UNIT – IV
POWER FROM RENEWABLE ENERGY

1. Draw the Layout diagram of Hydro Power Plant and also explain the components and working of Hydro power plant?

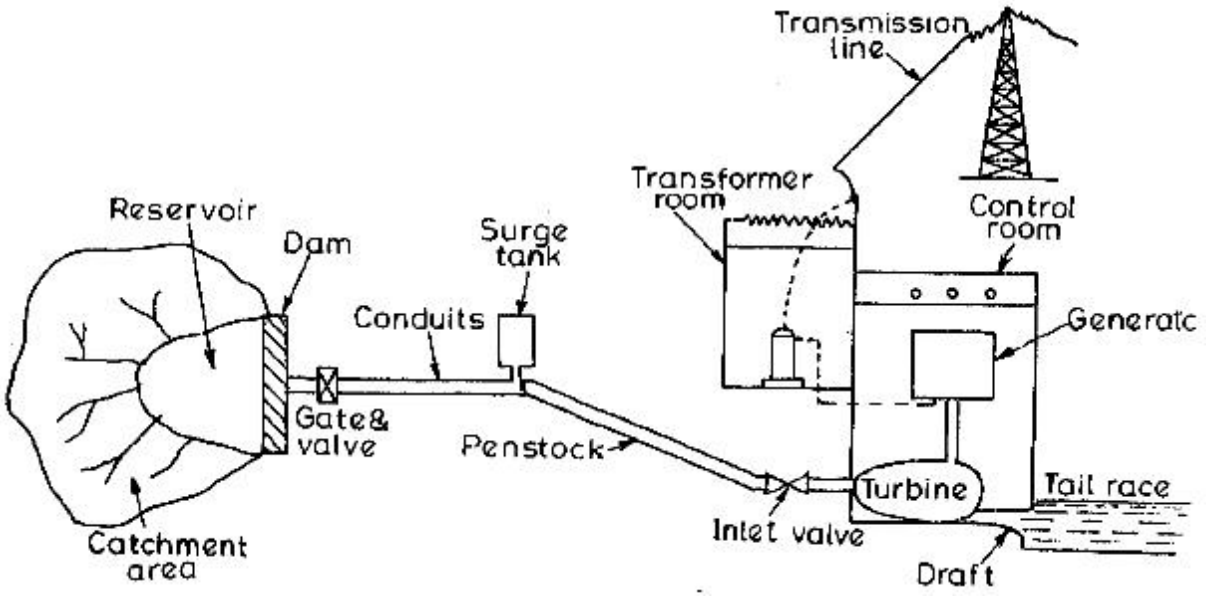
Introduction:

Hydro-electric power plant utilizes the potential energy of water stored in a dam built across the river. The potential energy of water is used to run water turbine to which the electric generator is coupled. The mechanical energy available at the shaft of the turbine is converted into electrical energy means of the generator.

Elements of Hydro Power Plant:

The schematic representation of a hydro-electric power plant is shown in figure.

- Catchment area
- Water reservoir
- Dam and the intake
- Inlet water ways
- Penstock and Surge Tanks
- Power house and its equipment
- Forebay and Spillways
- Draft Tube and Tail race



Catchment area:

- The area behind the dam, which collects rain water and drains into a stream or river is called catchment area.
- Water collected from catchment area is stored in a reservoir behind the dam.

Water reservoir:

- The water reservoir is the large area to store huge amount of water for the future irrigation purpose.
- The purpose of the reservoir is to store the water during rainy season and supply it during dry season.
- Water surface in the storage reservoir is known as head race level or simply head race.
- A reservoir can be either natural or artificial.
- A natural reservoir is a lake in high mountains and an artificial reservoir is made by constructing a dam across the river.
- Water held in upstream at the reservoir is called **storage** whereas water behind the dam at the plant is called **pondage**.

Dam:

- A dam is a structure of masonry earth and/or rock fill built across a river.
- It has two functions:
  a) To provide the head of water
  b) To create storage or pondage
- The basic requirements of a dam are economy and safety.
- The dam foundation must provide for dam stability under different forces and supports its weight.
- The foundation should be sufficiently impervious to prevent leakage of water under the dam.
- Concrete and masonry dams are quite popular and are made as:
  c) Solid gravity dam
  d) Buttress dam
  e) Arched dam

Water Intake:

- The intake house includes the work head which are the structure at the inlet of canals, tunnels or waterfalls.
- There are booms, screens or trash racks and channels for by passing the foreign particles and gate valves for controlling the water flow.
- Gates discharge excess water during flood duration.
- Gates are of different types such as **radial gates, sluice gates, wheeled gates, plain sliding gates, crest gates, rolling or drum gates, etc.**
- The various types of valves used are **needle valve and butterfly valves**.

Inlet water ways:

- Inlet water ways are the passages through which water is conveyed from the dam to the power house.
- It includes canal, penstock or tunnel, flume, forebay and also surge tank.

- Tunnel is made by cutting the mountains where canal or pipe line cannot be used due to slope regions.
- Tunneling provides a direct and short route for the water passages.

Penstocks:

- Water may be conveyed to turbines through open canals or closed pressure pipes called penstocks made of reinforced concrete or steel.
- It is desirable that the penstock should be slopping towards the power house.
- Penstocks usually are not covered and placed as exposed pipes which facilitates easy maintenance and repair.
- When there is danger from slides of snow, rock, earth etc. covered penstocks are used.
- The thickness of the penstock increases as working pressure or head of the water increases.
- Long penstocks are manufactured in sections and joined together by welding, the welded joints give less friction loss.

Surge Tanks:

- Surge tank is an additional storage space near the power unit which is usually provided in high head or medium head plants
- The surge tank provides additional water when the load on the turbine increases.
- When the load on the generator decreases, the gates allowing water to the turbines are suddenly closed, this cause sudden rise of pressure in the penstock above normal due to reduced load on generator is known as water hammer.
- Surge tank relieves water hammer pressures when the penstock under conditions of sudden changes in condition of water flow.
- The surge tank has the following functions:
    - To regulate the flow of water through the penstock,
    - To relieve water hammer pressures
    - To improve performance of the machines by providing better speed regulation.

Forebay:

- The water carried by the power canals is distributed to various penstocks leading to the turbine through the temporary storage path is called as Forebay also known as head pond.
- Water is temporarily stored in the forebay, this water is supplied when the load is suddenly increased.
- The forebay also acts as a sort of regulating reservoir.

Spillways:

- These structures provide for discharge of the surplus water from the storage reservoir into the river.
- Spillway is considered a safety device for a dam, which has the ability to discharge major floods without damage to the dam.
- There are several designs of spillways such as simple spillway, side channel spillway, siphon spillway, etc.

Power House:

- The power house is a building in which the turbines, alternators and the auxiliary plant are housed.
- Here conversion of energy of water to electrical energy takes place.
- Some of the main equipments provided in a power house:
    - ✓ Turbines coupled with generators
    - ✓ Turbine governors
    - ✓ Gate valves
    - ✓ Water circulating pumps and Flow measuring devices
    - ✓ Transformers and Reactors
    - ✓ Switch board equipment and instruments
    - ✓ Oil circuit breakers
    - ✓ Cranes
    - ✓ Shops and offices
- The turbines which are in common use are Pelton turbine, Francis turbine, Kaplan turbine and Propeller turbines.

Tail Race:

- Tail race is a passage for discharging the water leaving the turbine into the river.
- In certain cases, the water from the tail race can be pumped back into the original reservoir.
- The water held in the tail race is called as tail race water level.

Draft Tube:

- The draft tube is an essential part of reaction turbine installation.
- It is a diverging passage from the point of runner exit down to the tail race.
- Thus a draft tube has two main functions:
    - ✓ It permits the establishment of negative head below the runner and so makes it possible to set the turbine above the tail race level, where it is more easily accessible and yet does not cause a sacrifice in head.

- ✓ Its diverging passage converts a large portion of the velocity energy rejected from the runner into useful pressure head, thereby increasing the efficiency of the turbine.

2. What is the classification of Hydro Power plant? Explain in detail. (or) Explain the types of Hydro-Power plant with its proper layout.

Introduction:

- In hydro-plants, water is collected behind the dam through reservoir.
- Water reservoir may be classified as either storage or pondage according to the amount of water flow.
- The function of the storage is to hold excess river flow during the rainy season to increase the low rates of flow during dry seasons.
- With pondage, the water level always fluctuates during operations:
  - ✓ It rises at the time of storing water
  - ✓ It falls at the time of drawing water
  - ✓ It remains constant when the load is constant.

Classification of Hydro-power Plant:

The hydro-power plants can be classified as below:

- Storage plant
  - a) High head plants
  - b) Low head plants
  - c) Medium head plants
- Run-of-river power plants
  - a) With pondage
  - b) Without pondage
- Pumped storage power Plants.

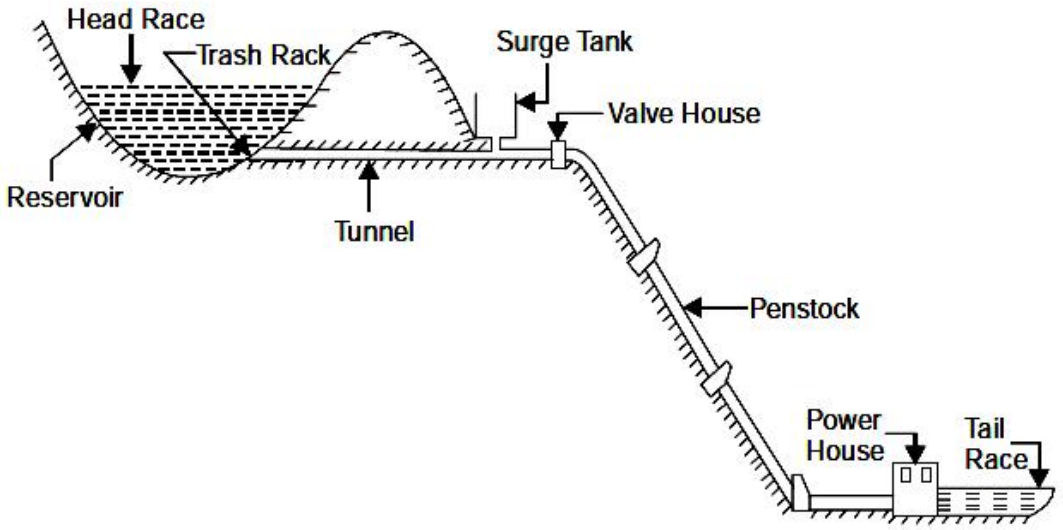
STORAGE PLANTS:

- These plants are usually base load plants.
- The power plant can be classified on the basis of head in the following manner:
  - (a) High head plants: **About 100 m and above**
  - (b) Medium head plants: **About 30 to 100 m**
  - (c) Low head plants: **Upto about 50 m**

High Head Plants:

- The water from the reservoir can be taken to a smaller storage known as a forebay by means of tunnels.

- The function of the forebay is to distribute the water to penstocks leading to turbines. The incoming flow to the forebay is so regulated that the level in the forebay remains nearly constant.
- The turbines will get constant water flow from forebay based on load condition.



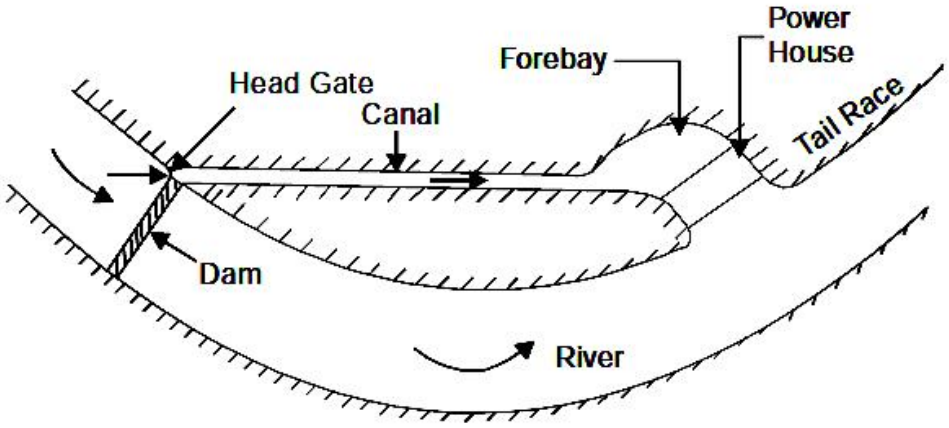
Schematic layout of High head plant

- Trash racks are fitted at the inlets of the tunnels to prevent the foreign matter from going into the tunnels.
- When the construction of forebay is not possible, vertical constructions known as `surge tanks' are built.
- The surge tanks are provided before the valve house and after the tunnel from the head works.
- The function of the surge tank is to prevent a sudden pressure rise in the penstock when the load on the turbines decreases and the inlet valves to the turbines are suddenly closed.
- In the valve house, the butterfly valves or the sluice type valves control the water flow in the penstocks and these valves are electrically driven.
- Gate valves are also there in the power house to control the water flow through the turbines.
- Finally, the water is discharged to the tail race.

Low Head Power Plants:

- These power plants are also known as Canal power plants.
- A dam is built on the river and the water is diverted into a canal.
- At the mouth of the canal, head gates are fitted to control the flow in the canal.
- The canal water is passed into a forebay which is allowed to flow through turbines.
- Screens or Trash-racks are designed in the final stage of forebay to prevent foreign particles into the turbines.
- After this process, the water is again discharged into the river through a tail race.

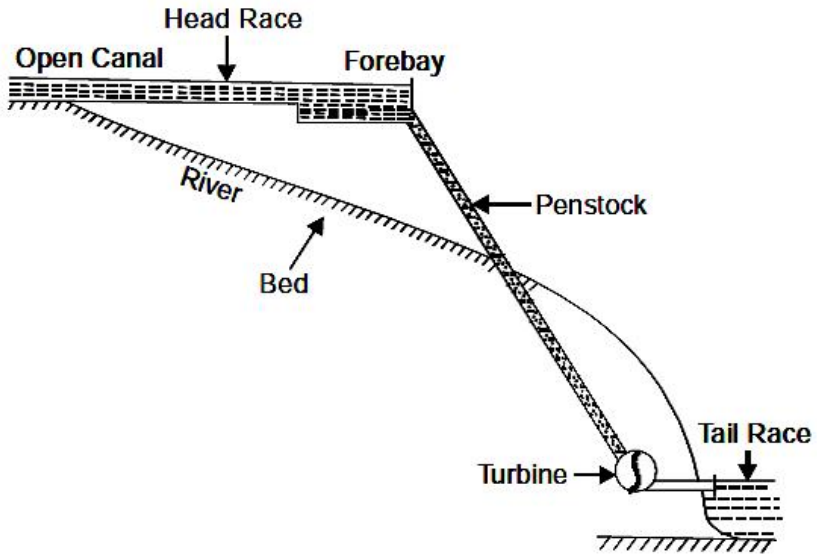
- If there is any excess water due to increased flow in the river or due to decrease of load on the plant, it will flow over the top of the dam and handled down into the river.
- For cleaning and repair of the canal and the forebay, the head gate is closed and the drain gate is opened so that whole of the water is drawn into river.



Low Head hydro power plant

Medium Head Plants:

- If the head of water available is more than 50 metres, then the water from the forebay is conveyed to the turbines through pen-stocks. Such a plant will then be named as a medium head plant.
- In these plants, some amount of the river water is diverted into the canal without the help of dam across the river.
- The canal water is passed into a forebay which is allowed to flow through turbines by means of penstock.
- Screens or Trash-racks are designed in the final stage of forebay to prevent foreign particles into the turbines.
- After this process, the water is again discharged into the river through a tail race.



Medium Head hydro power plant

RUN-OF-RIVER POWER PLANTS:

Run-Off power can be classified as

- ✓ Plants without pondage
- ✓ Plants with pondage.

a) Plants without pondage:

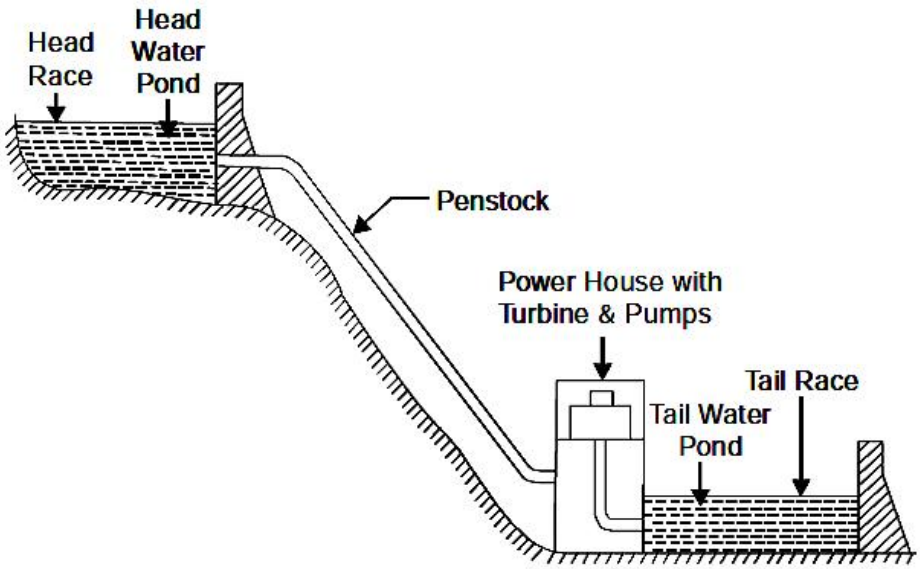
- A run-off river plant without pondage has no control over river flow and uses the water as it comes.
- These plants usually supply peak load.
- During floods, the tail water level may become excessive and so the plant is inoperative.

b) Plants without pondage:

- A run-of-river plant with pondage may supply base load or peak load power.
- At high water flow, the plant may be worked under base loaded conditions
- At low and medium water flow, the plant may be worked under peak loaded conditions

PUMPED STORAGE POWER PLANTS:

- These plants supply the peak load for the base load power plants and pump all or a portion of their own water supply.
- The usual construction would be a tail water pond and a head water pond connected through a penstock.
- The generating pumping plant is at the lower end.
- During off peak hours, some of the surplus electric energy is being generated by the base load plant.
- This energy is utilized to pump the water from tail water pond into the head water pond and this energy will be stored there.
- During times of peak load, this energy will be released by allowing the water to flow from the head water pond through the water turbine of the pumped storage plant.



- Pumped storage plant is nothing but a hydraulic accumulator system and is shown in figure.
- These plants can have either vertical shaft arrangement or horizontal shaft arrangement.
- The latest pumped storage plant uses a Francis turbine which is just the reverse of centrifugal pump.
- When the water flows through it from the head water pond it will act as a turbine and rotate the generator.
- When rotated in the reverse direction by means of an electric motor, it will act as a pump to shunt the water from the tail water pond to the head water pond.
- The efficiency of such a plant is never 100 percent because of some water may evaporate from the head water pond

Advantages of pumped storage plants:

- Peak load capacity of the plant at comparatively low capital cost.
- Due to rated load on the plant, the operating efficiency of the plant is high.
- There is an improvement in the load factor of the plant.
- Load on the hydro-electric plant remains uniform.
- The hydro-electric plant becomes partly independent of the stream flow conditions.

3. Draw and explain the construction and working principle of Pelton turbine.

Introduction:

- Pelton turbine is a commonly used impulse type turbine.
- It is named after an American engineer Lester.A.Pelton who developed this turbine.

- The Pelton wheel is suitable for very high heads and it requires a lesser quantity of water.
- It consists of a runner, buckets, a nozzle, a guide mechanism, a hydraulic brake and casing.

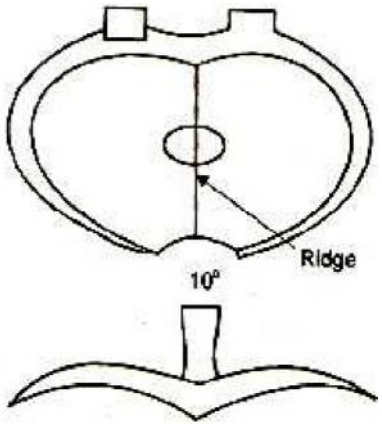
Construction:

Pelton turbine consists of:

A) Runner and buckets
B) Nozzle and guide mechanism
C) Hydraulic brake
D) Casing

a) Runner and Buckets:

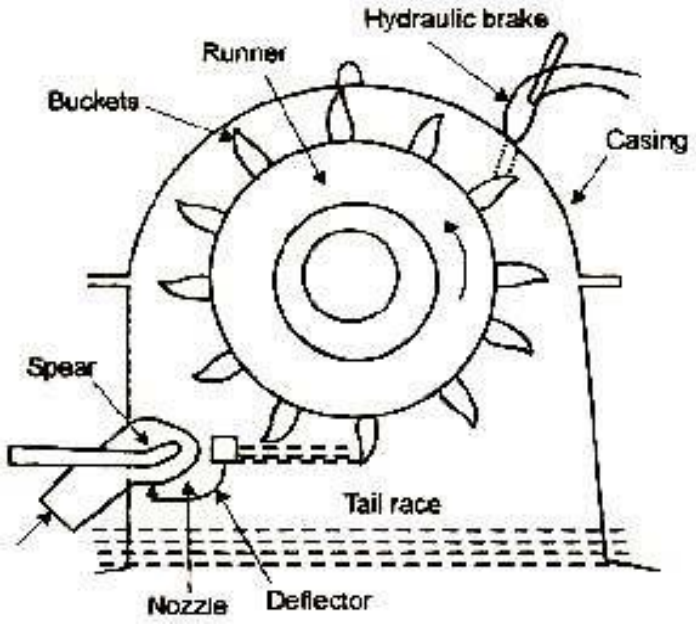
- The runner is a circular disc and consists of a number of semi-ellipsoidal buckets evenly spaced around its periphery.
- The buckets are divided into two hemi-spherical cups by a sharp edged ridge known as a splitter.
- Generally, the buckets are bolted to the periphery of the runner.
- In some cases, the buckets and the wheel are cast integral as one piece in some cases.
- For low heads, the bucket is made of case iron and for high heads, they are made of bronze or stainless steel to withstand heavy impact.



Bucket of pelton wheel

b) Nozzle and Guide mechanism:

- A nozzle is fitted to the end of the penstock near the turbine.
- The nozzle is provided with a conical needle or spear to regulate the quantity of water coming out of the nozzle, thereby control the speed of the runner.
- The spear may be operated manually by a hand wheel or automatically by a governing mechanism.



Pelton Turbine

c) Hydraulic brake:

- When the turbine has to be brought to rest by closing the inlet valve of the turbine, the runner generally takes a very long time to come to rest due to its inertia.
- To bring it quickly, a small brake nozzle is provided.
- This nozzle is opened and it directs a jet of water at the back of the buckets.
- This acts as a mechanical brake to bring revolving runner quickly to rest.

d) Casing:

- The casing is made up of cast-Iron or fabricated steel plates.
- It is provided for the following purposes:
  - ✓ To prevent splashing of water
  - ✓ To lead the water to the tail race
  - ✓ To act as a safeguard against any accidents

Working principle:

- The water is conveyed to the power house from the head race through penstocks.
- The nozzle is fitted to the end of the penstock (power house end) delivers a high velocity water jet into the bucket.
- One or more jets of water are arranged to interfere on the buckets tangentially.
- The impact of water jet on the bucket causes the wheel to rotate, thus producing mechanical work.

- An electric generator is coupled to the runner shaft and mechanical energy is converted into electrical power.
- After leaving the turbine wheel, water falls into the tail race.
- The Pelton wheel is located above the tail race so that, the buckets do not splash the tail race water.

4. Draw and explain the construction and working principle of Francis turbine.

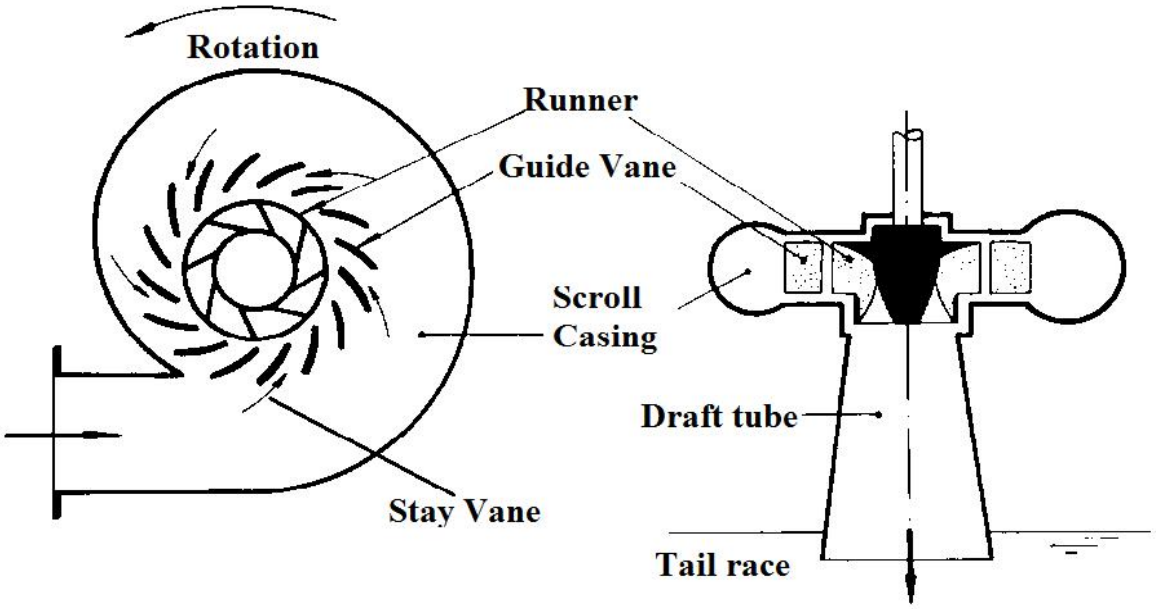
Reaction turbine:

- Reaction turbines operate under pressure of water.
- Only a part of the total head of water is converted into a kinetic energy before it reaches the runner.
- The water completely fills all the passages in the runner (turbine runs full) and flows through the vanes.
- When flowing through the vanes, both the pressure and velocity change. The water leaves the turbine to the tail race at a reduced pressure and velocity.

- Reaction turbines may be:
    a) Radially inward flow turbines
    b) Outward flow turbines
    c) Axial flow turbines
    d) Mixed flow turbines.

Francis Turbine Introduction:

- Francis turbine is one type of Reaction Turbine.
- The modern Francis turbine is a mixed flow type of reaction turbine.
- In this turbine, water enters the runner towards the centre in a radial direction and leaves the runner axially(parallel).
- It operates under medium heads and requires a moderate quantity of water.



(a) Cross sectional view of Scroll casing **(b) Francis Turbine**

Construction:

Francis turbine consists of:

A) Scroll casing
B) Stay ring(Stay vane)
C) Guide mechanism(Guide vane)
D) Runner
E) Draft tube

a) Scroll Casing:

- Water from the penstock is received by a scroll casing.
- The scroll casing (also called spiral casting) surrounds the guide wheel and runner.
- The cross-sectional area of the casing decreases uniformly to distribute the water around the guide ring uniformly.
- The casing is made of welded steel plates or cast steel.

b) Speed ring or Stay ring:

- The speed ring or stay ring consists of two rings held together by a series of fixed vanes called stay vanes.
- This ring directs water from the scroll casing to the guide vanes.
- It also transfers the loads (caused by the water pressure, weight of turbine and the weight of the generator) to the foundation.
- It is made of cast iron, cast steel or fabricated plate steel.

c) Guide mechanism(Guide vane):

- The guide blades (wicket gates) are fitted between two rings in the form of a wheel known as a guide wheel.

- The guide vanes guide the water to enter tangentially (radially) to the runner blades.
- Each guide vane is pivoted and it can be rotated about its pivot by a system of levers and links.
- This rotation of guide vanes alters the width of the water passage between them.
- The guide vanes are generally made of case steel or stainless steel.

d) <u>Runner:</u>

- The runner consists of series of curved vanes.
- The vanes (16 to 24) are evenly arranged around the circumference in the space between two plates.
- The vanes are properly shaped to receive the water without a shock.
- The runner is set to the shaft which may be vertical or horizontal.
- The runner is made of cast iron for small turbines and it is made of cast steel or stainless steel for large turbines.

e) <u>Draft tube:</u>

- This is a pipe or passage which leads the water exhausted from the turbine into the tail race.
- Its cross-section increases gradually towards the outlet.
- The bottom enlarged end is submerged in a tail race water level.
- It is made of cast steel, welded plate steel or concrete.

<u>Working principle:</u>

- The water from the reservoir is carried to the turbine through penstocks and enters the scroll casing.
- The casing distributes water evenly around the circumference of the turbine runner.
- From the scroll casing, the water passes through the stay ring and this ring directs water to the guide vanes.
- The air foil shape of the guide vanes allows the water to flow smoothly without a shock.
- The water enters the runner with a low velocity and considerable pressure.
- As the water flows through the runner, the direction of flow of waters changed from axial to radial.
- The pressure energy is gradually converted into kinetic energy and the runner is rotated at high speed.
- This high speed produces torque that is transmitted to the generator which is coupled to the runner shaft.

- After passing through the runner water enters the tail race through a draft tube.

5. Draw and explain the construction and working principle of Kaplan turbine?

Introduction:

- The Kaplan turbine works on the principle of reaction turbine.
- It is an axial flow reaction turbine.
- It is suitable for relatively low water head regions.
- It requires a large quantity of water to develop high power.
- It operates in an entirely closed conduct from the head race to the tail race.
- The basic difference between Kaplan turbine and Francis turbine is the **runner blade arrangement**.

Construction:

The main components of a Kaplan turbine are given as:

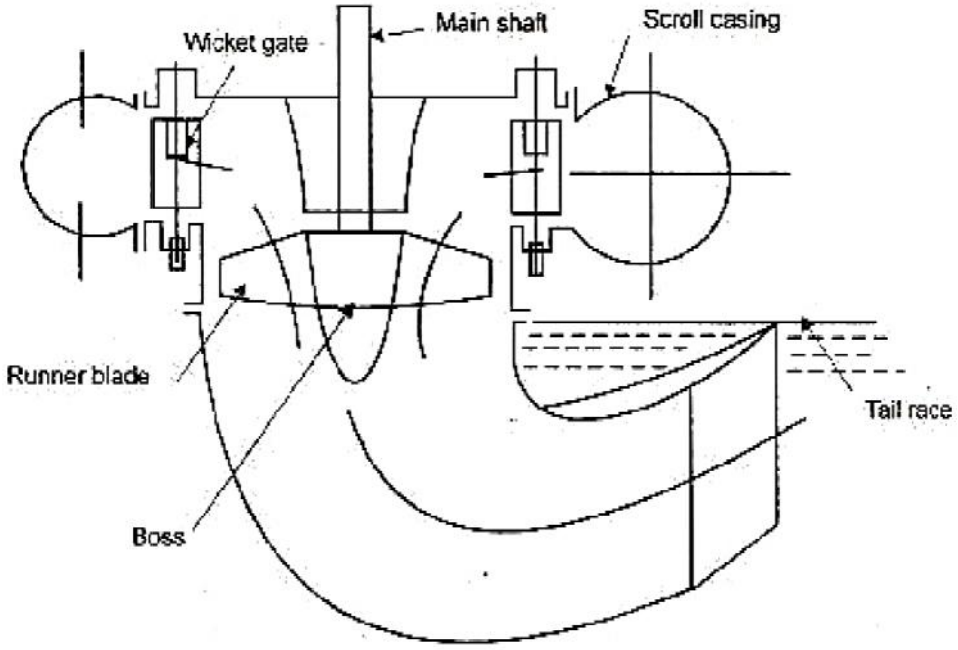
A) Scroll casing
B) Stay ring(Stay vane)
C) Guide mechanism(Guide vane)
D) Runner
E) Draft tube

a) Scroll Casing:

- Water from the penstock is received by a scroll casing.
- The scroll casing (also called spiral casting) surrounds the guide wheel and runner.
- The cross-sectional area of the casing decreases uniformly to distribute the water around the guide ring uniformly.
- The casing is made of welded steel plates or cast steel.

b) Speed ring or Stay ring:

- The speed ring or stay ring consists of two rings held together by a series of fixed vanes called stay vanes.
- This ring directs water from the scroll casing to the guide vanes.
- It also transfers the loads (caused by the water pressure, weight of turbine and the weight of the generator) to the foundation.
- It is made of cast iron, cast steel or fabricated plate steel.



Schematic diagram of Kaplan turbine

c) <u>Guide mechanism(Guide vane):</u>

- The guide blades (wicket gates) are fitted between two rings in the form of a wheel known as a guide wheel.
- The guide vanes guide the water to enter tangentially(radially) to the runner blades.
- Each guide vane is pivoted and it can be rotated about its pivot by a system of levers and links.
- This rotation of guide vanes alters the width of the water passage between them.
- The guide vanes are generally made of case steel or stainless steel.

d) <u>Runner:</u>

- The runner has 4 to 6 blades attached to a hub or boss.
- It resembles like a ship propeller and hence a Kaplan turbine is a type of propeller turbine.
- The blades are so shaped that water flows axially through the runner.
- The blades of the runner can also be adjusted to any desired angle and the area of flow passage can be varied.
- Both the guide vane angle and runner blade angle may be varied thus results in higher efficiency.
- Even at partial load, when a lower quantity of water is flowing through the turbine high efficiency can be obtained.

e) <u>Draft tube:</u>

- This is a pipe or passage which leads the water exhausted from the turbine into the tail race.
- Its cross-section increases gradually towards the outlet.
- The bottom enlarged end is submerged in a tail race water level.
- It is made of cast steel, welded plate steel or concrete.

Working principle:

- The water from the scroll casing flows over the guide vanes.
- It is deflected through 900 between guide vanes and runner.
- The blades are shaped such that water flows axially in the runner and the water flows axially into the runner.
- The force exerted on the blades causes the runner shaft to rotate.
- This rotation is transmitted to the generator which is coupled to the runner shaft.
- The generator produces an electrical power due to rotation(mechanical energy) given by the turbine.
- After passing through the runner, the water enters the tail race through a draft tube.

6. Draw and explain the Wind-Electric Generating power plant.

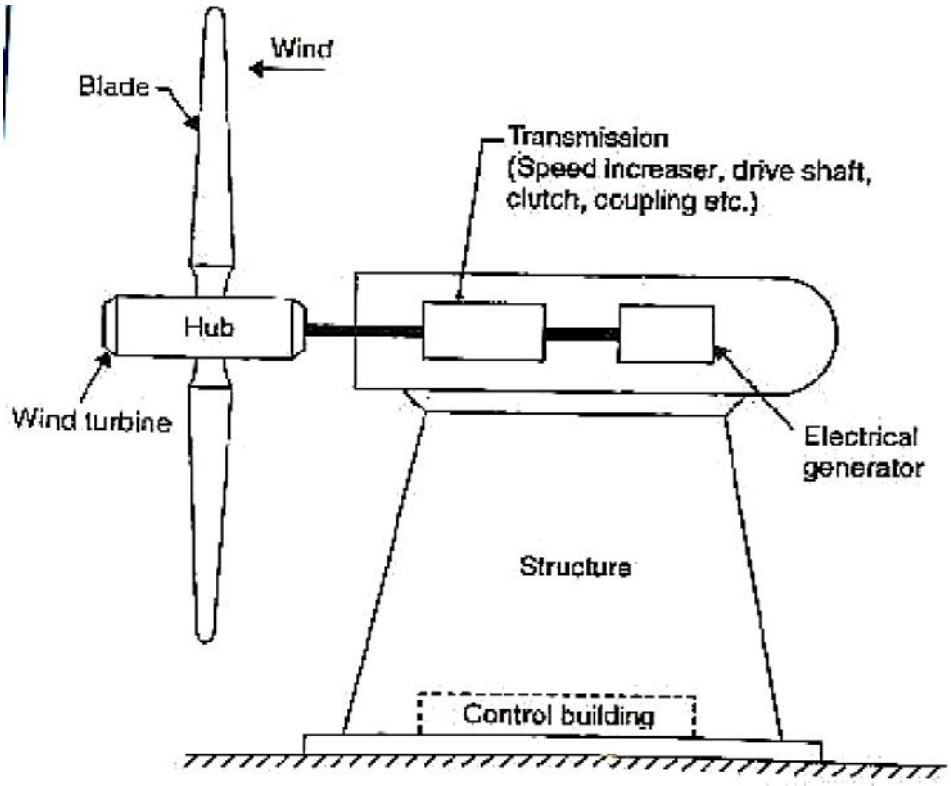
Introduction to wind:

- Wind energy is the potential source of energy.
- Winds are the motion of air caused by uneven heating of the earth surface by the sun and rotation of the earth.
- It generates due to various global phenomena such as air-temperature difference associated with different rates of solar heating.
- The strong winds are created by sharp temperature difference between the land and the sea.
- Wind resources in India are tremendous and so wind power plants are mainly located near the sea coasts.
- Wind machines are also called as an Aero-generators.

Construction of Wind Power plant:

Wind power plant consists of the following essential components:

a) Wind turbine or rotor
b) Wind mill head – it houses speed increaser, drive shaft, coupling, etc.
c) Electric generator
d) Tower



Wind-Electric power plant layout

a) <u>Wind turbine (or) wind Rotor:</u>

- The wind turbine is a rotating part which consists of center shaft and rotor blades.
- There are two types of forces operating on the blades of wind turbine such as circumferential force and axial force.
- The Circumferential forces in the direction of wheel rotation that provide the torque.
- The axial forces in the direction of the wind stream that provide an axial push that must be neutralized by proper mechanical design.
- The wind turbine may be located either unwind or downwind of the power.
- In unwind rotors, the wind encounters the turbine blades before reaching the tower.
- In downwind rotors, the wind encounters the tower before reaching the turbine blades.

b) <u>Wind mill head:</u>

- Wind mill head is facilitated by mounting it on the top of the supporting structure on suitable bearings.
- The wind mill head performs the following functions:
  - ✓ It supports the rotor housing and the rotor bearings.
  - ✓ It also houses any control mechanism like changing the pitch of the blades for safety devices.
  - ✓ It changes the position of tail vane to set the rotor in wind direction.

c) Electric Generator:

- The generator is coupled with the wind turbine shaft.
- When the turbine rotates, it also rotates the generator shaft by means of mechanical force.
- By the generator principle, the mechanical force is converted into an electrical energy.

d) Tower:

- Tower is the supporting structure which is designed to withstand the wind load.
- Its type and height is related to cost and transmission system incorporated.
- Horizontal axis wind turbines are mounted on towers so as to be above the level of instability and other ground related effects.

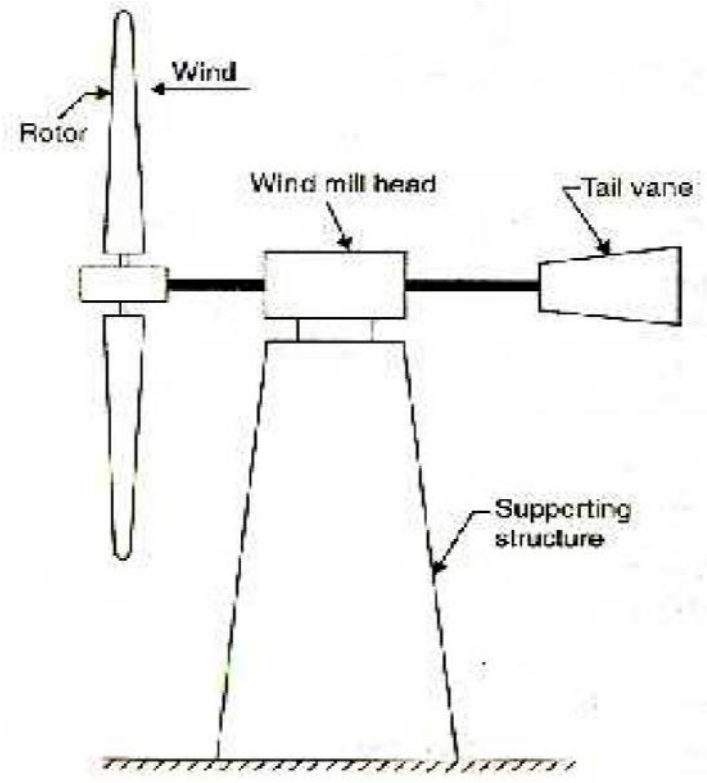
Types of Wind Machines:

Wind machines (aero-generators) are generally classified as follows:

a) Horizontal axis wind machines.

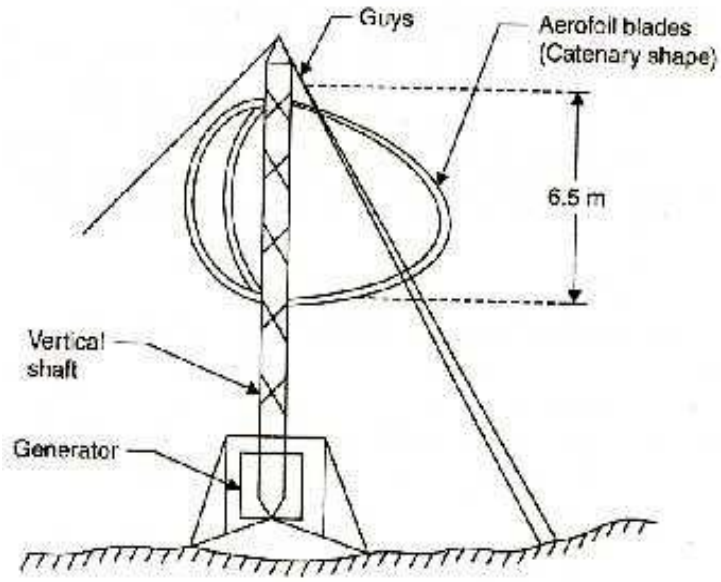
b) Vertical axis wind machines.

Horizontal axis wind machines:



- The common wind turbine with horizontal axis is simple in principle.
- Especially a large one that would produce electric power economically but the design of a complete system is complex.
- It is of primary importance that the components like rotor, transmission, generator and tower should not only be as efficient as possible but they must also function effectively in combination.

Vertical axis wind machines:



- One of the main advantages of vertical axis rotors is that they do not have to be turned into the wind stream as the wind direction changes.
- Because their operation is independent of wind direction, vertical axis machine are called **Panemones**.

7. Explain the construction and working principle of Tidal power plants.

Introduction:

- Tide or wave is periodic rise and fall of water level of the sea.
- Tides occur due to the attraction of sea water by the moon.
- Tides contain large amount of potential energy which is used for power generation.
- When the water is above the mean sea level, it is called flood tide or High tide.
- When the water level is below the mean level it is called ebb tide or Low tide.

Principle:

Tidal energy is a form of hydropower that converts the energy of tides into useful forms of power such as electricity. This conversion is achieved by means of turbine coupled with an electric generator.

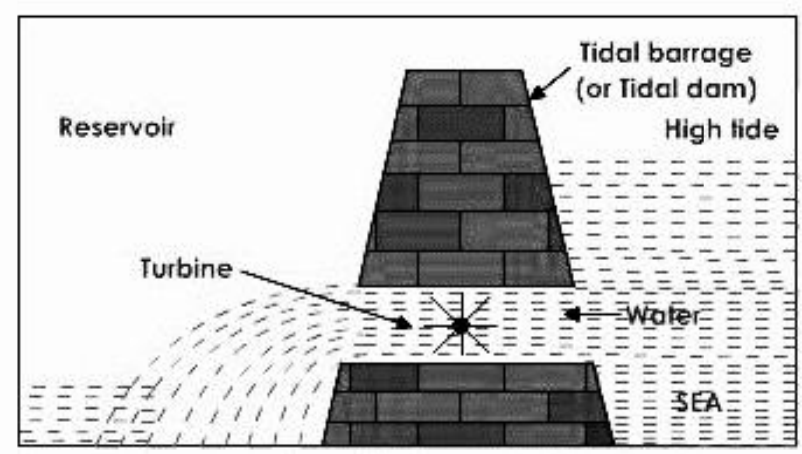
Construction:

- A dam is constructed in the sea for separating the water reservoir (water basin) from the sea
- The dam consists of power house which holds Turbine and electric generator for Power generation.
- The ocean tides rise and fall depends on the attraction of sea with the moon.
- During high tide, water from the sea can be stored in the water reservoir.

- During low tide, the stored water from the water reservoir is flowed into the sea which rotates turbine in the dam.
- A difference in water level is obtained between the basin and sea and the arrangement of the system is shown in figure.

Working:

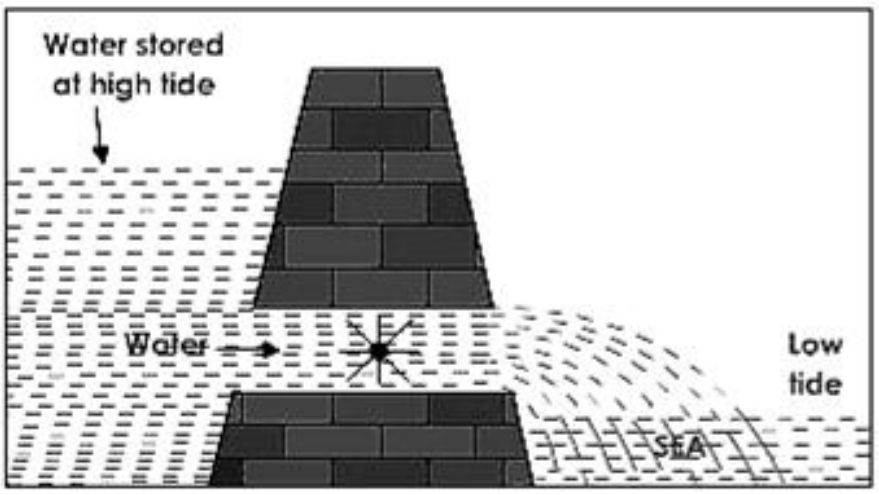
High tide duration:



High Tide: water from Sea to Reservoir

- During high tide period, the height of tide is above that of water level in the reservoir.
- So the water flows from the sea into the water reservoir through the water turbine.
- During the water flow from sea to reservoir, the turbine unit in the dam rotates due to speed of the water flow.
- When the turbine rotates, the generator coupled with turbine shaft is also rotates due to mechanical force on the turbine shaft.
- Then the generator produces electrical energy(power) from the mechanical energy given by the turbine.

Low tide duration:



ow Tide: water from Reservoir to Sea

- During low tide period, the height of tide is below that of water level in the reservoir.
- So the water flows from the water reservoir into the sea through the water turbine.
- During the water flow from reservoir to sea, the turbine unit in the dam rotates due to speed of the water flow.
- When the turbine rotates, the generator coupled with turbine shaft is also rotates due to mechanical force on the turbine shaft.
- Then the generator produces electrical energy(power) from the mechanical energy given by the turbine

The generation of power stops only when the sea level and the tidal basin level are equal. For the generation of power economically using this source of energy requires some minimum tide height and suitable site. Kislaya power plant of 250 MW capacity in Russia and Rance power plant in France are the only examples of this type of power plant.

Classification of Tidal power plant:

The tidal power plants are generally classified on the basis of the number of basins used for the power generation. The classification of Tidal power Plants are:

- Single basin - one way cycle
- Single basin - two way cycle
- Single basin - two way cycle with pump storage
- Double basin type
- Double basin with pump storage

Advantages of tidal power plants:

- It is free from pollution as it does not use any fuel.

- It is superior to hydro-power plant as it is totally independent of rain.
- It improves the possibility of fish farming in the tidal basins

Disadvantages:

- Tidal power plants can be developed only if natural sites are available on the bay.
- Transmission cost and transmission losses are high due to long distance from cities.
- The supply of power is not continuous as it depends upon the timing of tides.
- Utilization of tidal energy on small scale is not economical.

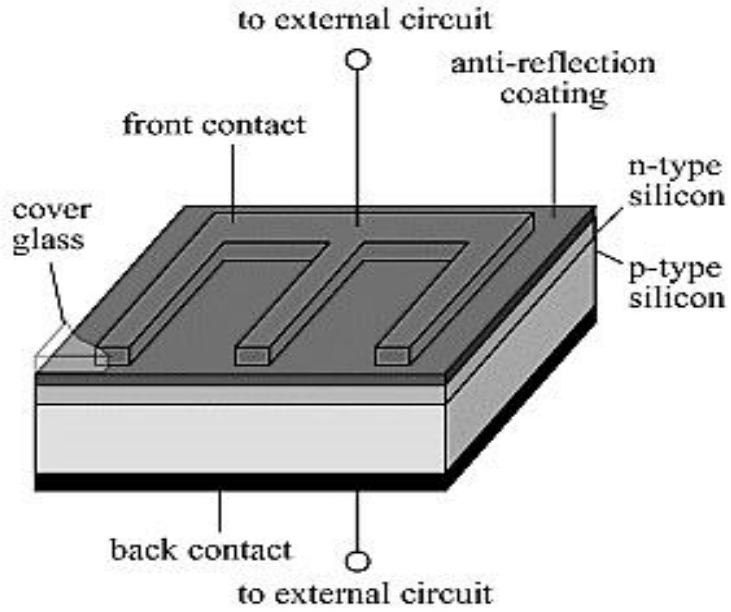
8. Explain the construction and working of solar photovoltaic cell with the neat diagram. (or) Explain the construction and working of PV cell with the neat diagram.

Introduction:

- A solar cell or photovoltaic cell is an electrical device that converts the energy of light directly into electricity.
- It works on the principle of by the photovoltaic effect.
- It is a form of photoelectric cell which is a device whose electrical characteristics such as current, voltage, or resistance, vary when exposed to light.
- Solar cells are the building blocks of photovoltaic modules, otherwise known as solar panels.
- Solar cells are being photovoltaic irrespective of whether the source is sunlight or an artificial light.

Basic principle of PV cell:

Photovoltaic effect is the process in which two dissimilar materials are in close contact produce an electrical voltage when it is exposed to light or other radiant energy. It is a physical and chemical phenomenon.



Construction of PV cell:

- Solar cells are always made up of crystalline silicon which is a semiconductor material.
- Solar cell consists of n-type semiconductor (emitter) layer and p-type semiconductor layer (base).
- The two layers of different semiconductors are joined to form a connection called as p-n junction.
- The surface is coated with anti-refection coating to avoid the loss of incident light energy due to reflection.
- There is a transparent gum layer over the anti-reflection coating to absorb the solar radiations.
- The front and back contact is used to transfer the produced electric field to the external circuit.
- The photovoltaic cell requires 3 basic characteristics:
  - ✓ The absorption of light for generating either electron hole pair or excitons.
  - ✓ The separation of charge carriers of opposite types.
  - ✓ The separate extraction of those carriers to an external circuit.

Operation of Photovoltaic cell:

- When light falls on the photovoltaic cell, the absorption of photons from the solar radiations occurs.
- By the absorption of photons, the free electrons in n-type is excited and tries to acquire holes in p-type silicon.
- The electron and holes are diffuse across the p-n junction and there is a formation of electron-hole pair.
- As electron continuous to diffuse, more electrons build on n-type side and positive charge build on p-type side.
- The accumulation of similar charged particles near p-n junction creates the region called the depletion region.

- This weak region cannot allow the formation of an electron hole pair near to p-n junction.
- When the PN junction is connected with external circuit by using front and back contact in the photovoltaic cell.
- The free electrons flow through an electrical circuit to acquire holes in p-type silicon and process an electric field.
- The electric field in the circuit operates a load connected in the external circuit by means of flow of current.

Types of Photovoltaic Solar Cell:

There are 4 types of PV cells according to their manufacturing technology:

a.)Single or Mono-Crystalline Cell:

Mono-crystalline cells which are made of pure silicon surface and a thin structure are known to have high efficiency. Examples: Si (Silicon) and Gallium Arsenide (GaAS).

b.) Polycrystalline PV cell:

It has a crystalline structure. It has a manufacturing technology in the form of a thin film. Efficiency is not more than 10%. Examples: Cadmium telluride (CdTe) or Copper indium di-selenide (CIS).

c.) Amorphous silicon PV cell:

It has a non-crystalline structure. Rate of efficiency is not very high. It is used in small devices such as calculators and digital dictionaries.

d.) Hybrid Solar Cell:

Organic and chemical substances are used together in its structure. Even though it has quite a high rate of energy efficiency, it is not yet used in industries.

Advantages of photovoltaic cells:

- It is clean and non-polluting
- Solar cells do not produce noise and they are totally silent operation.
- They require very little maintenance
- They are renewable sources of energy which can be used almost anywhere
- They have long life time
- There are no fuel costs or fuel supply problems

Limitations of photovoltaic cells:

- Soar power cannot be obtained in night time.
- Solar panels are very expensive.
- Energy has not be stored in batteries.
- Air pollution and weather can affect the production of electricity.

Applications of photovoltaic cells:

- Rural electrification Hybrid system

- Water pumping
- Communication stations
- Street lighting

9. Explain the construction and working principle of Solar thermal power plant?

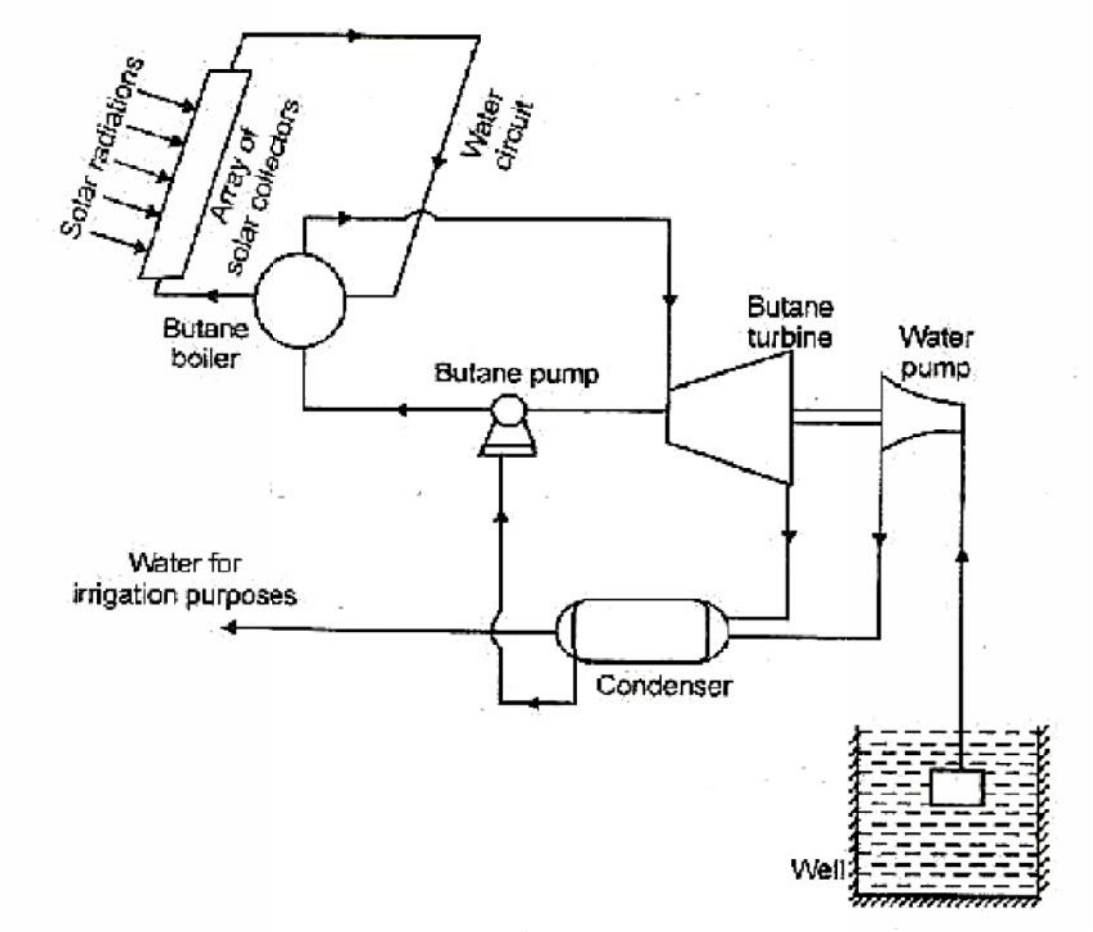
Introduction:

- Solar thermal technology is not the same as solar panel or photovoltaic technology. Solar thermal electric energy generation concentrates the light from the sun to create heat.
- The heat is used to run a heat engine, which turns a generator to make electricity. The working fluid that is heated by the concentrated sunlight can be a liquid or a gas.
- Different working fluids include water, oil, salts, air, nitrogen, helium, etc.
- Different engine types include steam engines, gas turbines, etc.
- All of these engines can be quite efficient and are capable of producing 10 to 100 megawatts of power

Construction of solar thermal Power plant:

Solar thermal power plant consists of the following essential components:

a) Solar collectors
   - ✓ Flat plate collector
   - ✓ Cylindrical parabolic concentrator collector
   - ✓ Solar tower system
b) Butane boiler
c) Turbine
d) Generator



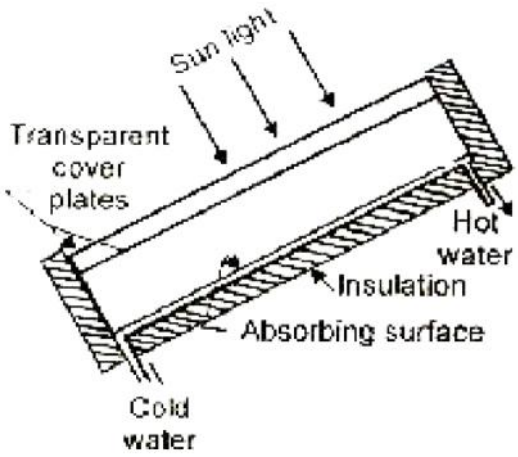
Layout of Solar thermal power plant

A) <u>Solar collectors:</u>

- Solar collector is an equipment which receives the solar radiation from the sun.
- It gains heat from the radiation and transferred the heat to the water in the absorber tube.
- There are two different types of solar collectors:
  - ✓ Flat plate collector
  - ✓ Cylindrical parabolic concentrator collector
  - ✓ Solar tower system

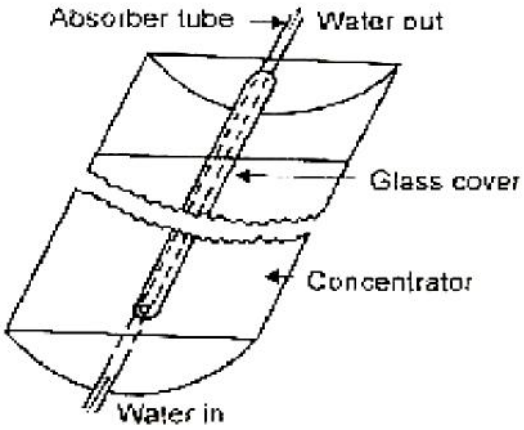
<u>Flat plate collector:</u>

- In a flat plate collector, the radiation energy of the sun falls on a flat surface coated with black paint having high absorbing capacity.
- It is placed facing the direction of the sun.



- The materials used for the plate may be copper, steel or aluminium.
- Copper tubes is provided in thermal contact with the plate.
- Heat is transferred from the absorbed plate to water which is circulated in the copper tubes.
- Thermal insulation is provided behind the absorber plate to prevent heat losses from the rear surface.
- Insulating material is generally fibre glass or mineral wool.
- The front cover is made up of glass and it is transparent to the incoming solar radiations.

Cylindrical parabolic concentrator collector:



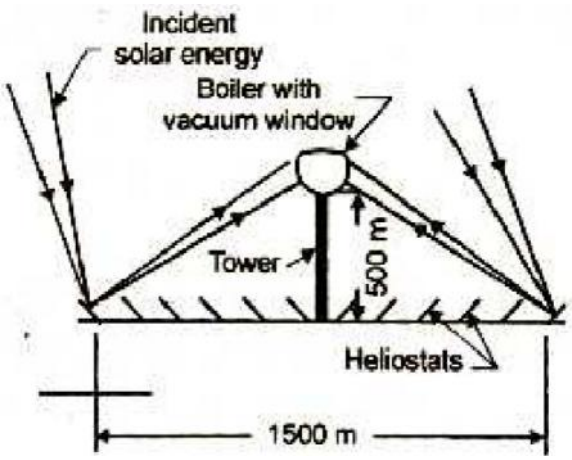
Cylindrical parabolic concentrator collector

- Concentrator collectors are of reflecting type utilizing mirrors.
- The reflecting surface may be parabolic mirror.
- The solar energy falling on the collector surface is reflected and focused along a line where the absorber tube is located.
- As large quantity of energy falling on the collector surface is collected over a small surface.
- Heat is transferred from the absorbed tube to water which is circulated in the copper tubes.

- The temperature of the absorber fluid is very much higher than in flat plate collector.
- This type of collectors are designed to heat water to medium and high temperature ranges.

Solar Tower system:

- The tower concept consists of an array of plane mirrors or heliostats.
- The plane mirrors are individually controlled to reflect radiations from the sun into a boiler
- The boiler is placed on a 500 metres supporting structure named as Tower. Steam in generated in the boiler, which may attain a temperature upto 2000 K.
- Then the steam is used to rotate the turbine which inturn rotates the generator
- Electricity is generated by passing steam through the turbine coupled to a generator.



Tower concept for power generation

B) **Butane boiler:**

- The vessel used for heating is normally called as Boiler.
- For solar power plant, the butane gas is used as burning fuel because of its low boiling point.
- Boiling point of butane is about 500C.
- The water heated in solar collector to 800 C is used for boiling butane at high pressure in the butane boiler.

C) Turbine and Generator:

- A turbine is a mechanical device which converts the kinetic energy at blades into rotating energy in the shaft.
- The butane vapour generated at high pressure in the boiler is used to run the vapour turbine

- The rotation of turbine also drives the electrical generator due to coupling between turbine and generator.
- By the generator principle, this rotational energy is converted into an electrical energy.
- The vapour coming out of the turbine at low pressure is condensed in a condenser using water.
- The condensed liquid butane is fed back to the butane boiler using feed pump.

Advantages of solar thermal power plant:

- Solar energy is a very large inexhaustible and renewable source of energy
- It is environmentally very clean and hence pollution-free.
- It is a dependable energy source without new requirements of a highly technical design.
- It is the best alternative for the rapid depletion of fossil fuels.

Disadvantages of solar thermal power plant:

- Very large collecting area are required.
- Capital cost is more for the solar plant.
- Solar energy is not available at night or during rainy days.

Applications of Solar thermal power plant:

- Solar engines for pumping
- Solar water heaters
- Solar cookers
- Solar driers
- Solar furnaces
- Solar power generation

10. Explain the construction and working principle of geothermal power plant? (or) Explain the layout of Power plant which uses geothermal energy as source.

Introduction:

- Geothermal energy is energy that is an intensive heat continuously flows outward from deep within the Earth.
- Word "geothermal" has its roots in two Greek words, "geo" means Earth and "thermal" means heat.
- This energy is mainly generated from Earth's core since temperature of Earth's center is reaching temperatures above 6000 degrees Celsius which is even hot enough to melt a rock.

Principle:

The heat energy is extracted from the deep of the earth is converted into electrical energy by means of Thermal process.

Construction of Geothermal plant:

Geothermal power plant consists of the following essential components:

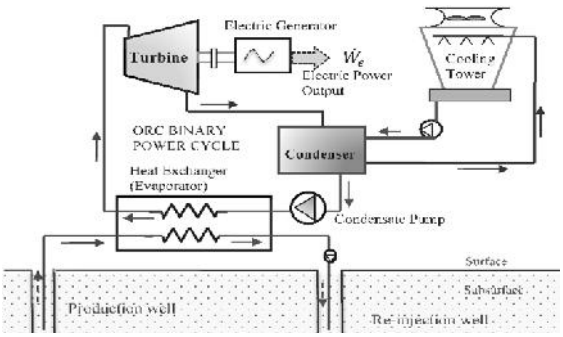
a) Steam well
b) Heat Exchanger
c) Turbine
d) Generator
e) Condenser

Steam well(Production well and Re-injection well):

- Pipes are embedded for pouring cooled water at the places of subsurface of an earth with high temperature called steam wells.
- By sending water through embedded pipes, the water is converted into hot water due to high temperature.
- The hot water is extracted from the subsurface of earth by using another wall named as Production well.

Heat exchanger(Evaporator):

- Heat exchangers are devices that facilitate the exchange of heat between two fluids that are at different temperatures while keeping them from mixing with each other.
- The steam heat is transferred to cooled water in the heat exchanger for power generation process
-



Turbine:

- A turbine is a turbo-machine with at least one moving part called a rotor assembly,

- The rotor may be shaft or drum which are provided with rotating blades .
- Moving fluid acts on the blades so that they move and communicate rotational energy to the rotor.
- The steam from the heat exchanger is passed through the turbine which in turn rotates the turbine.

Generator:

- Generator is an electrical machine which converts the mechanical energy into an electrical energy.
- The generator starts rotating due to coupling between turbine and generator and produces an electricity.

Condenser:

- Condenser is a device used to shrink a substance from its gaseous to its liquid state by cooling it.
- The exhaust steam from the turbine is condensed, so the steam is converted into water.
- The condensed water is pumped into the earth to absorb the ground heat again and to get converted into steam.

Working:

- The cold water is injected to subsurface of the earth by using Injection well.
- The water is converted into hot water due to high temperature at the subsurface of earth.
- From the production well the hot water is extracted, the hot water is converted into steam at the surface of earth.
- The steam is then circulated to the heat exchangers.
- The steam heat is transferred to the cooled water in the heat exchanger and then the water is converted into super-heated steam.
- The super-heated steam is used to drive the turbine.
- The turbine rotates the electric generator which is already coupled with the turbine shaft.
- The generator converts the mechanical force into an electrical power(electricity).
- At the same time, the steam coming out from the turbine reaches the condenser.
- The condenser converts steam into hot water and it is cooled down through the cooling towers.
- The cooled water is again injected into the subsurface of the earth to get the heat again for the next power generation process.

Advantages of Geothermal Power Plant:

- Geothermal energy is a renewable energy resource.
- It is non-polluting and environment friendly.
- There is no wastage or generation of by-products.
- Geothermal energy can be used directly.
- Maintenance cost of geothermal power plants is very less.
- Geothermal power plants requires less space.
- Unlike solar plants, it is not dependent on the weather conditions.

Disadvantages of Geothermal Power Plant:

- Geothermal power plants are far from cities and difficult to consume power.
- Total power generation of this source is too small.
- There is always a danger of eruption of volcano.
- Installation cost of steam power plant is very high.
- It may release some harmful, poisonous gases that can escape through the holes drilled during construction.

11. Explain in detail about the Biogas power plant with its construction and operation. (or) Describe the bio-conversion processes involved in the biomass energy applications.

BIO-CONVERSION PROCESS

There are mainly three aerobic and anaerobic bio-conversion process for the biomass energy applications: There are:

(i) Bio-products:

The conversion of biomass into chemicals for making products that are made from petroleum-based products.

(ii) Biofuels:

The conversion of biomass into liquid fuels for transportation is called as Biofuel. For transportation, the common types of biofuels are Ethanol, Biodiesel and Methanol.

(iii) Bio-power:

Burning biomass directly or indirectly converted into a gaseous fuel or oil to generate electricity. There are six major types of bio-power systems:

- Fermentation
- Direct fired system
- Co-firing system
- Gasification system
- Pyrolysis
- Small modular system

Biogas Introduction:

- Biogas is a good renewable energy resource.
- Biogas refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen.
- It can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste.
- The constituents involved in biogas are given as:

Gas	%
Methane (CH_4)	55 – 70
Carbon dioxide (CO_2)	30 – 45
Hydrogen sulphide (H_2S), Hydrogen (H_2), Ammonia (NH_3)	1 – 2
Carbon monoxide (CO)	trace
Nitrogen (N_2)	trace
Oxygen (O_2)	trace

Properties of Biogas:

- Comparatively simple and can be produced easily.
- Burns without smoke and without leaving ash as residues.
- Household wastes and bio-wastes can be disposed in suitable manner.
- Reduces the use of wood and to a certain extent prevents deforestation.
- The slurry from the biogas plant is used as fertilizer.

Basic principle of Biogas energy:

- The process of organic degradation without oxygen is called as Fermentation.
- It is the process of degradation of the organic substances using the micro-organisms also known as anaerobe (or) anaerobic digestion. It converts the solid biomass into a gas called Biogas.

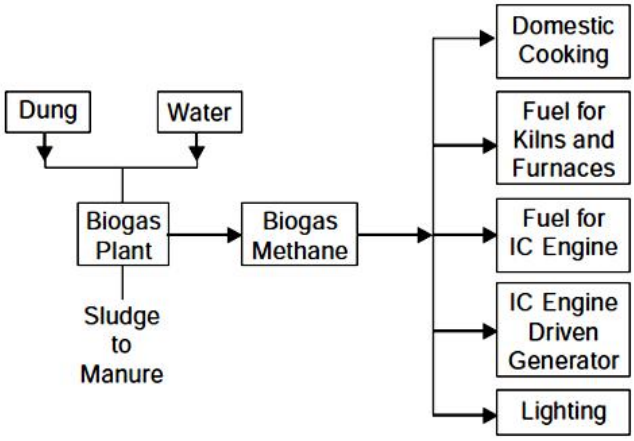
Raw materials for Biogas plant:

The biomass used as a raw material can be classified into the following categories:

Wastes	***Cultivated and Harvested***
Agricultural wastes	Agricultural energy crops
Rural animal wastes	Aquatic crops
Wastes from Poultry	Forest crops
Urban waste (garbage)	
Aquatic wastes	
Forest wastes	
Coconut husk waste	
Industrial wastes	

Parts of Biogas plant:

- The tank where biomass undergoes decomposition (digester)
- The tank where biomass is mixed with water (mixing tank)
- The tank where slurry of biomass is collected (out flow tank)
- Arrangement to store gas.



Energy route for Biogas power plant

Classification of Biogas plant:

Biogas plants are classified into following main types:

- Continuous type or batch type
    a) Single stage continuous type Biogas plant
    b) Two state continuous type Biogas plant
- Dome type
    a) Fixed dome type
    b) Floating gas type (or) Drum type

Continuous type (or) Batch type Biogas plant:

- Continuous type biogas plant delivers the biogas continuously and is fed with the biomass regularly.
- It delivers gas intermittently and dis-continuously.
- It may have several digesters which are operated in a sequential manner to obtain the biogas continuously.
- It have longer digestion time.
- It needs initial seeding to start the anaerobic fermentation.
- It needs larger volume of the digester and hence initial cost is higher.
- Operation and maintenance is more complex for batch type biogas plant.

(A) Single stage continuous type Biogas plant:

- In such a plant acid formation and methane formation are carried out in the same chamber without barrier.
- Such plants are simple, economical, easy to operate and control.
- These plants are generally preferred for small and medium size biogas plants.

- Single stage plants have lesser rate of gas production than the two stage plant.

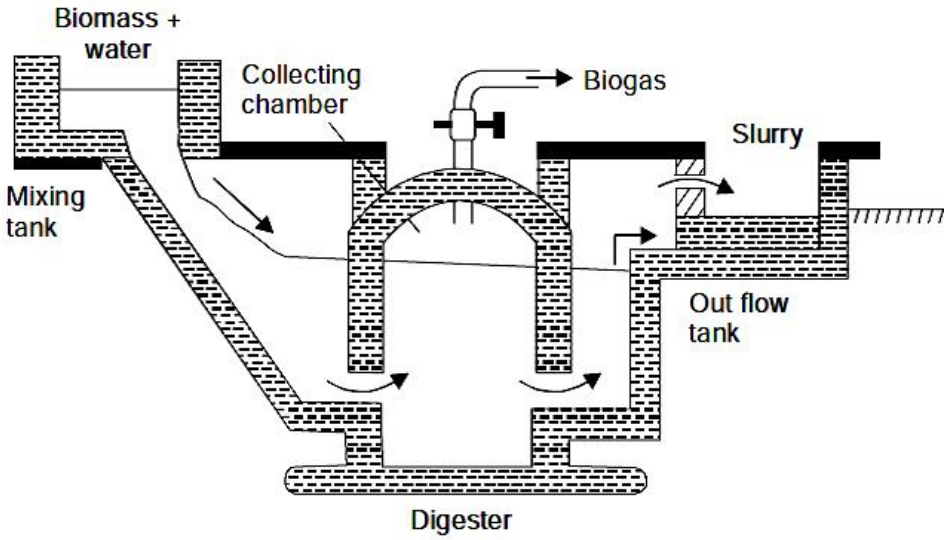
(B) Two state continuous type Biogas plant:

- In such a plant the acid formation and methane formation take place in separate chambers.
- The plant produces more biogas in the given time than the single stage plant.
- The process is complex and the plant is costlier, difficult to operate and maintain.
- Two stage plant is preferred for larger biogas plant systems.

Dome type Biogas plant:

(a) Fixed dome type:

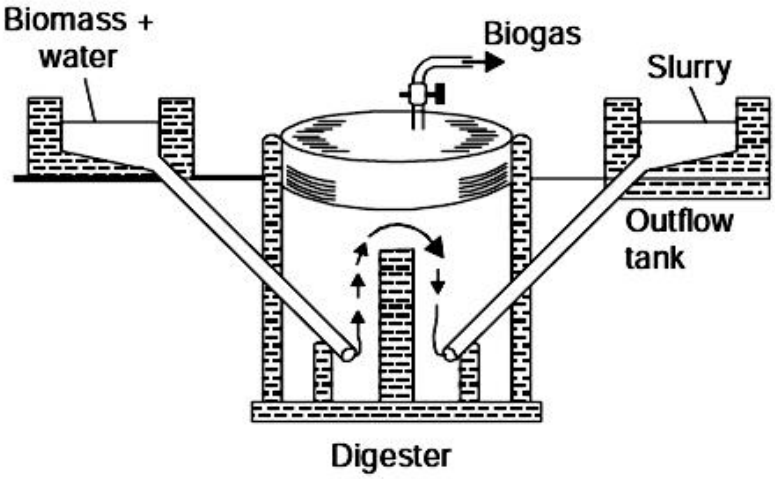
- In the fixed dome type digester biogas plant, the digester and gas-collector (gas dome) are enclosed in the same chamber.
- The digester is conveniently built at or below ground level in comparatively cooler zone.
- The pressure inside the digester increases as the biogas is liberated.
- The biogas gets collected in the upper portion of the digester in a dome shaped cavity.
- The outlet pipe is provided at the top of the fixed dome.
- Alternatively the gas collector (gas holder) is a separately installed chamber.
- The digester tank and gas collector chamber are separated by a water seal tank.
- An additional displacement chamber may be provided for providing space to the displacement slurry in the digester due to gas pressure in the upper dome.
- The excess slurry in the digester gets accommodated in the displacement chamber.



(b) Floating Gas Holder Type:

- In this design a dome made floats above the slurry in the disaster.
- The disaster tank is of cylindrical masonry construction.

- The floating dome is of fabricated steel construction.
- The dome guide shaft provides the axial guide to the floating dome and the gas is collected in it.
- The gas generated in the slurry gets collected in the dome and the dome rises.
- The water seal tank provides separation between the gas in the dome and the outlet gas.



- In this type, the cylinder rises up as the gas fills the tank and the storage capacity increases.
- Residue of biomass (slurry) can be used as good manure.

Advantages of Biogas plant:

- Provides a non-polluting and renewable source of energy.
- Efficient way of energy conversion.
- Wastes from this plant are used as fertilizers.
- Provides a source for decentralized power generation.
- Leads to employment generation in the rural areas.
- Household wastes and bio-wastes can be disposed in useful manner.
- The technology is cheaper and much simpler than those for other bio-fuels, and it is ideal for small scale application.
- Biogas plants significantly lower the greenhouse effects on the earth's atmosphere.

Disadvantages of Biogas plant:

- The process is not very attractive economically as compared to other biofuels.
- It is very difficult to enhance the efficiency of biogas systems.
- Biogas contains some gases as impurities which are corrosive to engine metal parts.
- Not feasible to locate at all the locations.

Applications of Biogas plant:

- Biogas is used as a fuel
- Slurry from plant is used as Fertilizers
- Additive fuel in vehicles to reduce toxic emissions
- Biogas is used for an electric power generation

12. Write a short notes of Fuel cell with Schematic diagram?

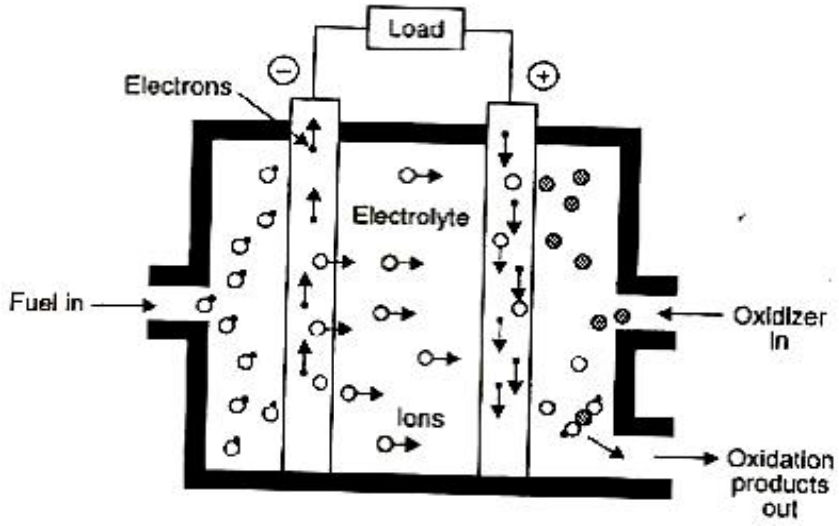
Introduction:

- A fuel cell is a device that converts the chemical energy from a fuel into electricity through a chemical reaction of positively charged hydrogen ions with oxygen or another oxidizing agent.
- Of the available fuels, hydrogen gas is mostly used as fuel.
- Cells consuming coal, oil or natural gas would be economically much more useful for large scale applications.
- Some of the possible reactions for different fuels are:

Fuel used	Output in Volts	Chemical reaction	Oxidation product
Hydrogen/oxygen	1.23 V	$2H_2 + O_2 \rightarrow 2\,H_2O$	Water
Hydrazine	1.56 V	$N_2H_4 + O_2 \rightarrow 2H_2O + N_2$	Water and Nitrogen
Carbon (coal)	1.02 V	$C + O_2 \rightarrow CO_2$	Carbon-di-oxide
Methane	1.05 V	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$	Water and carbon-di-oxide

Principle:

The chemical energy of a conventional fuel is converted directly and efficiently into low value of direct-current electrical energy by the oxidation process.



Schematic diagram of a fuel cell

Working:

- A fuel cell is often described as primary battery.
- The fuel is supplied from external to the anode of the fuel cell as needed.
- The oxidizer is supplied from external to the cathode of the fuel cell as needed.
- The fuel gas diffuses through the anode and is oxidized, thus releasing electrons to the external circuit.
- The oxidizer diffuses through the cathode is combined with the Hydrogen ions from the anode and produces some oxidation products.
- The transfer of electrons from anode to cathode gives supply to the small load connected in the fuel cell.
- The flow of electrons through the load has the value of low voltage from 1.0 to 2.0 volt.

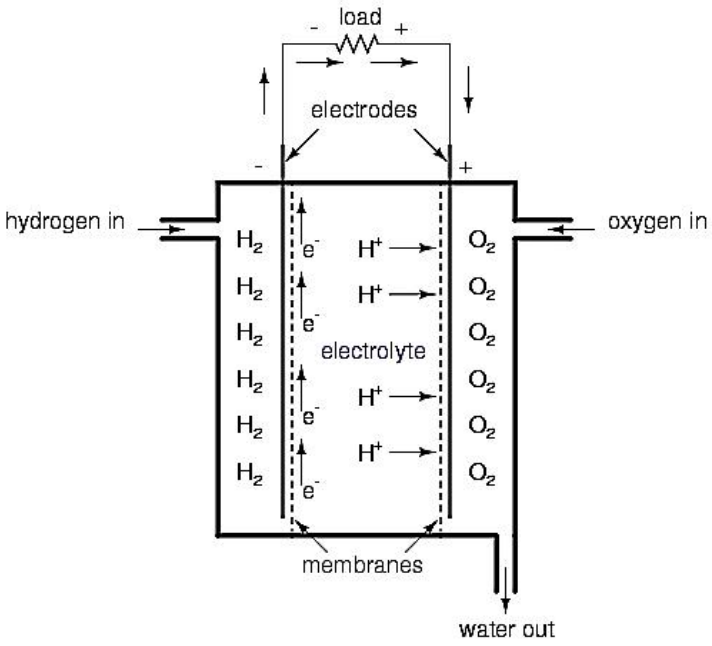
Contruction:

Hydrogen-oxygen cell :

- The hydrogen-oxygen fuel cell has three chambers separated by two porous electrodes, the anode and the cathode.
- The middle chamber between the electrodes is filled with a strong solution of potassium hydroxide as electrolyte.
- The surfaces of the electrodes are chemically treated to repel the electrolyte, so that there is minimum leakage of potassium hydroxide into the outer chambers.
- The gases diffuse through the electrodes, undergoing reactions are show below:

Electrolyte:	$4KOH \rightarrow 4K^{+} + (OH)^{-}$
Anode:	$2H_2 + 4\,(OH)^{-} \rightarrow 4H_2O + 4e^{-}$
Cathode:	$O_2 + 2H_2O + 4e^{-} \rightarrow 4\,(OH)^{-}$
Cell reaction:	$2H_2 + O_2 \rightarrow 2H_2O$

- The water formed is drawn off from the side.
- The electrolyte provides the (OH)- ions needed for the reaction and remains unchanged at the end, since these ions are regenerated.



- The electrons liberated at the anode find their way to the cathode through the external circuit.
- This transfer is equivalent to the flow of a current from the cathode to the anode.
- Such cells when properly designed and operated have an open circuit voltage of about 1.1 volt. Unfortunately, their life is limited since the water formed continuously dilutes the electrolyte.
- Fuel efficiencies as high as 60%-70% may be obtained.

Advantages of Fuel cell:

- A fuel cell is less complicated than a conventional gas or diesel engine.
- It is not involved to high temperatures for power generation.
- No Corrosion problems which are found in other engines.
- The output product of fuel cell is harmless to an environment.
- Fuel cell is free from pollution.

Disadvantages of Fuel cell:

- High costs compared to other energy systems technology
- Operation requires disposable fuel supply
- Fuel used in fuel cell is highly flammable such as Hydrogen.
- Transfer of hydrogen fuel is too difficult

13. Comparison between Impulse turbine and Reaction turbine

Sl. No.	Impulse turbine	Reaction turbine
1.	**Head:** The machine is suitable for high installation. (H=100 + 200 m).	The machines can be used for medium heads(H=50 to 500 m) and low heads (less than 50 m)

2.	**Nature of input energy to the runner:** The nozzle converts the entire hydraulic energy into kinetic energy before water strikes the runner.	The head is usually inadequate to produce high velocity jet. Hence water is supplied to the runner in the forms of both pressure and kinetic energy.
3.	**Method of energy transfer:** The buckets of the runner are so shaped that they extract almost all the kinetic energy of the jet.	The wicket gates accelerate the flow a little and direct the water to runner vanes to which energies of water are transferred.
4.	**Operating pressure:** The turbine works under atmospheric pressure. Which is the difference between the inlet and exit points of the runner.	The runner works is a closed system under the action of reaction pressure.
5.	**Admission of water to the wheel:** Only a few buckets comprising a part of the wheel are exposed to the water jet.	The entire circumference of the wheel receives water and all passages between the runner blades are always full of water.
6.	**Discharge:** They are essential low discharge turbines.	Since power is a product of head and weight of the rate of flow, these turbines consume large quantities of water in order to develop a reasonable power under a relatively low head.
7.	**Speed of operation:** The speed are invariably high.	Although the specific speeds of these turbines is high, their actual running speeds are comparatively low.
8.	**Size :** These are generally small size.	The turbines sizes is much larger than impulse wheels, in order to accommodate heavy discharge.
9.	**Casing:** It prevents splashing of water. It has no hydraulic function to serve.	The spiral casing has an important role to play; it distributes water under the available pressure uniformly around the periphery of the runner.
10.	**Turbine setting:** The head between the wheel and race is lost.	The draft tube ensures that the head of water below tail race level is not lost.
11.	**Maximum efficiency:** The highest efficiency (=88%) is less than that of reaction turbine.	The maximum efficiency (=95%) of design output is higher than that of impulse wheels.
12.	**Part load operation:** From about 20% to 100% of design output, the efficiency remains nearly the same. Hence the machine is ideal for generating small loads over long periods of time.	With the exception of a Kaplan turbine, all reaction turbines give poor part load performance i.e., appreciably low efficiency at less than design output.

13.	**Cavitation:** These machine are not susceptible to cavitation.	Runner blades and draft tube invariably undergo cavitation on damage.
14.	**Civil engineering works:** Civil works like excavation and concreting are much simpler and economical.	Civil works are more expensive on account of spiral casing and draft tube.

14. Discuss in detail about nuclear waste management.

Nuclear Waste Management:

- Nuclear power is characterized by the very large amount of energy available from a very small amount of fuel.
- The amount of waste is correspondingly very small.
- However, much of the waste is radioactive and therefore must be carefully managed as hazardous waste.
- Radioactive wastes comprise a variety of materials requiring different types of management to protect people and the environment.
- They are normally classified as low-level, medium-level or high-level wastes, according to the amount and types of radioactivity in them.
- For each kind of radiation, the higher the intensity of radioactivity in a given amount of material, the shorter the half lives involved.

Three general principles are employed in the management of radioactive wastes:

i. Concentrate-and-contain.
ii. Dilute-and-disperse.
iii. Delay-and-decay.

- The first two are also used in the management of non-radioactive wastes. The waste is either concentrated and then isolated, or it is diluted to acceptable levels and then discharged to the environment.
- Delay-and-decay however is unique to radioactive waste management; it means that the waste is stored and its radioactivity is allowed to decrease naturally through decay of the radioisotopes in it.

Types of radioactive waste

i. Low-level waste:

- It is generated from hospitals, laboratories and industry, as well as the nuclear fuel cycle.
- It comprises paper, rags, tools, clothing, filters etc. which contain small amounts of mostly short-lived radioactivity.
- Usually it is buried in shallow landfill sites.
- To reduce its volume, it is often compacted in a closed container before disposal.
- Worldwide it comprises 90% of the volume but only 1% of the radioactivity of all radwaste.

ii. Intermediate-level waste:

- It contains higher amounts of radioactivity and may require special shielding.
- It typically comprises resins, chemical sludges and reactor components, as well as

contaminated materials from reactor decommissioning.

- It may be solidified in concrete or bitumen for disposal.
- Generally short-lived waste (mainly from reactors) is buried, but long-lived waste (from reprocessing nuclear fuel) is disposed of deep underground.
- Worldwide it makes up 7% of the volume and has 4% of the radioactivity of all radwaste

iii. High-level waste:

- It may be the used fuel itself, or the principal waste separated from reprocessing this.
- While only 3% of the volume of all radwaste, it holds 95% of the radioactivity.
- It contains the highly-radioactive fission products and some heavy elements with long-lived radioactivity.
- It generates a considerable amount of heat and requires cooling, as well as special shielding during handling and transport.

a. Reprocessing

- If the used fuel is later reprocessed, it is dissolved and separated chemically into uranium, plutonium and high-level waste solutions.
- About 97% of the used fuel can be recycled leaving only 3% as high-level waste.
- The recyclable portion is mostly uranium depleted to less than 1% U-235, with some plutonium, which is most valuable.
- Arising from a year's operation of a typical l000 MWe nuclear reactor, about 230 kilograms of plutonium (1% of the spent fuel) is separated in for recycle.
- This can be used in fresh mixed oxide (MOX) fuel (but not weapons, due its composition).
- The separated high-level wastes – about 3% of the typical reactor's used fuel – amounts to 700 kg per year and it needs to be isolated from the environment for a very long time.

b. Immobilising separated high-level waste

- Solidification processes have been developed in several countries over the past fifty years. Liquid high-level wastes are evaporated to solids, mixed with glass-forming materials, melted and poured into robust stainless steel canisters which are then sealed by welding.
- This block contains material chemically identical to high-level waste from reprocessing.
- A piece this size would contain the total high-level waste arising from nuclear electricity generation for one person throughout a normal lifetime.

c. Waste disposal

- Final disposal of high-level waste is delayed for 40-50 years to allow its radioactivity to decay, after which less than one-thousandth of its initial radioactivity remains, and it is much easier to handle.
- Hence canisters of vitrified waste, or used fuel assemblies, are stored under water in special ponds, or in dry concrete structures or casks, for at least this length of time.
- The ultimate disposal of vitrified wastes, is burial in stable geological formations

some 500 metres deep.

- Several countries are investigating sites that would be technically and publicly acceptable, and in Sweden and Finland construction is proceeding in 1.9 billion year-old granites.