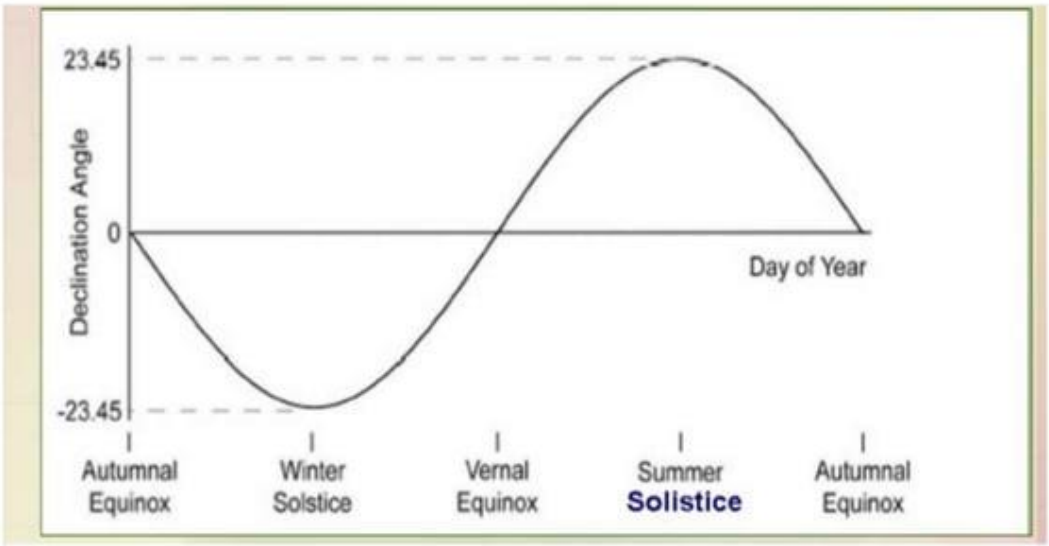
Declination is the direct consequence of earth's tilt and It would vary between 23.5º on June 22 to -23.5º on December 22. On equinoxes of March 21 & Sept 22 declination angle is zero

The declination is given by the formula

$$\delta = 23.45\ Sin\left\{\frac{360}{365}(284 + n)\right\}$$

Where n is the day of the year starting from Jan 1.
284 is the total solar days in a year.

DECLINATION (δ) (contd.)

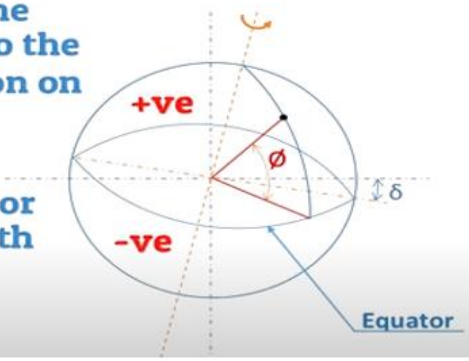


The variation in the declination angle throughout the year.

2. Angle of Latitude (ϕ)

It is the vertical angle between the line joining that point of location to the centre of the earth and its projection on an equatorial plane.

When the point is north of equator the angle is positive and when south it is negative.



Angles are represented as Ø° N or Ø° S of equator.

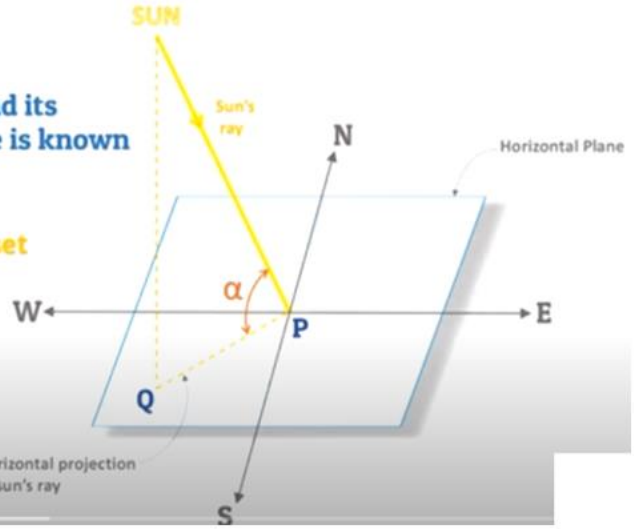
Also,

Ø = 0° for point on the equator
Ø = ±90° for a point at the poles

3. Inclination Angle (α)

The angle between sun's ray and its projection on a horizontal surface is known as the inclination angle (α).

→ α = 0° at sunrise and sunset



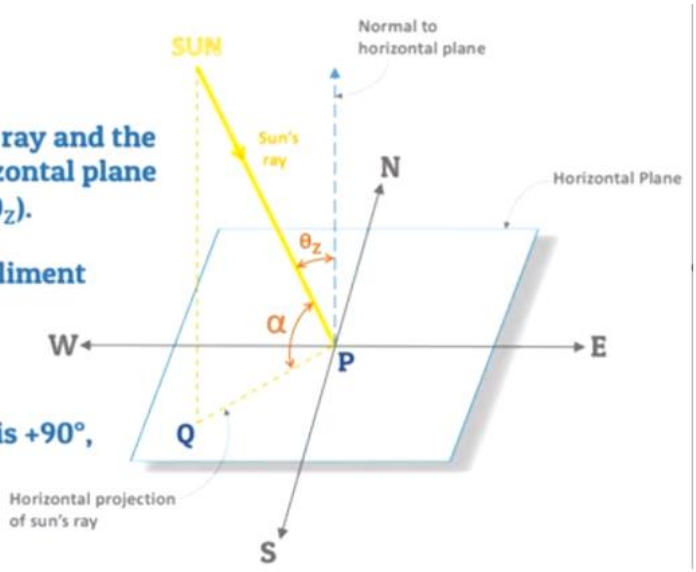
4. Zenith Angle (θz)

The angle between the sun's ray and the perpendicular (normal) to horizontal plane is known as the Zenith angle (θ_Z).

Also, Zenith angle is compliment of inclination (altitude) angle,

i.e. $\alpha + \theta_Z = 90°$

Hence, at sunrise zenith angle is +90°, whereas -90° at sunset.

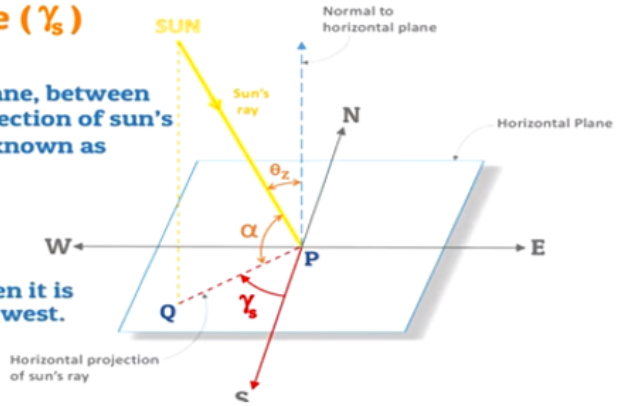


4. Solar Azimuth Angle (γs)

Solar azimuth angle (γ_s)

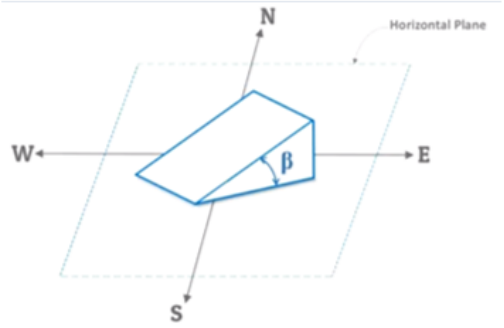
The angle on a horizontal plane, between the line due south and the projection of sun's ray on the horizontal plane is known as Solar azimuth angle (γ_s).

It is considered as positive when it is measured from south towards west.



5. Tilt angle/ slope angle (β):

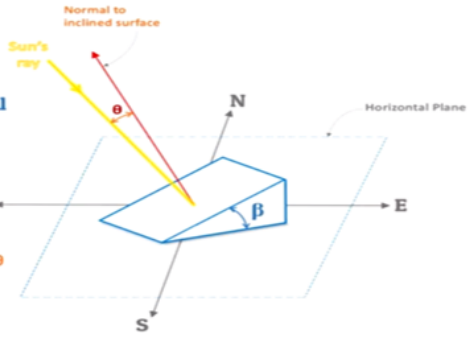
It is the angle made between the inclines collector surface with the horizontal plane.



6. Solar Incidence Angle (θ)

It is an angle between sun's ray incident on plane surface and normal to that surface.

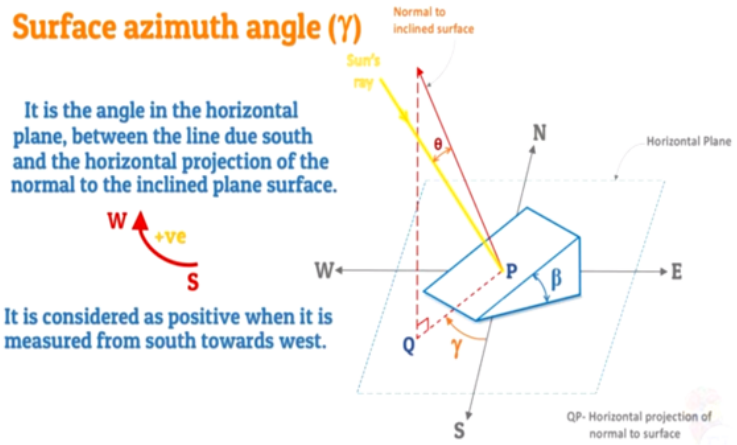
For Horizontal Surface,
Slope, β = 0°
Zenith Angle θ_z = Angle of Incidence θ



7. Surface Azimuth Angle (γ)

8. Hour angle(ω):

Hour angle is the angle through which the earth must turn to bring meridian of the point directly in line with the sun rays. Hour angle is equal to 15° per hour.



Define (i) Local Apparent Time (ii) Apparent motion of the sun.

Local Apparent Time (LAT)

The Local Apparent Solar Time at a particular geographical longitude is the hour angle of the Apparent Sun plus 12 hours. It is the time indicated by a sundial. local apparent solar time does not proceed at a uniform rate.
Local Solar Time can be calculated from standard time by applying **two corrections.**

The first correction arises due to the difference in longitude of the location and meridian on which standard time is based. The correction has a magnitude of 4minutes for every degree difference in longitude.

Second correction called the equation of time correction is due to the fact that earth's orbit and the rate of rotation are subject to small perturbations. This is based on the experimental observations.

Apparent Motion of Sun.

The position of the sun at sunrise appears to change on the horizon every day. Its position appears to move towards the north or south in the course of a year. However, in reality, the sun does not move anywhere. This movement of the sun towards the north or south in a year is **called the apparent movement of the sun.**

Day Length

The duration of the period of light between sunrise and sunset is called as **Day Length**.

Calculate the number of sun shine hours for New Delhi on December 22 and June 22 1995.

Calculate the number of daylight hours (sunshine hour) in Delhi on 22 December & 22 June 1995.

Solution: Here $\emptyset = 28^0 35^I$ (Value of Latitude for the location of Delhi)

For 22 December 1995, n=356

Find

$$\delta = 23.45 Sin\left[\frac{360}{365}(284+n)\right] = -23.44^0$$

$$N = \frac{2}{15} Cos^{-1}\left[-\tan(\delta).\tan(\phi)\right] = 10.18\, hours$$

Similarly, for 22 June 1995, n=173

$$\delta = 23.45 Sin\left[\frac{360}{365}(284+n)\right] = 23.45^0$$

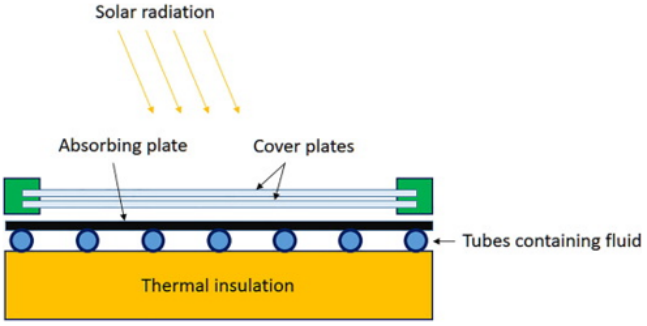
$$N = \frac{2}{15} Cos^{-1}\left[-\tan(\delta).\tan(\phi)\right] = 13.82\, hours$$

With a neat sketch, explain the process of generation of heat energy from flat plate collectors using solar radiation.

SOLAR FLAT PLATE COLLECTORS

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

This plate heats up, transferring the heat to water which is held between the glazing and absorber plate.
These absorber plates are painted with black coatings to absorb and retain the heat. These plates are usually made out of metal that is a good conductor usually copper or Aluminium.



ADVANTAGES

- we can easily design the flat plate collector
- Low cost in market 💰
- it can capture the heat from direct and diffuse both radiations 🌞
- Tracking mechanism is not used so it's simple
- Less maintenance is required
- it's operation is based on renewal energy source that is big advantage
- it receives the radiation from all directions
- it's operation is pollution free

DISADVANTAGES

- Low thermal efficiency
- we can't use in rainy season
- requirement of Larger collecting area
- it can not operate in absence of solar radiation

Explain (i) Parabolic dish solar collector (ii) parabolic trough solar collector with a neat sketch.

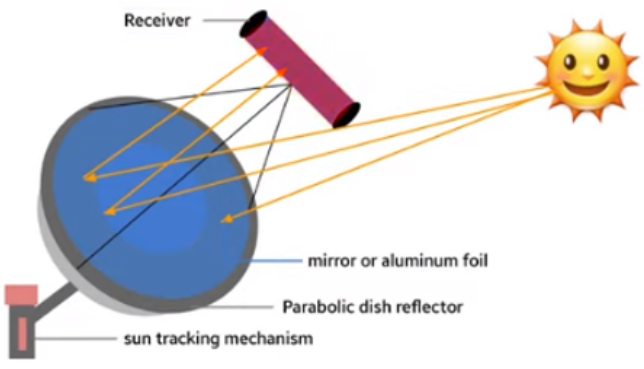
PARABOLIC DISH TYPE SOLAR CONCENTRATOR

This device resembles a parabolic shape and hence the name is parabolic dish collector/concentrator.

The main principle of this is that it reflects the solar radiation.

This device consists of

- Mirror or aluminum foil
- Parabolic dish reflector
- Sun tracking mechanism or reflector stand
- Receiver – a transparent glass hollow piper which absorbs all types of radiation



WORKING PRINCIPLE

- Solar Parabolic Dishes work by focusing sunlight onto a central receiver, where it is absorbed and transformed into heat using a parabolic reflector. The parabolic dish has two (2) functions: either collecting or refracting solar energy.
- Solar Parabolic Dish is a type of Solar Collector that uses a parabolic reflector to focus sunlight onto a central receiver, where the solar energy is absorbed and converted into heat.
- It accomplishes this through the use of a computer and dual-axis tracking.
- The central receiver shaped like a glass tube and coated with black paint contains a fluid which gets heated up and evaporated there by resulting in generation of electrical energy.

ADVANTAGES

- Parabolic dish solar concentrators has high conversion efficiency .
- It can withstand a high temperature range.

Disadvantages:

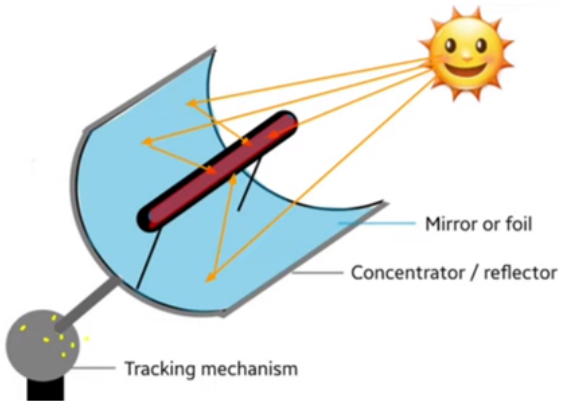
- High maintenance.

SOLAR PARABOLIC TROUGH COLLECTOR

This device consist of

- Mirror or a Aluminum foil
- A reflector or concentrator
- A Solar Tracking mechanism used to track the solar radiation on to the reflector
- A receiver – a transparent hollow pipe coated with black material as it receives the heat.

It uses a single-axis tracking curved mirror system to concentrate solar radiation onto a single point. A receiver tube, containing a heat transfer fluid, is located at the focal point of the mirror and collects the concentrated solar heat energy.



WORKING PRINCIPLE

- Parabolic trough consists of a series of curved mirrors which are used for concentrating the sunlight on thermal efficient receiver tubes located in the focal line of the trough.

- During the working , the direct solar radiation strikes on the mirror and also on the receiver.

- The radiation falling on the reflector are absorbed and reflected to receiver.

- The receiver receives the heat from over all solar radiation and the temperature rises.

- This receiver contains a fluid or gas or Synthetic oil, which is heated up to 400°C by the concentrated sunlight through the receiver tubes, is used as a heat transfer medium.

ADVANTAGES:

- It is used in domestic heating, industrial heating, solar pumping for irrigation etc
- Parabolic trough solar collectors are also reliable and have a long lifespan

Module 3

Derive an expression for power generated in wind mill.

Due to motion of wind, it posses certain energy. The wind mills are the devices converts kinetic energy of the wind into mechanical energy. The out put from the wind mill depends upon

i) the wind speed
ii) the cross section of the wind swept by rotor and
iii) the overall conversion efficiency of the rotor, transmission system and generator or pump.

It is not possible to design the wind mills to extract all of the wind's energy. An aero generator with 100 percent efficiency converts 60 to 70 percent of the available energy in the wind in to mechanical energy. The over all wind turbine efficiency is around 35 percent due to losses in gearbox, transmission system, generator or pump.

We know that

$$m = \rho AV$$

where m = Mass of air
ρ = Air density
A = Area through which air is traversing
V = Wind speed

But kinetic energy, $KE = 1/2\ mV^2$

substitute the value of m in the above equation, we get

$$KE = \frac{1}{2} \rho A\, V.V^2$$

$$\therefore \quad KE = \frac{1}{2} \rho.A.V^3 \text{ Watts}$$

From the above equation, it is clear that the wind speed have a significant effect on the power of the wind. It is also to be noted that the wind power is proportional to density of air, and the area incercepted by air. Thus an aero turbine with a large swept area has higher power. Considering horizontal axis aero turbines, then $A = \pi D^2/4$.

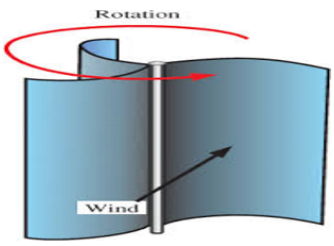
$$\therefore \text{ Available wind power, } P = \frac{1}{2} \rho \frac{\pi D^2}{4} V^3$$

$$\boxed{P = \frac{1}{8} \pi \rho D^2 V^3}$$

From the above equation, it is clear that the maximum power available from the wind is proportional to the square of the rotor diameter ie, swept area of the aero turbine.

With a neat sketch explain the working of savonius vertical axis wind mill.

i) Savanious rotor type vertical axis wind mill



➢**It has S shaped cross sectional rotors. In this case , rotor is subjected to lift & drag the forces. But drag force is more dominant as compared to lift forces , hence this devices is considered as drag device.**

➢**It has high starting torque, but lower power output per given rotor size, weight and cost.**

Advantages :
i) cost is less
ii) it is not depending of wind direction , hence yaw & pitch control is not required.
iii) Maintenance cost I s low

Disadvantages:
i) It is not suitable for large power generation.
ii) It is not suitable for very tall installation

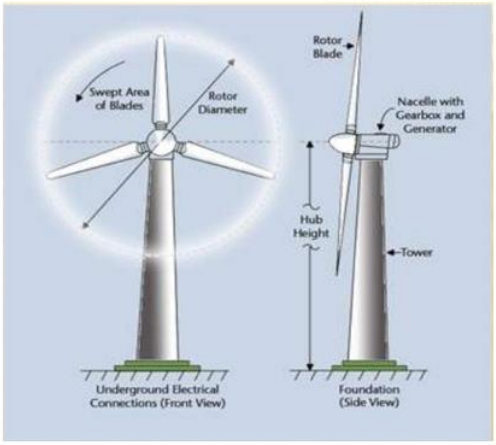
Briefly Explain the major problems associated with wind energy production.

Major problems associated with wind power:

- Its availability is not continuous i.e intermittent.
- Grid integration.
- Large space availability.
- Regulatory Barriers.
- The power output is very low even with large size wind mill rotors.
- The use of special controls and suitable materials, and costly designs are essential to avoid smashing of the wind mill plants.
- The wind mill has very low power coefficient and can have a maximum value of 0.593.
- It is not economical to develop wind power on a large scale. The electricity generation, storage and distribution is much costlier.
- Energy is available in very dilute form and large areas are needed to install wind mills.

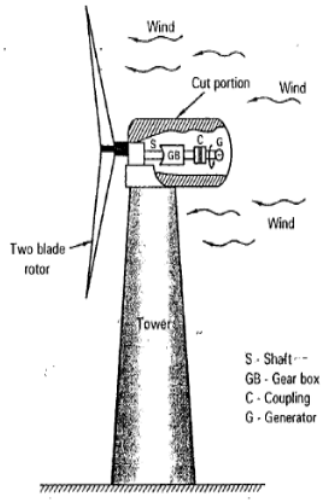
With a neat sketch explain the working of doubled bladed horizontal axis wind mill.

b) Multiblade Horizontal axis wind mill

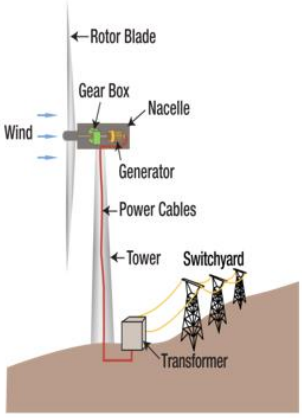


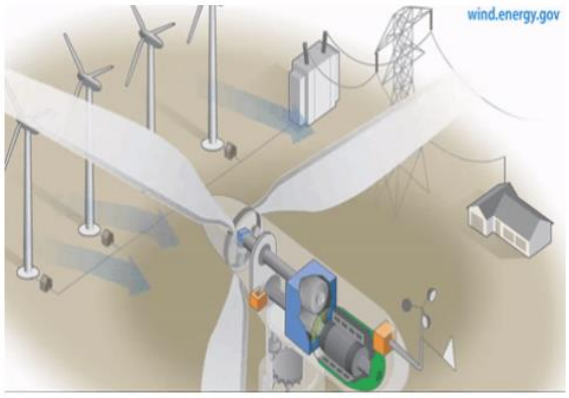
➢It consist of a propeller type rotor with aerodynamically designed blade.

➢The rotor is located downward of the tower . the transmission system is mounted directly on the tower. Tail vane is provided in order to change the face of blade according to direction of wind



- *Blades* are the main mechanical parts of a wind turbine. The blades convert wind energy into usable mechanical energy. When the wind strikes on the blades, the blades rotate. This rotation transfers its mechanical energy to the shaft.
- The *shaft* directly connected to the hub is a low-speed shaft. When the hub rotate, this shaft spins with the same rpm as the rotating blade.
- The low-speed shaft is geared with a high-speed shaft through a gearbox. The wind turbine does not rotate at high speed rather it rotates gently at low speed. *Gearbox* increases the speed to much higher value.
- The *generator* is an electrical device that converts mechanical energy received from the shaft into electrical energy.
- *Tower:* It's the cylindrical structure on which wind mill housing/casing is mounted. The transmission cable from generator comes down inside this tower to the high voltage transformer.





- The kinetic energy of the flow of wind causes the blades to rotate at slow speeds.
- The gear box comprising of many gears is used to increase the rotational speed of the shaft to that range required to produce electricity.
- The high speed of the shaft thus drives the generator to produce electricity.
- The power produced by the generator is transferred down the tower to the power grid system and then through the transmission lines.