UNIT-II HYDRO-ELECTRICPOWER PLANT

Introduction, selection of site for for hydro- electric power plants, classification of hydro- electric plants, layout of Hydro Electric power plant, working principle, Description of main components, types of Turbines- pelton, Francis& Kaplan turbines, Pumped storage plant, Advantages and disadvantages of Hydro Power plant

INTRODUCTION

- Hydro – electric Projects harness water power for generation of electrical energy.
- A generating station which utilizes the potential energy of water at a high level for the generation of electrical energy is known as hydro-electric power station.
- In Hydro Power Plant the water is utilized to move the turbines which in turn run the electric generator.

- The Potential energy of the water stored in the dam gets converted into the Kinetic Energy of the moving water in the penstock. And this Kinetic Energy gets converted into the Electrical Energy with the help of Turbine & Generator (T-G) combination.

ADVANTAGES AND DISADVANTAGES OF HYDRO POWER PLANT

Advantages:-

- No fuel charges.
- Less supervising staff is required.
- Maintenance & operation charges are very low.
- Running cost of the plant is low.
- The plant efficiency does not changes with age.
- It takes few minutes to run & synchronize the plant.
- No fuel transportation is required.
- No ash & flue gas problem & does not pollute the atmosphere.
- These plants are used for flood control & irrigation purpose.
- Long life in comparison with the Thermal & Nuclear Power Plant.

Dis Advantages:-

- The initial cost of the power plant is very high.
- Takes long time for construction of the dam.
- Generally, Such plant's are located in hilly area's far away from load center & thus they require long transmission lines & losses in them will be more.
- Power generation by hydro power plant is only dependant on natural phenomenon of rain .Therefore at the time of drought or summer session the Hydro Power Plant will not work Effectively .

SITE SELECTION FOR HYDROELECTRIC POWER PLANT

1. **Water Availability:**

Main fuel of this plant is water. So, such plant should be located nearer to river, canal etc. where sufficient water is available all the time.

2. **Water Storage:**

Storage of water in a suitable reservoir or dam has to be placed by a careful geological study of the area to get the maximum advantage of that water. Dam should be located across the river to get continuous water supply throughout the year specially in a dry season. Adequate facilities of erection a dam and storage of water are two important matters for site selection of hydro electric power plant.

3. **Water Head:**

It is an important point for site selection of hydroelectric power plant. Water head is directly related to the cost of generation of electric power. If effective head is increased, water storage has to be reduced as well as capital cost of the plant is reduced.

4. **Distance from the load center:**

Since it is located away from the load center, more transmission line is required to supply the power. To avoid the line loss and economical power supply, distance of such plant should need more attention.

5. **Transportation Facilities:**

Good transportation facilities must be available to any hydro electric power plant, so that necessary equipment should be reached easily.

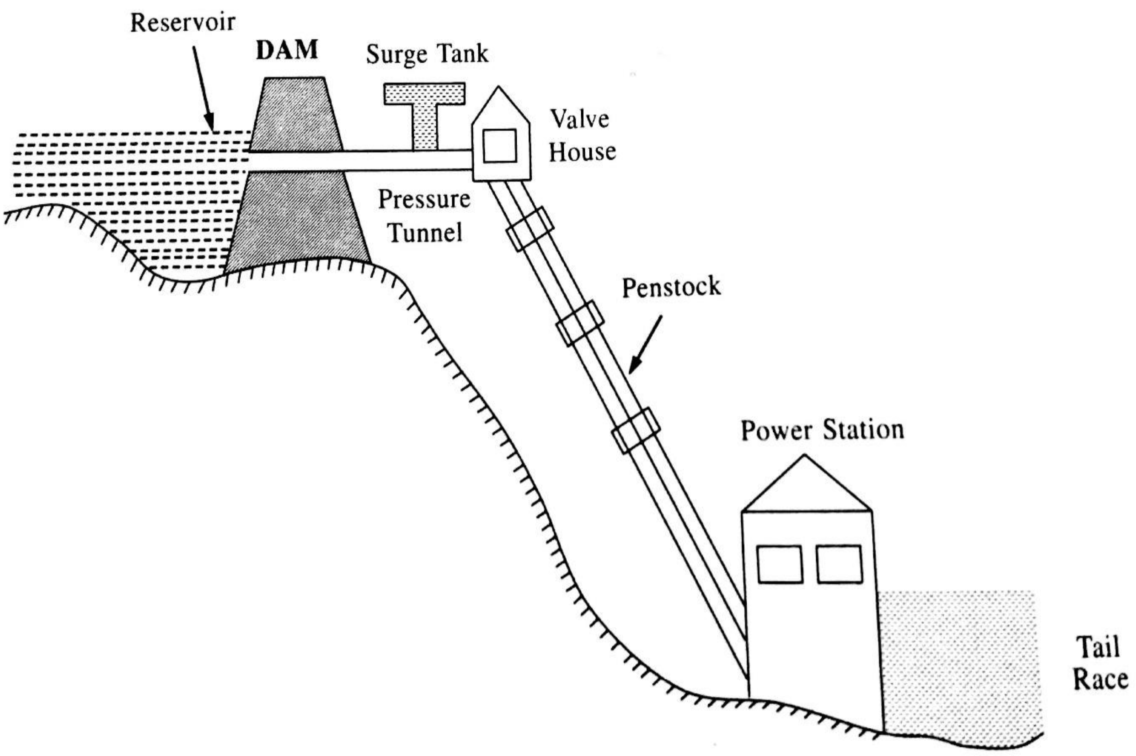
6. **Availability of land:**

Hydro electric power plant needs enough space. It should be kept in mind that land cost must be cheap.

7) Water pollution:

Polluted water may cause excessive corrosion and damage to metallic structure. This may render the operation of the plant unreliable and uneconomic. As such it is necessary to see that the water is of good quantity and will not cause such troubles.

Layout of Hydroelectric Power Plants



Principle of Working of hydroelectric power plant

The water from the reservoir is carried to valve house through pressure tunnel and from valve house to the water turbine through pipes of large diameter made of steel or reinforced concrete called Penstock.

The water turbine converts hydraulic energy into mechanical energy and the alternator which is coupled on the same shaft of the water turbine will convert mechanical energy in to electrical energy. Water after doing useful work is discharged to the tail race.

The following are the Main parts of a hydroelectric power plant

1. Catchment area	2. Dam	3. Reservoir
4.valve house	5.Surge tank	6. Penstock
7.Turbine	8. Generator	9.Draft tube
10.Tailrace	11. Trash tracks	

1**. Catchment area: T**he area behind the Dam, which collects the rain water, drains in to a stream (or) river is called " catchment area".

2. Dam: A Dam is a structure of masonry (or) some other concrete material built at a suitable location across a river.

The dam is constructed on a large river in hilly areas to ensure sufficient water storage at height.

The Dam provides the following functions, namely

(i) To provide the head of water

ii) To create storage (or) pondage

3. Reservoir: The place in which the water is stored in a Dam is called Reservoir. A Reservoir may be natural (or) artificial. A natural Reservoir is a lake in high mountains and artificial Reservoir is made by constructing a Dam across the River. The height of water level (called as water head) in the reservoir determines how much of potential energy is stored in it.

4. Valve house: In the valve house, there are two types of valves available. The first one is main sluicing valve and the second one is an automatic isolating valve. The sluicing valves control the water flowing to the downstream and automatic isolating valves stop the water flow when the electrical load is suddenly thrown off from the plant. Automatic isolating valve is a protecting valve does not play any direct role control the flow of water to the turbine. It only operates during emergency to protect the system from burst out.

5. Surge Tank:

Surge tanks are usually provided in high or medium head power plants when considerably long penstock is required. A surge tank is a small reservoir or tank. It is fitted between the reservoir and the power house. The water level in the surge tank rises or falls to reduce the pressure swings in the penstock. When there is sudden reduction in load on the turbine, the governor closes the gates of the turbine to reduce the water flow. This causes pressure to increase abnormally in the penstock. This is prevented by using a surge tank, in which the water level rises to reduce the pressure. On the other hand, the **surge tank** provides excess water needed when the gates are suddenly opened to meet the increased load demand.

6. Penstock: The penstock is a steel pipeline of suitable diameter connected between the valve house and powerhouse. The water flows down from upper valve house to lower powerhouse through this penstock only. Potential energy of the water is converted into kinetic energy as it flows down through the penstock.

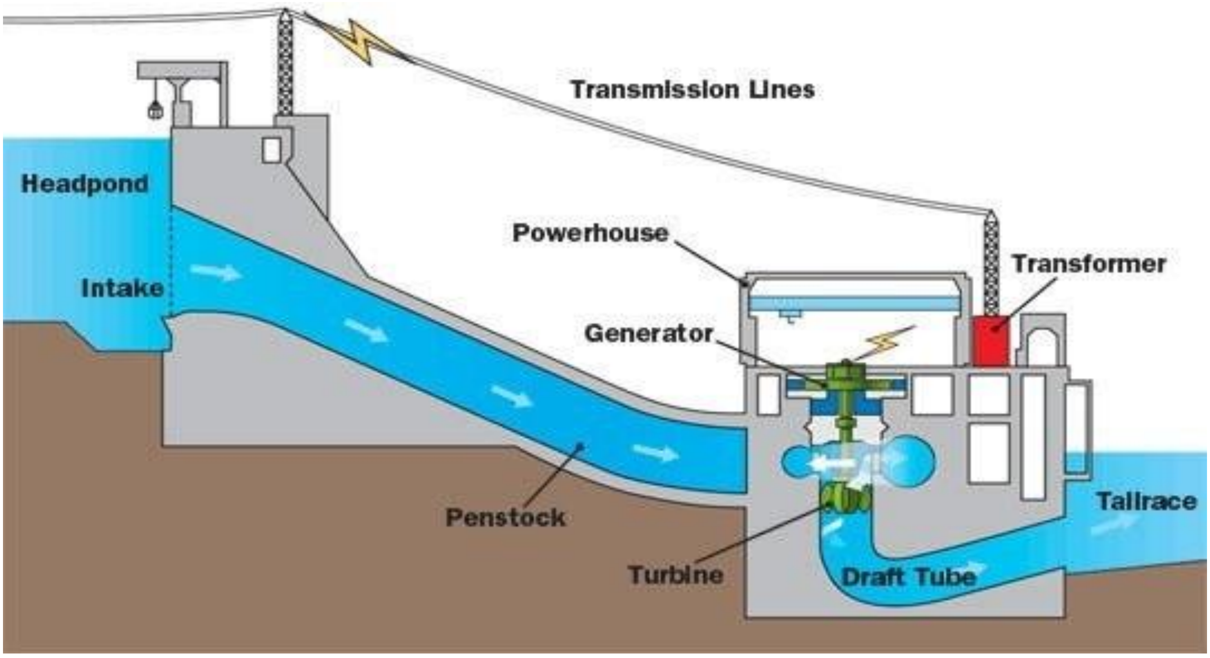
7. Water Turbine: Water from the penstock is taken into the water turbine. The turbine is mechanically coupled to an electric generator. Kinetic energy of the water drives the turbine and consequently the generator gets driven. There are two main types of water turbine; (i) Impulse turbine and (ii) Reaction turbine. Impulse turbines are used for large heads and reaction turbines are used for low and medium heads.

8. Generator: A generator is mounted in the power house and it is mechanically coupled to the turbine shaft. When the turbine blades are rotated by water flow, it drives the generator and electricity is generated which is then stepped up with the help of a transformer for the transmission purpose.

9. Draft Tube: Draft tube connects the runner exit to tail race. Draft tube is a metallic pipe or concrete tunnel having gradually increasing cross sectional area towards outlet to the tail race.

10. Tail race: The tail race, containing tail water, is a channel that carries water away from a hydroelectric plant. The water in this channel has already been used to rotate turbine blades. This water has served its purpose, and leaves the power generation unit

11. Trash Tracks: **Trash-racks** are installed in **hydroelectric power plants** to prevent entrance of large debris which can damage turbine parts and cause serious problems in **power plant** operation. Another main purpose of **trash-rack** is to prevent fish species from entering system.



CLASSIFICATION OF HYDRO-ELECTRIC POWER PLANT

1. Based on the availability of head

(a) Low head plants (less than 30 meters)

(b) Medium head plants (30 to 100 meters)

(c) High head plants (above 100 meters)

2. Based on nature of load

(a) Base load plants

(b) Peak load plants

3. Based on water regulations (hydraulic considerations)

(a) Run off river Plants without pondage

(b) Run off river plants with pondage

(c) Reservoir plants.

(d)Pumped storage hydro power plant

1. Based on the availability of head

i) Low head plants:-

If the head of water available is below 30meter, then this type of power plant is known as low-head plant

A dam or barrage across the river creates the necessary head.

In this type of plants no surge tank is required as the power house is located near the dam itself.

Ex: - Francis (or) Kaplan turbines are use

ii) Medium head plants:-

If the head of water lies between 30 to 100 meter then this type of power plant is known as medium head plant.

The forebay is provided at the beginning of penstock serves as water reservoir.

An open channel (canal) brings water from main reservoir to the forebay from where penstocks carry water to the turbines.

Francis or Kaplan turbines are used.

iii) High head plants:-

If the head of water for power generation exceeds 100meters, then this type of power plant is knows as high head power plants.
The civil works for these plants include dam, reservoir, tunnel, surge tank and penstock.
In this type of plant the water from the main reservoir is first carried by a tunnel up to surge tank and then it is carried though penstock (steel pipe) to the power house.
Heads below 200m (Francis turbine) above 500m (pelton wheel turbine).

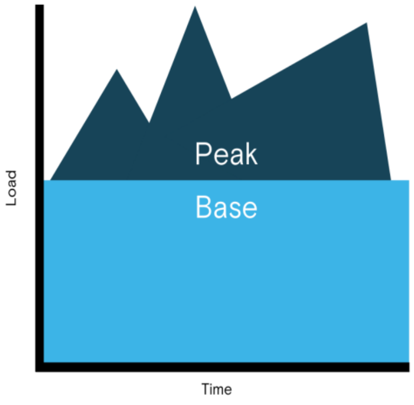
CLASSIFICATION* OF *HYDRO-ELECTRIC STATIONS BASED ON LOAD

The hydro-electric power stations are mainly classified in to two types based on the type of loads, namely.
1. Base load plants
2. Peak load plants

1. **Base Load Plants:** A plant supplying base load, which is more (or) less constant is known as *"Base load plant".* These type of plants work on almost constant load and its operating efficiency is usually high.
Run-off river plants without pondage are used as base load plants.

2. **Peak Load Plants:** Plants which are used to supply the peak load of the system, then these plants are called *"Peak load plants".*
Run-off river plants with pondage and pumped storage plants are used as peak load plants

Peak load plants have large seasonal storage. They store water during off peak periods and are operated during peak load periods. Load factor of such plants is low.



CLASSIFICATION OF* HYDRO POWER PLANTS ON THE BASIS *OF HYDRAULIC CONSIDERATIONS

1) <u>Run-off River Plants Without Pondage:</u>

-

This type of plants does not store the water and uses the water as it comes. This plant has no control over the water flow. Hence, the water is wasted during low load conditions and high flood conditions.

During dry seasons, the capacity of plants goes down due to the low flow rates of the water. The utility of these plants is very less compared to other plants.
Ex : Niagara falls plant is good example for run-off river plant.

2) **<u>Run-off River Plant with Pondage:</u>**

The usefulness of the run-off river plants is increased by using pondage in the plant. Pondage is nothing but collection of water behind a dam near the plant.
This is mainly useful to store water during off peak hours and uses the same water during the peak hours of the same day. Pondage plants will work satisfactorily as base load and peak load stations.

3. Storage Plants (Reservoir plants):
If the rain fall Occurs a short period of the year and remaining period of the year is dry, it becomes essential to store water during rainy season and supply the same during dry season.

A storage type plant is one with a reservoir of sufficiency large size to permit carry-over storage from the wet reason to the dry reason and thus to supply firm flow substantially more than the minimum natural flow.

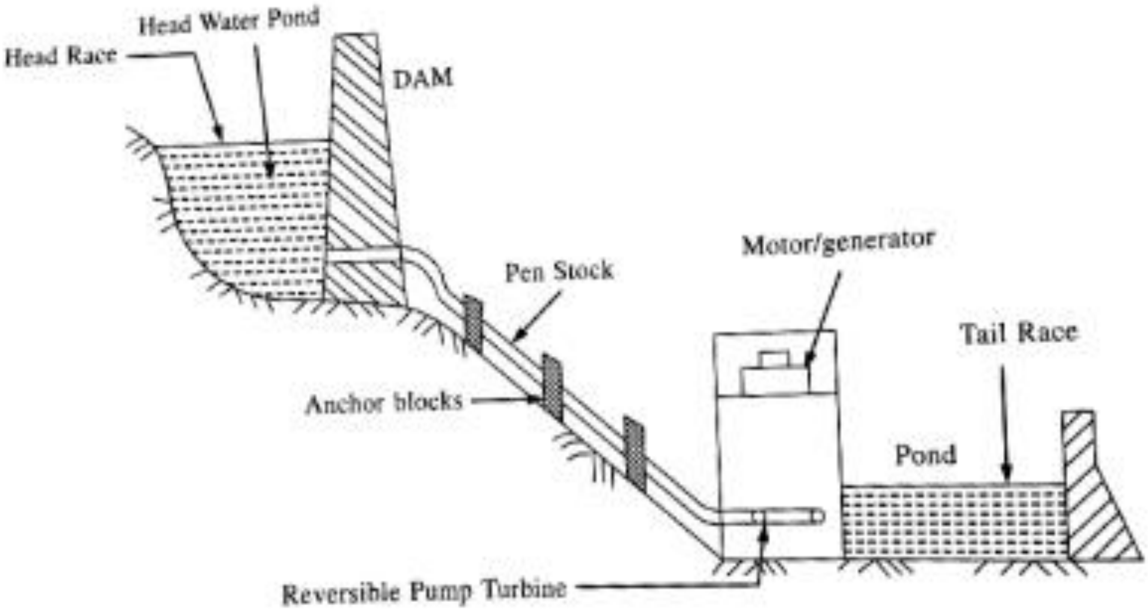
This plant can be used as a base load plant as well as peak load plant as water is available
In India majority of hydro-electric plants are of this type.

4. Pumped Storage hydro power Plants:
This type of plants are mainly used for supplying the sudden peak loads for short duration. These plants will work in two modes, namely.

i) Generating Phase: In this mode of operation, the water flows from higher level to tail race for generation of electric power.

i) Pumping Phase: In this mode of operation the water is pumped from tail race side to higher level of the reservoir. In this mode the generator will work as a Motor.

This type of power plant is available at Srisailam left bank which is of the capacity 900 *MW*.



Pumped storage plants are a special type of power plants which work as ordinary hydro power plants for part of the time and when such plants are not producing power, they can be used as pumping stations which pump water from tail race to the head race.

In pumped storage plant, a **second reservoir** second is constructed near the water outflow from the turbine. When the demand of electricity is low, the water from lower reservoir is pumped into the upper (main) reservoir.

The modern trend is to use **reversible pump turbine unit**. While generating, the turbine drives the electric generator and in the reverse operation, the generator runs as a motor driving the turbine, which, now acts as a pump.

Advantages of pumped storage hydro power plant:

i) Free from environmental pollution.
ii) Readily adaptable to automatic and remote controls.
iii) Greater flexibility in the operational schedules of the system.
iv) Economical as a peaking power station.
v) Improves load factor of the overall plant as it works as a load during off-peak periods of the system.

HYDRAULIC TURBINES

TYPES OF TURBINES:

Hydro-turbine is a prime mover coupled to the hydro-generator. The water flowing through the turbine blades rotates the turbine and hence in turn rotates the generator. Thus potential energy of water is converted into kinetic energy, which is converted into mechanical energy through the turbine and this mechanical energy is converted into electric energy. Mainly,

There are 3 types of turbines:

1. Pelton Turbine 2.Francis Turbine 3) Propeller and Kaplan Turbine

Hydraulic turbines can be classified into impulse and reaction turbines.

Pelton wheel is an impulse turbine and suits high heads

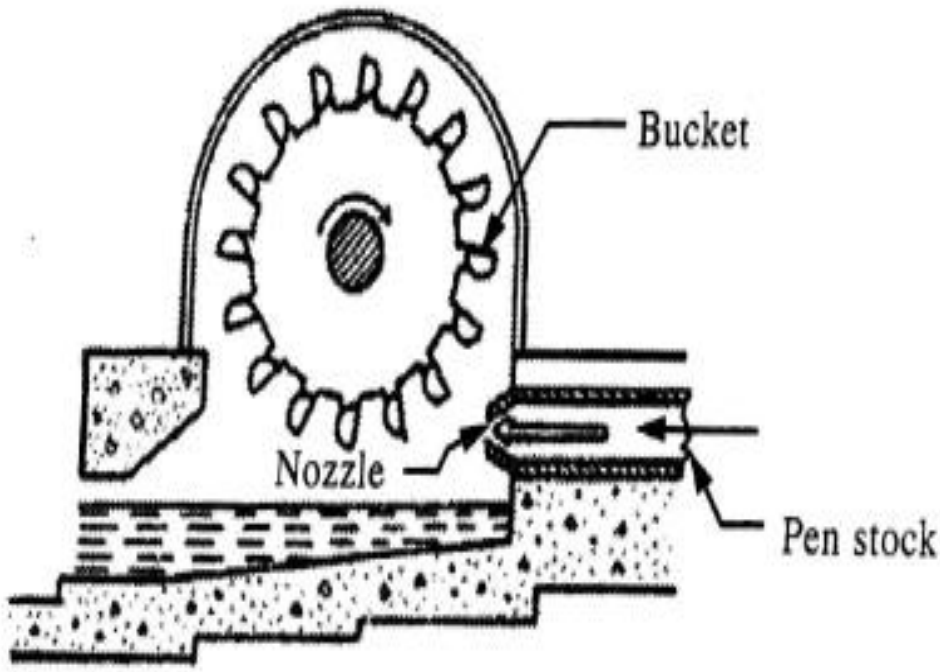
The reaction turbine can be either Francis or Propeller.

Francis turbine suits medium heads. Propeller turbines are meant for low heads.

A classification of turbines according to range of head and specific speed is as under:

Type of turbine	Head	Specific Speed (rpm)
Pelton (High Head)	Above 200 m	10 – 50
Francis (Medium Head)	30 m - 200 m	60 – 300
Propeller (Low Head)	Less than 30 m	300 - 1000

'**PELTON TURBINE**



'PELTON TURBINE

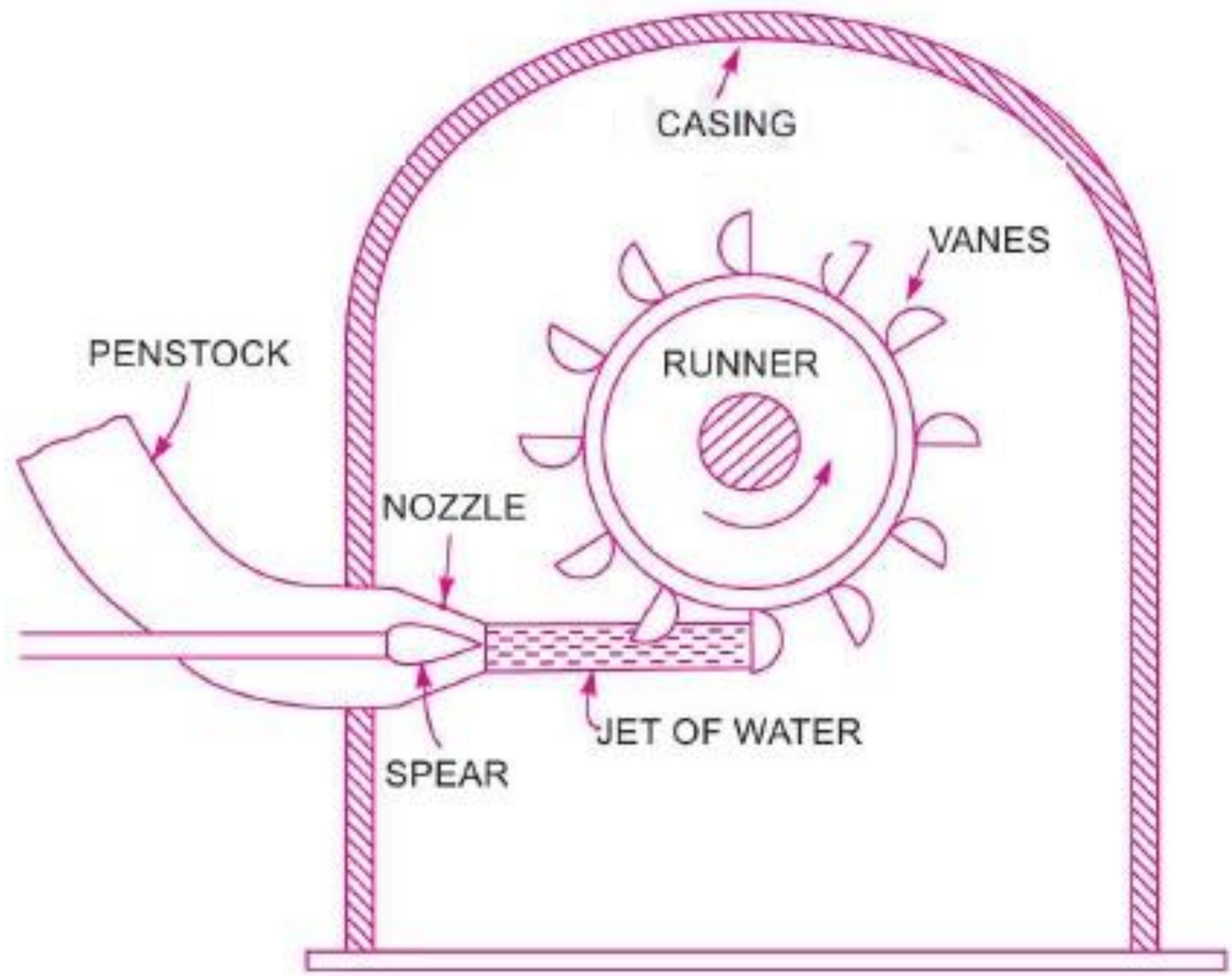
Pelton turbines/wheels are suitable for power extraction, when the water energy is available at high head and low flow rate.

Working Principle:

Working principle of Pelton turbine is simple. When a high speed water jet injected through a nozzle hits buckets of Pelton wheel; it induces an impulsive force. This force makes the turbine rotate. The rotating shaft runs a generator and produces electricity.

In short, Pelton turbine transforms kinetic energy of water jet to rotational energy.

Demand of power may fluctuate over time. A governing mechanism which controls position of the spear head meets this requirement. With lowering power demand the spear head at water inlet nozzle is moved in. So that water flow rate is reduced. If power demand increases spear head is moved out this will increase the flow rate.



Number of Buckets in Pelton Wheel:

One of the most important parameter of Pelton turbine design is number of buckets on the disk. If number of buckets is inadequate, this will result in loss in water jet.

So there should be an appropriate number of buckets, which will make sure that no water is lost.

Pelton Bucket - Design & Features

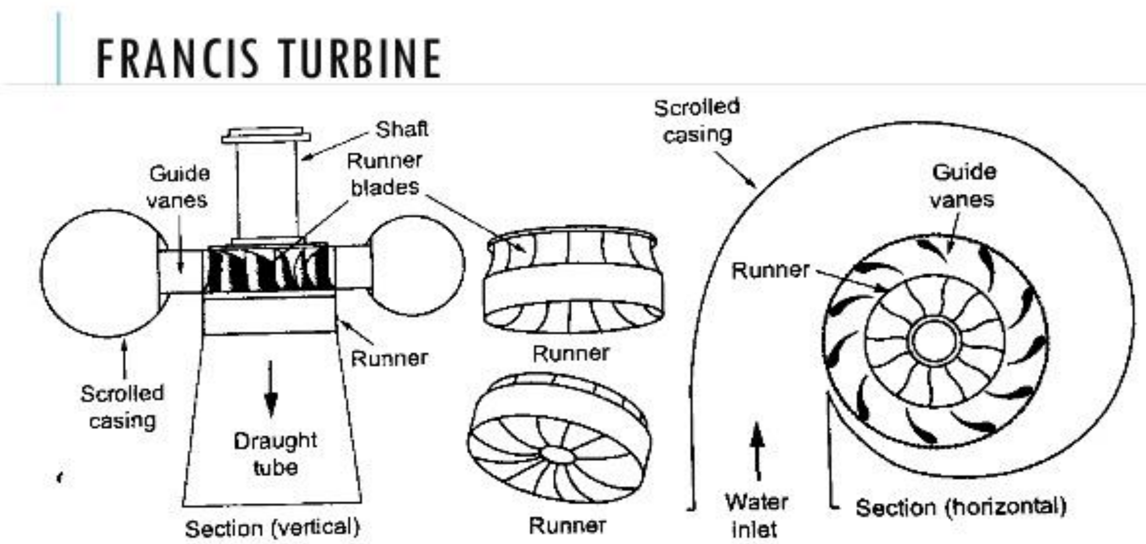
Most vital component of Pelton wheel is its bucket. Buckets are casted as single solid piece, in order to avoid fatigue failure. You can note that force acting on the turbine bucket is not constant with time.

Pelton – An Impulse Turbine:

Since the water jet is always open to atmosphere, inlet and exit pressure of water jet will be same and will be same as atmospheric pressure.

So it is clear that Pelton turbine gains mechanical energy purely due to change in kinetic energy of jet, not due to pressure energy change. Which means Pelton turbine is a pure impulse machine.

FRANCIS TURBINE



A reaction turbine develops power partly due to the velocity of water and partly due to the difference in pressure acting on the front and back of the runner buckets.

A Francis turbine is a reaction turbine suitable for medium heads and medium flows.

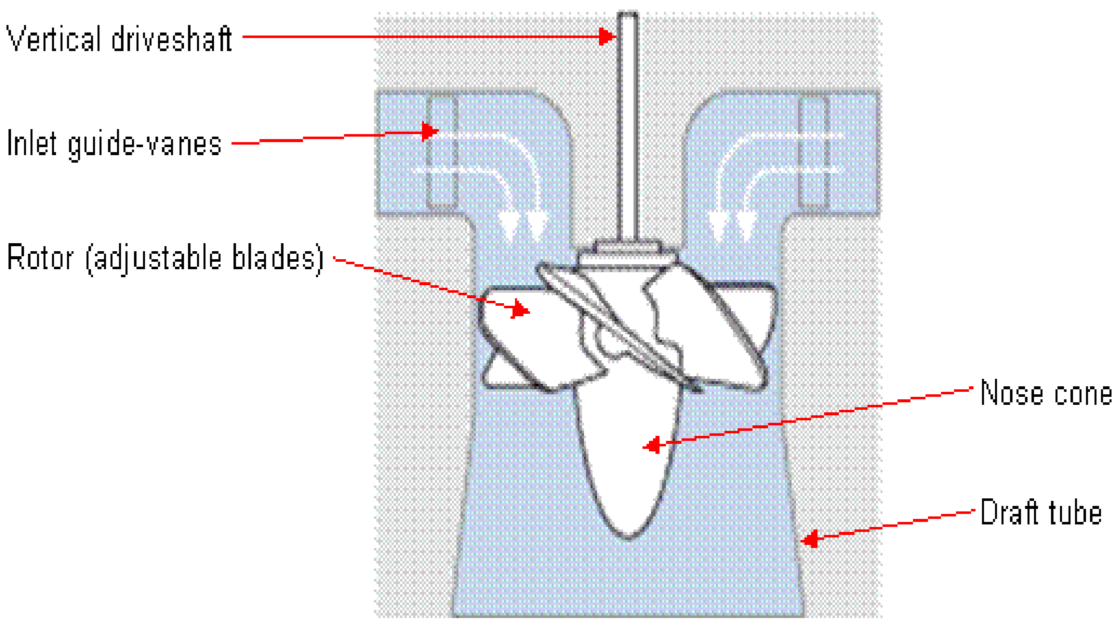
They are built in large sizes and are generally of vertical type to effect economy in space. The alternator is mounted above the turbine and is thus free from flooding.

A modern Francis turbine is an inward mixed flow reaction turbine. The water, under pressure, enters the runner from guide vanes radially and discharges out of the runner axially.

The motion of water is controlled by movable inlet wicket gates , fixed around the runner, through which the water passes on its way from the spiral casing to the runner. Since the pressure at inlet is more than that at outlet, the water flows in a closed circuit and the runner is always full of water.

KAPLAN TURBINE

It is suitable for **heads below 30 m**.



A Kaplan turbine is a propeller' turbine with adjustable blades, the advantage of adjustable blades being that a Kaplan turbine operates at high efficiency even under part load conditions.

Their specific speeds vary from **300 to 1000** or even higher.

All parts of a Kaplan turbine such as spiral casing, guide mechanism and draft tube **except runner** are similar to those of a Francis turbine. A Kaplan runner has **only 3 to 6 blades** as compared to 16 - 24 for a Francis runner.

The speed of Kaplan turbines is more than that of Francis turbines and lies in the range of **300-1000 rpm**, the high speed results in lower cost of runner and alternator and cheaper power house structure.

A Kaplan turbine has a vertical configuration.

A Kaplan runner is also capable of reverse operation as a **pump** and is ideally suitable for a **pumped storage scheme**.

The **cavitation problem** in Kaplan turbines is more serious than in Francis turbines.

Working Principle:

Kaplan Turbine works on the principle of axial flow reaction. In axial flow turbines, the water flows through the runner along the direction parallel to the axis of rotation of the runner.

At first water from pen stock is entered into scroll casing. Then from the scroll casing the guide vanes direct the water to the runner. In Kaplan turbine, the guide vanes are adjustable and can be adjusted to meet the required flow rate.

When the guided vanes direct water towards runner, water enters the main area where it meets the runner blades. Runner blades are adjustable in Kaplan turbine to maintain optimum angle of attack with varying flow rate.

From the runner blades, water enters into the draft tube and finally water is discharged from the turbine through trail race.