Power Generation and Economics (15EE361)
Module 1
Hydroelectric Power Plants

* **Hydrology** : It can be defined as the science that deals with the processes governing deletion and replenishment of water resources over and within the surface of earth.

* **Run-off** : It is the portion of precipitation which makes its way towards streams, lakes or oceans. Run-off can be possible only when the rate precipitation exceeds the rate ~~of~~ at which water infiltrates into the soil and after small and large depressions on the soil surface get filled up with water. Also losses due to evaporation have to be deducted. In general, the run-off is given by $R = P - E$
where R = Run off, P = Precipitation, E = Evaporation.

* **Stream flow** : It is the volume of water that moves through a specific point in a stream during a given period of time. It is also the flow of water in streams, rivers and other channels, and is a major element of the water cycle.

* **Hydrograph** : It is the plot between discharges versus time of the flow. Hydrograph is shown in figure1 below.

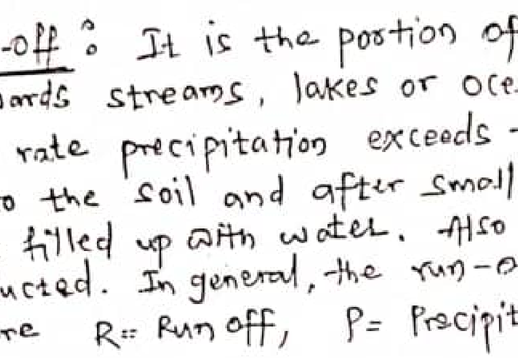

fig.1

Discharge is plotted on Y-axis and the corresponding time that may be months, hours etc. is plotted on the X-axis. Hydrograph also indicates the available power from the stream at different times.

* **Flow duration Curve** : It is a plot of discharge versus percentage of time for which the discharge is available. It is obtained from the hydrograph data. The flow or discharge can be expressed as cubic meters per second, per week or other unit of time. The flow duration curve becomes the load duration curve for hydroelectric plant and thus it is possible to know the total power available at the site. The maximum and minimum conditions of the flow can also be obtained by the flow duration curve where minimum flow condition decides the maximum capacity of plant that can be improved by increasing the storage capacity. fig 2. Shows the flow duration curve.

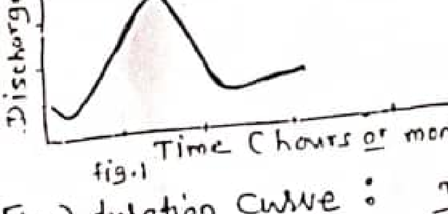

fig2.

* **Mass Curve & Reservoir Capacity:** It is a plot of cumulative volume of water that can be stored from a stre. flow versus time in days, weeks or months. Fig 3 shows a mass curve. Maximum intercept between line AB & mass curve is known as reservoir Cap. The capacity of reservoir, made for a period of deficiency to make available the flow of water at a required rate is studied by mass curve.

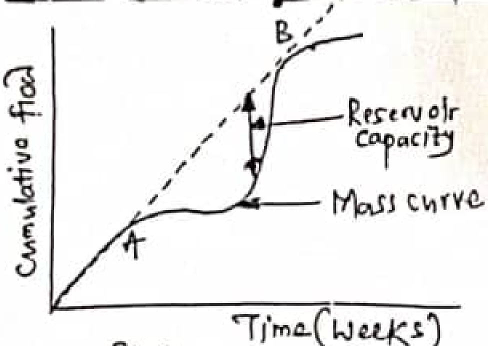

fig 3.

* **Dam Storage:** The function of dam is to provide a head of water to be utilised in the water turbine. Though many times high dams may be built solely to provide the necessary head to the plant, a dam also increases the reservoir capacity. Demand peaks or (short) periods of water shortage can be bridged by Dams as they can buffer water.

* **Hydrological cycle:** The cyclic movement called hydrologic cycle, is, water rotates water from the sea to the atmosphere by evaporation and then from there by precipitation to earth and finally through stream rivers, etc. back to the sea.

* **Merits and demerits of hydroelectric power plants:**

Merits:

i) It requires no fuel, as water is used for the generation of electrical energy
ii) It is quite neat and clean as no smoke or ash is produced
iii) It requires very small running charges because water is the source of energy which is available free of cost
iv) It is comparatively simple in construction & requires less maintenance.
v) It does not require a long starting time like a steam power station. Infact, such plants can be put into service instantly.
vi) It is robust and has longer life.
vii) Such plants serve many purposes. In addition to the generation of electrical energy, they also help in irrigation and controlling floods.
viii) Although such plants require the attention of highly skilled person at the time of construction, yet for operation, a few experienced persons may do the job well.

Demerits:

i) It involves high capital cost due to construction of dam.
ii) There is uncertainty about the availability of huge amount of water due to dependence on weather conditions.
iii) Skilled and experienced hands are required to build the plant.
iv) It requires high cost of transmission lines as the plant is located in hilly areas which are quite away from the consumers.

* Selection of site:

Selection of hydroelectric plants location depends on the following several factors.

i) <u>Availability of water</u>: water energy can be available in the form of either potential energy or kinetic energy. To extract the potential energy, a reservoir or pondage is required where-as to extract the ~~potential~~ kinetic energy, run-off-river project is used. In all the cases, a huge amount of water is required. Normally water is collected in reservoirs during the rain and used for the electricity production throughout the years. Hilly areas are most suitable for hydropower plants.

ii) <u>Storage of water</u>: when the kinetic energy of water is low it is preferable to have the reservoirs to collect the water for use of electricity production. Due to wide variation of rainfall during the year makes it necessary to have the reservoirs. The storage capacity of water is calculated by mass curve. The capacity of plants is based on the water energy available taking into the account of losses due to evaporation & percolation.

iii) <u>Head of water</u>: The availability of head depends upon the topography of the area. High head means high potential energy. To get most economical and effective head, it is necessary to consider all possible factors, which affect it.

iv) <u>Accessibility of site</u>: The site should be easily accessed by rail or road for transporting the plant equipments etc.

v) Distance from power station to the load centres: The generating stations are normally connected to the main grid through the transmission lines. The cost of transmission lines are also considered during the selection of site.

vi) <u>Availability of land</u>: The land should be available at reasonable price, for economical production of electricity.

vii) <u>Type of land</u>: Bearing capacity of the ground should be adequate to withstand the weight of heavy equipment to be installed.

* <u>General arrangement of hydel plant</u>: shows in figure 4 below.

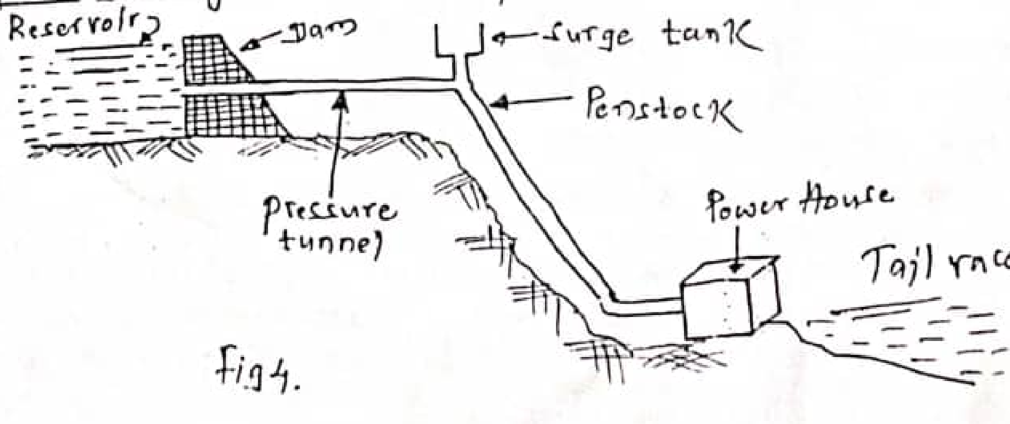

fig 4.

* Elements of the plant :

The main elements of a typical hydroelectric plant are : dam, reservoir water conduit system, tailrace, surge tank, trash rack, & power house (which consists of generator, prime mover, switchyards etc)

i) **Dam or barrage** : A dam or barrage is constructed to provide a head of water to be utilized in the water turbines. A dam across the river is a very important component in most of the high-and medium head hydropower plants. Dams are also built on top of hills, in case of pump storage power plants, where is no inflow.

ii) **Reservoir and forebay** : The main purpose of reservoir is to store water which may be used to generate electricity and for irrigation purposes. The water is mainly stored during the rainy season. The capacity of the reservoir is decided by the water requirement for power generation.
Forebay is a regulating reservoir storing water temporarily when the load on turbine is reduced and provide water when load is increased. It can be considered as the surge reservoir near the intake. This may be the pond behind the diversion dam or canal spread out.

iii) **Water conduit system** : A water conduit system carries water from the reservoir to the turbine of powerhouse through the pressure tunnel or pipes called penstocks those may be laid above ground or underground

iv) **Tailrace** : water is discharged into the tailrace after passing through the turbine, which carries it into the river. A tailrace is an open channel or tunnel depending upon the powerhouse location. A discharge from all the turbines is collected in the tailrace at its beginning by means of branch channels. The tailrace may discharge into the original river itself or some other river.

v) **Surge tank** : It is provided to act as pressure release valve of the water conduit system from the effect of water hammer, which is the sudden change of water pressure above the normal. When an additional storage space (called surge tank), near turbine is provided which stores water during the turbine load reduction and release water when sudden increase in load is required, it controls the pressure variation of penstock and prevents water hammer effect. Water hammering is takes place in the penstock when the abnormal surges are created in the penstock. Water hammering may affects on the penstocks in terms of bursting.
Different types of surge tanks being used namely, simple type, restricted orifice type, differential type, expansion chamber type and overflow type.

vi) Trash rack : It is provided to stop the entry of debris, which might damage the gates and turbine runners or choking of nozzles of the impulse turbines It is placed across the intake. and is made of steel bars.

vii) prime mover : The head of water is converted into the kinetic energy in prime mover, which rotates the shaft of the electric power generaters (normally synchronous alternators). Thus a prime mover also called a turbine, converts the kinetic and potential energy of water into the mechanical energy. The commonly used water turbines are francis, Kaplan, Propeller, Pelton. Normally water turbines rotate on the vertical axis.

viii) power house : Power house is normally located near the foot of the dam. It may be underground or open type. water is brought to the power house with help of penstocks and passed to the turbines those rotate the alternators. The location of the powerhouse is decided based on the maximum possible head at the turbine. In some locations underground power station may be more economical. In power house there are several in-house auxillaries and controls.

ix) Spillway : It discharges the excess water of reservoir beyond the full permission level and acts as a safty valve of reservoir. If excess water is not discharged, water level of reservoir will be raised water may start flowing over the dam, a phenomenon known as over topping. The spillways can be classified as a) over flow spill way b) side channel spillway c) emergency spill way d) chute or trough spillway e) shaft or siphon spillway.

* Classification of plants based on water flow regulation

According to this classification the plants may be divided into

i) Runoff River plants without pondage.
ii) Run-off River plants with pondage
iii) Reservoir plants.

i) Run-off River plants without pondage : As the name indicates this type of plant does not store water : the plant uses water as it comes. The plant can use water only as and when available. Since these plants depend for their generating capacity primarily on the rate of flow of water during rainy season high flow rates may mean some quantity of water to go as waste (i.e without being used for generation of power) while during low run-off periods, due to low flow rates, the generating capacity may be impaired. A typical runoff river plant has a powerhouse located with a weir spanning the river that also serves as the river flow regulator.

ii) Run-off river plants with Pondage : Usefulness of a run-off-river plant is increased by pondage. Pondage permits storage of water during the off-peak periods and use of this water during the peak periods. Depending up on the size of pondage provided it may be possible to cope, hour to hour with fluctuations of load throughout a week or some longer period. With Enough pondage the firm capacity of the plant becomes more. This type of plant can be used on parts of the load curve as required

iii) Reservoir plants : A (storage) reservoir plant is that which has a reservoir of such size as to permit carrying over storage from wet season to the next high dry season. water is stored behind the dam and is available to the plant with control and regulation as required. Such plant has better capacity and can be used efficiently throughout the year. Its firm capacity is increased and it can be used either as a base load plant or as a peak load plant as required. It can be also used on any portion of the load curve as required. Majority of hydroelectric plants are of this type

* Classification of plants based on water head

Hydroelectric plants may be classified into high-head, medium-head and low head plants. A plant may be classified as high head, if operating on head above 300 meters. Low head plants work under heads below 30 meters. Medium head plants are those lying between the above two Classes.

i) High head plants : Due to high head, small amount of water can produce large amount of power. Therefore these types of plants are very economical. Normally the reservoirs are high up in the mountains and the powerhouse is located at the foot, taking advantage of large level difference.

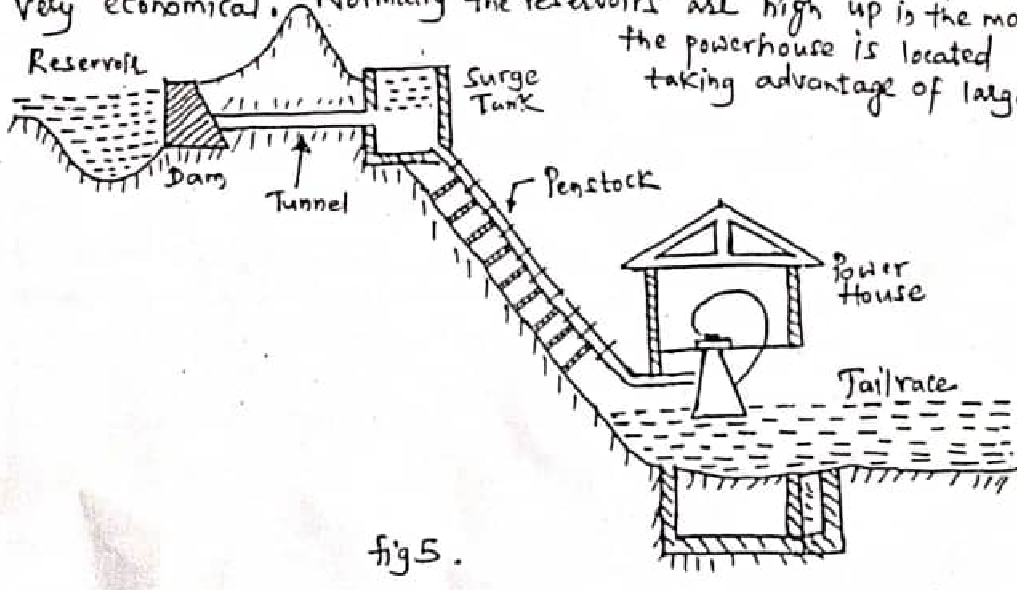

fig 5.

in hilly ...

The catchment area is small and if water from one stream is not sufficient, then water from neighbouring streams can be diverted to the lake through the pipelines or tunnels. The water is carried from main reservoir by tunnel to powerhouse via surge tank. The length of conduit system may be 15 km or more. For heads above 500 m, pelton turbine are used and Franci's turbines are common for low head.

Medium head plant: Larger volume of water is needed in such plants as compared to high head plants. Therefore, a reservoir of large capacity with large catchment area is required. In these plants, water is generally carried from main reservoir to the forebay and then to powerhouse through the short penstocks. There is no need of surge tank as forebay itself acts as surge tank. Generally there is one penstock per turbine. Francis, Kaplan and propeller type of turbines are common for the medium head plants.

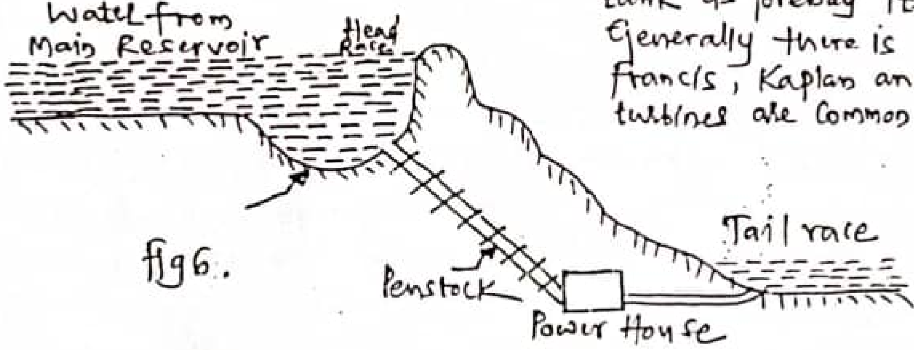

fig6.

Low Head Plants: To generate the same amount of power in such plants water required is much larger than the high head power plants. Generally run-off river plants, or tidal plants & midget plants fall into this catagory. The catchment area and the magnitude of peak flood are very large, the spillway length being considerable.

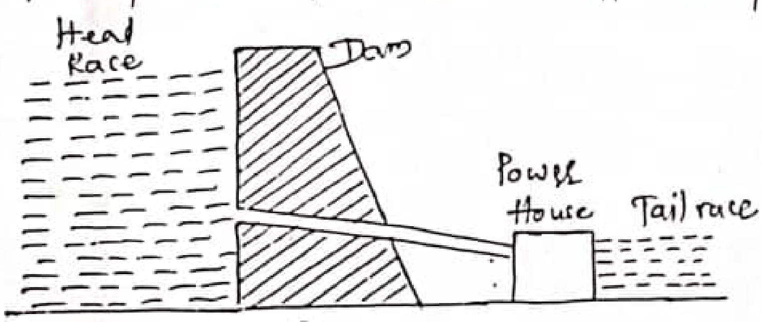

fig7.

Franci's, Kaplan or propeller turbines are used for low head plants. The size of turbine and powerhouse are large. No surge tank is required. Here in this case usually a small dam is built across the river to provide necessary head. The excess water is allowed to flow over the dam itself.

* Classification of plants based on type of load the plant has to supply

Hydroelectric plants may be classified into base load, peak and pumped storage plants for peak load.

* Base load plants : Such plants can take up load on the base portion of the load curve. These are generally of large capacity. Since such plants are kept running practically on block load the load on them is almost constant. Load factor of such plants is therefore high. Run off river plants without pondage can be used as base load plants. Similarly those plants which have large storage are ideally suited to work as base-load plants, particularly during the rainy-season when water level of reservoir due to rains will be high. In other words a hydro electric plant work as a base load plant if there is continuous power generation.
* Peak load plants : Run-off-river plants with pondage can be used as peak-load plants. In case there is enough a large portion of the load can be supplied by such plants. Reservoir plants with enough storage behind the dam can be used either as base load or as peak-load plants as required. If the conditions prevailing at the power station permit regulated release of water, plant can be used to generate peak power. (Plants used to supply the peak load of the system corresponding to the load at the top portion of the load curve are known as peak-load plants).
* Pumped storage plants for peak load : These plants are used when quantity of water available for generation of power is otherwise insufficient. If it is possible to pond at head water and tailwater locations water after passing through the turbine is stored in the tailrace pond from where it may be pumped back to the head water pond. The pumping back from the tailrace pond to the headwater pond is done during off-peak period. During the peak load period water is drawn from the head water pond through the penstock to operate turbines. The general arrangement of a pumped storage plant is shown in fig 8. Such plants can recover almost 70% of power used in pumping the water. Advantage of pumped storage plant is that it decreases the operating cost of the steam plant when working in combination with it because it serves to increase the load factor of the steam plant and provides added capacity to meet peak loads.

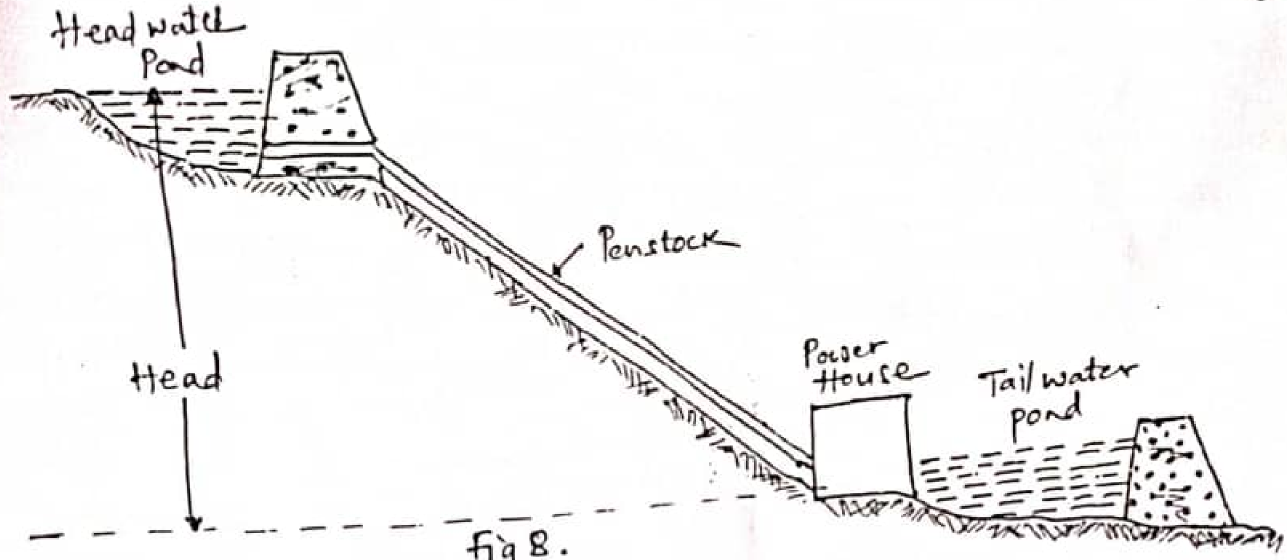

fig 8.

* Water Turbines :

Water Turbines, which Convert water energy into mechanical energy, can be considered as motors run by water. The main function of water turbines is to rotate the generator coupled to it to produce electricity.

Basically the water turbines can be divided into two main catagories : the impulse type and reaction type. Water flows out of a nozzle, in case of impulse type, in the form of a jet such that all the pressure energy is converted into Kinetic energy. The jet strikes the series of the buckets mounted on the periphery of the wheel. Because of the impact, the runner is rotated about the axis. Therefore the turbine is called the impulse turbine. Since the pressure throughout the turbine is at the atmospheric that is constant, the impulse turbine is also called a constant pressure turbine. Pelton turbine is an impulse turbine.

Reaction turbine works on the principle of reaction. Water enters the turbine at high pressure and low velocity, some energy is converted into Kinetic energy and water then enters the runner and pressure energy is successively Converted into the Kinetic energy. Water flowing through the runner Creates a reaction on the runner vane and runner is rotated. In reaction turbine, water is under pressure and turbine is filled with water when working. Therefore a casing is must in an impulse turbine so that water cannot Splash out. Reaction water turbines usually have vertical arrangement. Since water can be admitted all over the runner at one time in a reaction turbine, it is sometimes also called full admission turbine. Propeller, Francis, Kaplan and more recently Deriaz turbines fall in this catagory.

3, 4, 6, 7, 12, 13, 16, 17, 19, 27, 28, 29, 38, 43, 45, 46, 50, 57, 64

* Pelton Wheel :

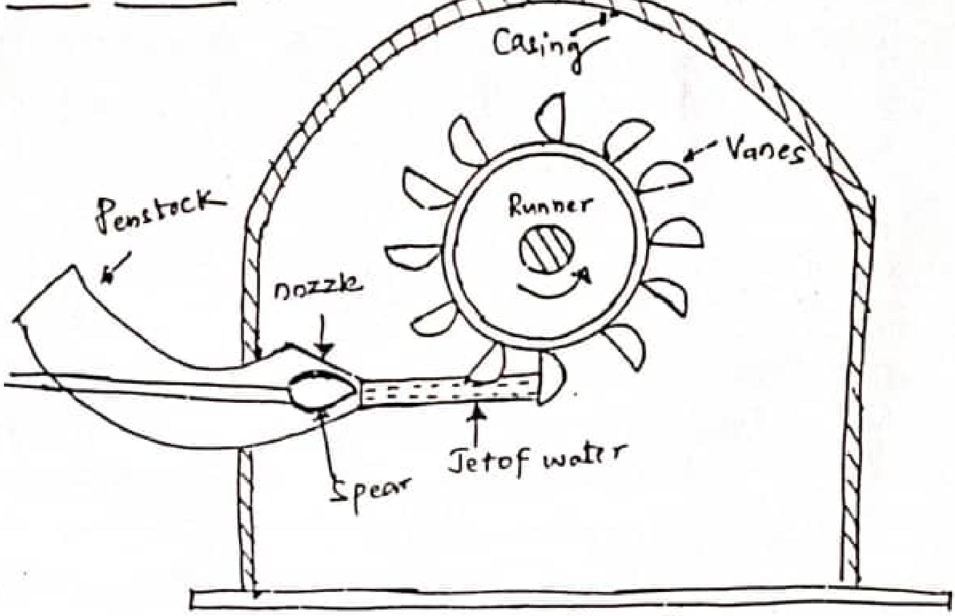

fig 9. Pelton Turbine

Pelton wheel is an impulse turbine and it is suitable for high head and low flow plants. The potential energy of water in the penstock is converted into Kinetic energy in a water jet issuing from a nozzle as shown in fig 9 above. Pelton wheel consists of rotor equipped with eliptical shaped buckets along the periphery of the turbine. The water jet impenges on the buckets, this impulse force causes the motion of the rotor. After doing useful work water discharges to the tail race. The quantity of water discharged through the nozzle is controlled by controlling the nozzle opening by means of needle placed in the nozzle tip. The movement of the tip is contolled by the governer. when the load on the turbine reduces the governer pushes the needle into the nozzle, thereby reducing the quantity of water striking the buckets. When load on the turbine increases the reverse action will takes place.

* Francis Turbine :

The Francis turbine is a reaction turbine as shown in fig 10. It is a inward radial flow turbine in which water at inlet possesses both Kinetic and pressure energies. As water flow through the runner, a part of pressure energy goes on converting into kinetic energy. Thus the water through the runner is under pressure. It consists of casing, guide mechanism, runner and draft tube as shown in fig 10.

As water from the casing enters the stationary guiding mechanism. The guiding mechanism consists of guide vanes or blades which the water to enter the runner which consists of moving vanes. The water flows over the moving vanes in the inward radial direction and is discharged at the inner diameter of the runner. outer diameter of the runner is inlet and the inner diameter of the runner is the outlet. for regulating the quantity of water entering the turbine, the guide blades are provided about an axis is so that, by turning them in one or other direction simultaneously, the passage may be varied to control the speed automatically by using servomechanism. The exist of the Franci's turbine is connected with draft tube, which allow the water to enter the tailrace. The turbine shaft is connected to the alternator which rotates along with turbine to generate the electric power.

** Kaplan Turbine :

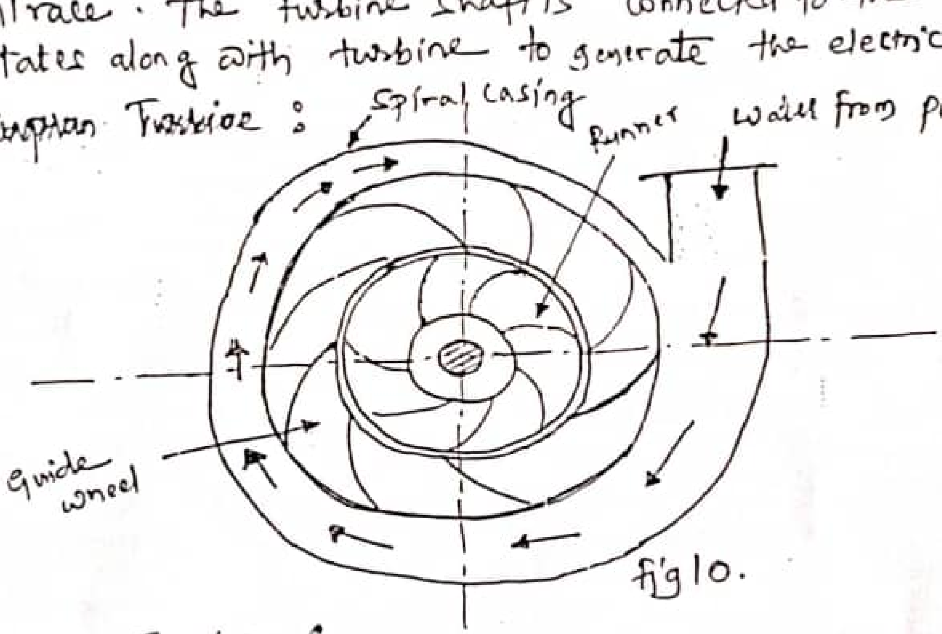

fig 10.

** Kaplan Turbine :

The Kaplan turbines are essentially a low head turbines (for heads upto 100 ft) These turbines are also known as reaction turbines and requires large quantity of water. The Kaplan turbine is a axial flow reaction turbine as shown in fig 11a. in which the shaft of the turbine is vertical provided with hub at lower end. The vanes are fixed on the hub and acts as a runner. These vanes are adjustable. The Kaplan turbine consists of a spiral casing guide mechanism, runner and draft tube. The water from the penstock enters the spiral casing and then moves to the guide vanes. From the guide vanes the water turns through 90° and flows axially through the runner as shown in fig 11. and discharges to the tailrace through the draft tube. The flow can be controlled by adjusting the gate opening & blade angle simultaneously by governing mechanism.

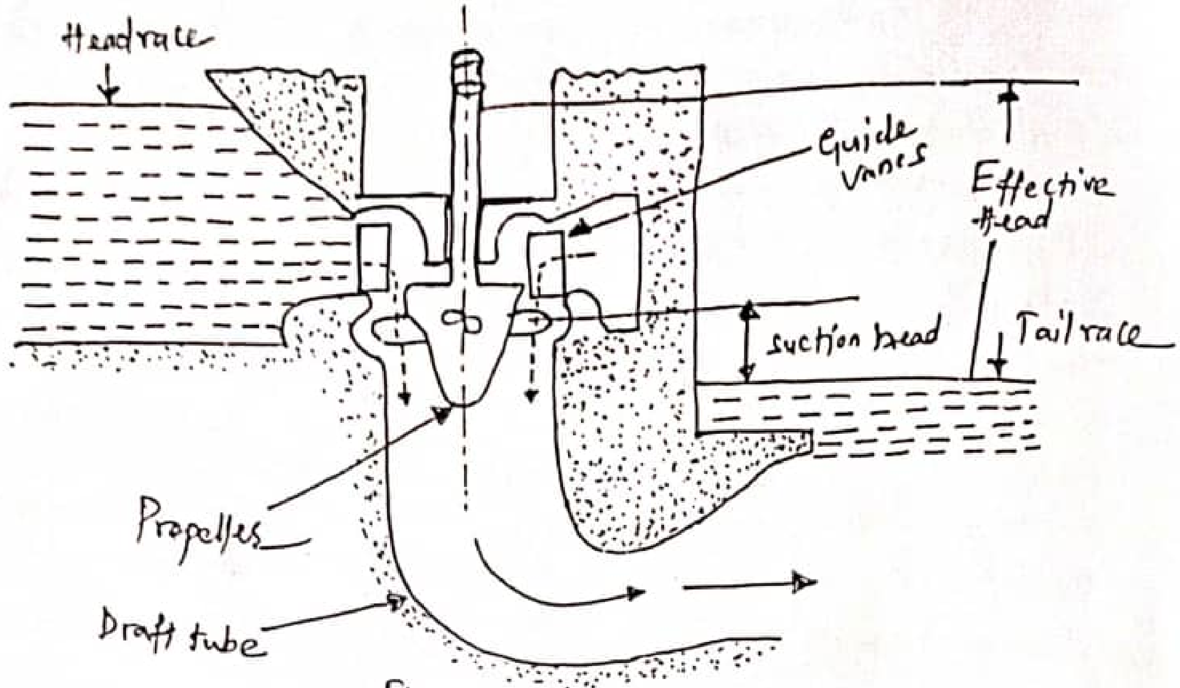

fig 11a. Kaplan Turbine

* Propeller Turbine:

The propeller turbine is a reaction turbine used for low heads (4m-80m) and high specific speeds (300-1000). It is an axial flow device - providing large flow area utilizing a large volume flow of water with low flow velocity. It consists of an axial-flow runner usually with four to six blades of airfoil shape (fig 11b). The spiral casing and guide blades are similar to those in Francis turbines. In propeller turbines as in Francis turbines the runner blades are fixed and nonadjustable.

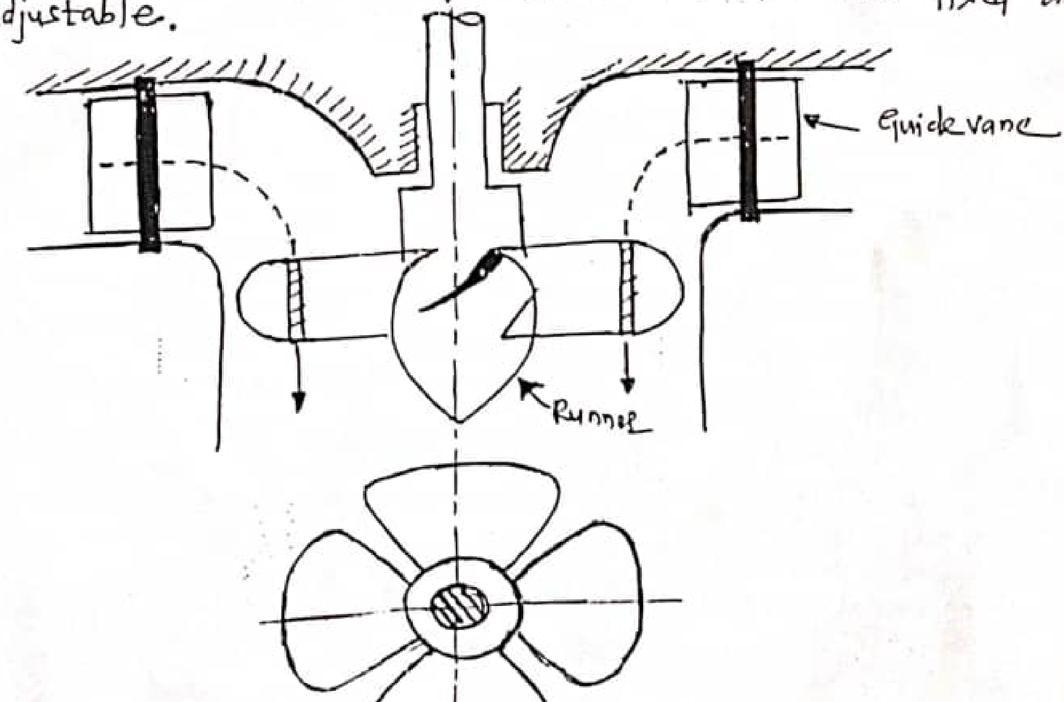

fig 11.b

* Characteristics of turbines :

i) **Head** : for heads above 500 meters reaction turbines of various types are used. For heads above 500 meters upto about 2000 meters pelton wheels are used.

Head and other Conditions	Type of Turbine
(a) Heads lower than 30 meters and for variable load operation	Kaplan or movable vane propeller
(b) Heads less than 70 meters and for fairly constant load operation	Fixed vane propeller
(c) Heads 70 to 500 meters	Francis

ii) **Efficiency at variable loads** : Fig. 12a and 12b show typical efficiency curves for an impulse turbine (Pelton wheel) and different types of reaction turbines.

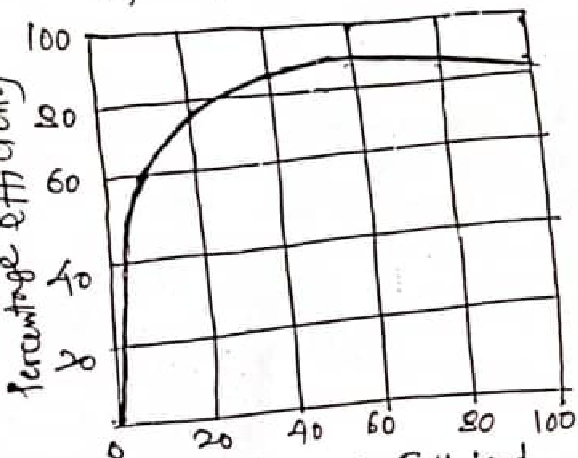

fig 12a
Efficiency curve of an impulse turbine

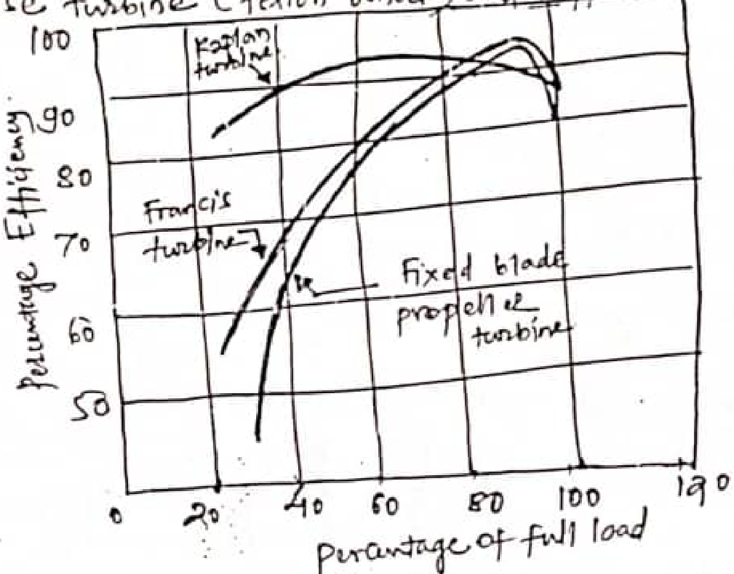

fig 12b
Efficiency curve of reaction turbine of various types

iii) **Specific speed**: This is defined as that speed at which a turbine would run when developing 1 metric horse power under a head of 1 meter. It can be shown that if n_s, n, P and h denote respectively the specific rotational speed, actual rotational speed, metric hp (= 736 watts) and head in meters respectively.

$$n_s = \frac{n P^{\frac{1}{2}}}{h^{\frac{5}{4}}} \text{ revolutions per minute}$$

Further, if power is expressed in kW the above expressions becomes

$$n_s = 1.165 \, \frac{n (kW)^{1/2}}{h^{5/4}} \text{ revolutions per minute}$$

ordinary ranges of n_s are as follows —

pelton wheel	12–70
Francis	80–420
Propeller and Kaplan	310–1,000

iv) <u>Turbine setting</u> : A pelton wheel is always set at a higher level than (usually at least two meters above) the ~~tail~~ highest tail race level. As against this a Francis turbine runner should be placed at a level very near or below the lowest tail race level.

v) <u>Runaway Speed</u> : This is the maximum speed at which a turbine wheel would run under the worst condition of operation ~~at which~~ with all gates open so as to allow all possible water inflow under maximum head. (The worst condition corresponds to load on the generator being suddenly thrown off and governer failing to act) This must be taken into account and the generator coupled to turbine must be able to withstand the full runaway speed of the turbine under maximum permissible speed.

*- <u>Governing of Turbines</u> :

All hydraulic modern turbines are directly coupled to electric generators. Irrespective of variations in the load the generators are required to run at a constant speed which is fixed by the number of pair of poles and required frequency. However when the load on the generator varies there will be corresponding variations of load on the turbine also. If the input to the turbine remains the same the speed of the runner will tend to increase or decrease depending on whether there is a decrease or an increase in the load. This will cause the speed of the generator also to vary which is however not desirable. In order that the generator may always run at a constant speed, the speed of turbine runner must be maintained constant. This is usually done by regulating the flow of water passing through the runner in accordance with variations in the load. Such an operation of speed regulation is <u>known as governing</u>; it is done automatically by means of a governer. One of the common types of governers predominantly used with modern turbines is oil pressure governer.

The component parts of such a governer are

i) servomotor also known as relay cylinder.

ii) Relay valve also known as control valve <u>or</u> distribution valve.

iii) Actuator or pendulum which is belt or gear driven from the turbine main shaft.
iv) oil sump
v) oil pump which is driven by belt connected to turbine main shaft.
vi) A system of oil supply pipes connecting oil sump with the relay valve and relay valve with servomotor.

The working of oil pressure governer will be clear with reference to to figure 13. The servomotor or relay cylinder has a piston moving under the action of oil pressure. First the movement of the piston rod is amplified and translated to the controlling device of the turbine. The distributing valve is actuated by the speed responsive elements of the governer and controls the supply of oil to the cylinders. The actuator is a flyball mechanism working as the speed responsive element. As stated it is driven from the turbine main shaft. Oil is pressurised by the oil pump.

Suppose the speed of the turbine falls. This will result in the sleeve on the actuator shaft descending and causing the main lever to raise the pistons of the distributing valve. As a consequence oil under pressure would be sent to one end of the oil cylinder and this would move the piston to one side. As would be clear from the figure this movement would be transmitted to the controlling device to open the nozzle of the impulse turbine or guide vanes of the reaction turbine. When the turbine speed rises reverse action would takes place. As long as speed of the turbine remains normal the main lever, the pistons in distributing valve and relay cylinder will occupy their normal positions.

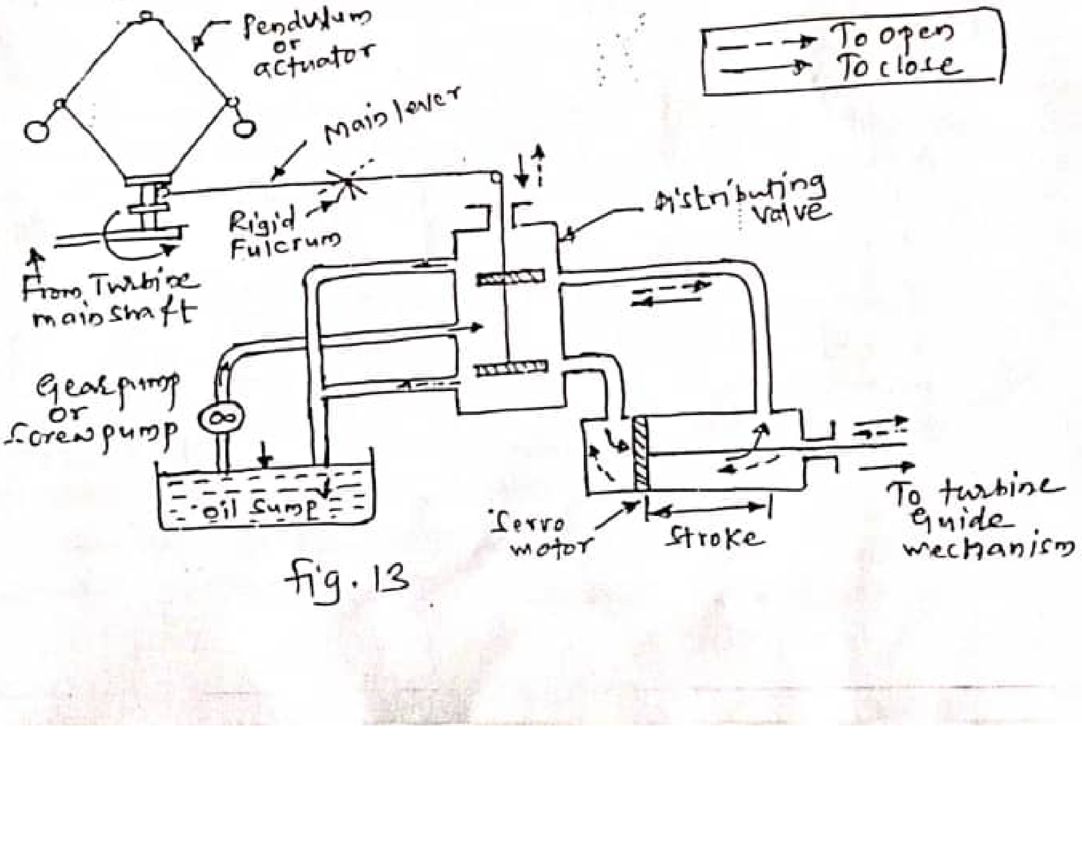

fig. 13

* Selection of water Turbines :

The hydraulic turbine is selected according to the specific conditions under which it has to operate and attain the maximum possible efficiency. The choice depends on the head available, power to be developed and the speed at which it has to run. The following factors basically govern the selection of a suitable type of turbine.

i) Operating head : The present practice is to use Kaplan and propeller type of turbines for heads up to 50m. For head from 50 to 400m, Francis turbines are used. For heads greater than 400m, impulse or pelton turbines are used. The range of heads as mentioned is not rigid and may change if other conditions dominate to achieve economy.

ii) Specific speed : It is better to choose turbines of high specific speeds. High speed turbines means small sizes of turbines, generators power house, etc. and therefore, more economical. The range of specific speeds of the turbines should correspond to the synchronous speed of the generator, $N = \frac{120f}{P}$, where f is the frequency and P the number of poles.

iii) Height of installation : It is better to install the turbines as high above the tail water level (TWL) as possible. This saves the cost of excavation for the draft tube. Care should be taken to ensure that cavitation does not occur.

iv) Performance characteristics of turbine : The performance characteristics of turbines (i.e. constant head characteristic curves, constant speed characteristic curves, constant efficiency curves) should be studied carefully before recommending the type of turbine to be used. A turbine has the maximum efficiency at a certain load. When a turbine has to operate mostly at part loads, only those turbines whose efficiencies do not fall appreciably with part loads should be selected. Kaplan and Pelton turbines are better than Francis & Propeller turbines in this respect.

v) Size of turbine : It is better to go in for as large a size of turbine as possible since this results in economy of size of the power house, the number of ~~runners~~ penstocks, the generator etc.. Bigger size means less number of runners. However, the number of runners should not be less than two so that atleast one unit is always available for service in the case of a plant breakdown.

* Underground, small hydro & pumped storage plants :

Underground : An underground power station is a type of hydroelectric power station constructed by ~~excavating~~ removing the major components (eg. machine hall, penstocks, & tailrace) from rock, rather than the more common surface-based construction methods. One or more conditions impact whether a power station is constructed underground. The terrain or geology as gorges or steep valleys may not accomodate a surface power station. A power station within bedrock may be more ~~or~~ inexpensive to construct than a surface power station on loose soil.

Often underground power stations form part of pumped storage hydroelectricity schemes. Their basic function is to level load. They use cheap or surplus off-peak power to pump water from a lower lake to an upper lake. Then, during peak periods (when electricity prices are often high), the power station generates power from the water held in the upper lake.

Small hydro :

As the name implies, small hydro is the smaller version of large hydro. According to Central Electricity Authority of India & Bureau of Indian Standards, small hydroelectric power stations are classified as follows,

(a) Depending on capacity
- Micro plant is upto 100KW
- Mini plant is from ~~101 to 1000 KW~~ - plant rating is more than 100kW & less than 2MW
- Small plant is from ~~1001 to 6000 KW~~ 2MW to 25MW

(b) Depending upon head
- Ultra low head : below 3 m
- Low head : less than 30m
- Medium head : between 30 and 75m
- High head : above 75m

Unlike other renewable energy sources, small hydro is not something that has been invented recently, but is, in fact, one of the technologies mankind has been using since centuries, just as it has been using wind energy, biomass, geothermal & solar energy. The first ever small hydro unit for generating electricity was commissioned in India in 1897 at Darjeeling. It had a capacity of 130 KW & is still operating today. Another small hydropower in 1902 to supply power to the Kolar gold mines. Power generated with small hydro station can be used for agro processing, local lighting, water pumps and small businesses.

* pumped storage plants.

The pumped storage plants are a special type of power plants which works as an ordinary conventional hydropower stations.

* These plants generate electricity during the peak load hours, called generating phase & pump the water back from tailrace to reservior during off peak hours known as pumping phase

* during the peak load period water is drawn ~~thro.~~ from head water pond through penstock in order to operate turbine.

* The general arrangement of a pumped storage plant is as shown below.

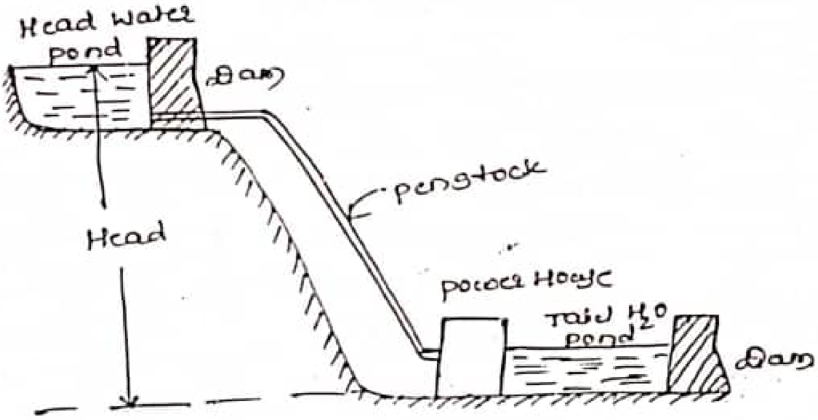

fig - pumped storage plant

* The pumped storage plant have following advantages
1) As compared to other peaking units, pump storage plants are economical.
2) pumped storage plants are free from environmental pollution.
3) It offers great flexibility in operation
4) These plants allow other units to run as base load and thus improve the overall efficiency of the sys

* The drawbacks of storage plant are
1) They have to be operated in narrow range of rated capacity to obtain the maximum efficiency.
2). Time interval required is about to full load the

3.14.13.

from the complete shut down

* **choice of size and Number of Generating units**

The load on the power station is never constant & it vary at different timings of the day. & the generating plant should have the capacity to meet the maximum demand.

* for example one unit is taken of certain size to meet the maximum demand of power station then the plant will be operating on full load, only for short duration and it will be operating on no load condition for rest of the day.
* ∴ The generating unit could not operating at all the times only it operates during best conditions giving - maximum efficiency.
* In isolated station, in order to maintain reliability of power supply at all the times, and continuity of power supply at all the times, and continuity of equal capacity is required. ∴ the another unit of equal capacity is required. ∴ the capital cost is considered for both the units.
* However the capital cost includes the cost of both the units, the capacity of each of unit is corresponding to the maximum load on power station.
* Alternatively number of small sized generating units can be choosen in order to fit the load curve as closely as posible, ie the generating units are selected of such sizes & in such number that they work on suitable portions of the load curve, in such a way that, each unit will operate on full load.
* during such condition one unit of the largest size is chosen, & this unit would be much smaller than the maximum load capacity required.

* The alternative will require large number of generating units & area required is also more & cost is more
* ∴ compromise is to be made during the selection of siz & no of generating units in generating station.
* The aim should have small number of units & to fit them as well as possible on the load curve
* Neither we should go for single generating unit of larger capacity nor for a large number of generating units of smaller sizes.

* Layout of Hydro power plant.

The general layout of hydro power plant is determined by its type

* For the plants consisting of vertical turbines, the most convient and economical layout will be with turbines installed in line parallel to the length of the turbine house as shown in below fig

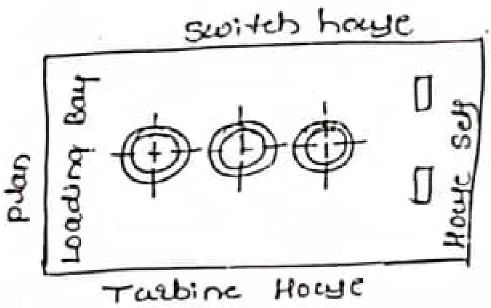

fig- Layout of Hydro power plant with vertical reaction turbines

The spacing b/n the machines will depend upon the size of scroll case, width of flume or by means of overall diameter of alternators.

* In case of turbines with horizontal shaft arrangement, the most suitable layout will be, placement of

turbines right angles to the length of turbine house. (11)

* The horizontal machines can also be placed llel to the longitudinal axis of turbine house.

* **Hydro plant Auxiliary**

The auxiliary essentially required for hydro-electric power plant are governor, cranes, lubricating oil pumps, drainage & dewatering pumps, valves, battery charging units, CO_2 cylinders etc.

* These auxiliary are electrically driven.
* Water is used to cool bearings of the turbines, generators & the transformers, & it is circulated through water pumps.
* Air compressors maintain supply of air under pressure for operation of generator brakes & other uses in the power station.
* Fans are required for ventilation of the turbine, cooling of transformers
* oil pumps handle transformer oil through the cleaning & cooling system.
* Cranes are required to fit heavy parts or place them in position during repairs.
* Water pumps are required for unwatering of turbine pits during repairs or during inspection.
* Storage battery are required to supply low voltage dc power for switchgear control, these batteries are constantly charged through a battery

charging equipment using a rectifier or motor generator set.

* The supply for the above auxiliary is usually obtain from the station transformer.

* ## Environmental Impacts of Hydro power plants.

Even though the hydal power plants are considered as clean & harmless but they have following environmental impacts

1) Hydro electric power plants require large quantity of water for power generation, hence the dams are to be constructed, which leads to displacement of the inhabitants of the area, which leads to some social & economic problems.

2) The dams change local ecological conditions, vary the amount of pressure applied to the ~~ground~~ land, & the ground water level, which adversely affect the plant and animal life nearby region.

3) The construction of hydroelectric power plant slows down the flow of water from rivers and they causes the pollution of water, causes the growth of blue green algae, encourages the reproduction of bacteria.

4) Large area acquisition means destruction of forest, which is harmful to environment.

5) Large number of workers required for construction are brought into area and disturb the very nature of local population.