ATME COLLEGE OF ENGINEERING

13th KM Stone, Bannur Road, Mysore - 570 028

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

NOTES

COURSE TITLE: ELECTRICAL POWER GENERATION AND ECONOMICS

COURSE CODE: BEE405A

SEMESTER: IV

MODULE-1: HYDRO POWER PLANT

Prepared by

Department of EEE,
ATME College of Engineering

INSTITUTIONAL VISION AND MISSION

VISION:

- Development of academically excellent, culturally vibrant, socially responsible and globally competent human resources.

MISSION:

- To keep pace with advancements in knowledge and make the students competitive and capable at the global level.
- To create an environment for the students to acquire the right physical, intellectual, emotional and moral foundations and shine as torchbearers of tomorrow's society.
- To strive to attain ever-higher benchmarks of educational excellence.

Department Vision and Mission

Vision:

To create Electrical & Electronics Engineers who excel to be technically competent and fulfill the cultural and social aspirations of the society.

Mission:

- To provide knowledge to students that builds a strong foundation in the basic principles of electrical engineering, problem solving abilities, analytical skills, soft skills and communication skills for their overall development.
- To offer outcome based technical education.
- To encourage faculty in training & development and to offer consultancy through research & industry interaction.

Program Educational Objectives (PEOs)

PEO1: To produce competent and ethical Electrical and Electronics Engineers who will exhibit the necessary technical and managerial skills to perform their duties in society.

PEO2: To make Graduates continuously acquire and enhance their technical and socio-economic skills.

PEO3: To aspire Graduates on R&D activities leading to offering solutions and excel in various career paths.

PEO4: To produce quality engineers who have the capability to work in teams and contribute to real time projects.

Program Outcomes (POs)

Engineering Graduates will be able to:

PO1: Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems.

PO2: Problem Analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: Design / Development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and team work: Function effectively as an individual and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of the engineering management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12: Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

Program Specific Outcomes (PSOs)

The students will develop an ability to produce the following engineering traits:

PSO1: Apply the concepts of Electrical & Electronics Engineering to evaluate the performance of power systems and also to control industrial drives using power electronics

PSO2: Demonstrate the concepts of process control for Industrial Automation, design models for environmental and social concerns and also exhibit continuous self- learning

MODULE-1

Hydroelectric Power Plants

Structure

1.0 INTRODUCTION

Power Generation and Economics deals with generation of Power (Electrical Energy) from different types of Renewable and non renewable energy sources such as Hydro, Thermal, Nuclear, Wind, Tidal, Diesel, Gas Turbine etc.

The generated power will be transmitted to the substations and Distributed to the Domestic and Industrial purpose. Economic aspects will be studied while distribution of power from the substations.

1.1 OBJECTIVES

Explain the arrangement and operation of hydroelectric power plant and working of major equipment in the plants.

1.2 IMPORTATNT TERMINOLOGY

- **Hydrology:** Hydrology can be defined as a part of science that deal with the study of the properties, distribution, quality and effects on water resources over and within the surface of the earth. Or the scientific discipline in the field of physical geography that deals with the water cycle is called hydrology.

- **Hydrological water cycle:** The cyclic movement of water is called the hydrological cycle. The water rotates from sea to atmosphere by evaporation and then from there by precipitation to the earth and finally back to sea through streams, rivers, etc. The inflow and outflow of water are calculated by considering various elements of water cycle, Inflow-precipitation, out flow-evaporation, surface runoff, infiltration, transpiration, interception, storage.
- **Run off and Stream flow:**

Stream flow: Stream flow, is the flow of water in streams, rivers, and other channels, and is a major element of the water cycle. Elements of water cycle are, *Precipitation:* It is a process where water from the atmosphere reaches the earth's surface. It is mainly of two types liquid precipitation (rainfall) and solid precipitation (snowfall).

Evaporation: It is the process by which water from liquid or solid state is converted into the vapors form.

Infiltration: it is a process by which water enters the surface of the soil and makes it way downward to the water table.

Transpiration: It is a process where moisture is absorbed by the root of the trees.

Interception: it is a quantity of water that is intercepted by vegetation, buildings and other which is subsequently evaporated without contributing to the runoff.

Storage: This a process of storage of water for future and other mankind needs.

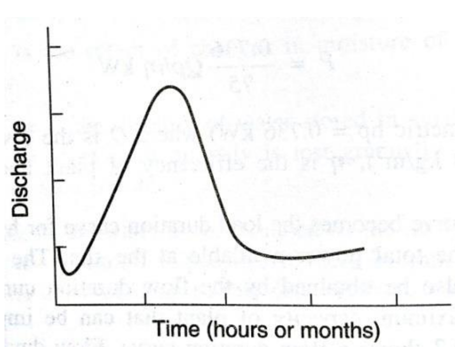
Run-off: It is that process of precipitation, which makes its way towards stream, lakes or oceans. Run off can be possible only when the rate of precipitation exceeds the rate at water infiltrates into the soil after small and large depression on the soil surface get filled up with water. Also losses due to evaporation of water to be deducted (including all elements).

Run-off = Precipitation – Evaporation

- **Hydrograph:** A graphical representation of water flow discharge with respect time. It is plotted by taking discharge on the y axis and time on the x axis. Time can be represented in hours, days, months, etc. It can also be used for calculating power available from stream at different times of the day or years.

Unit hydrograph: It is a hydrograph of actual run off where there is uniform rainfall and a real uniform distribution.

It is a hydrograph with a volume of 1 meter of runoff resulting from a rainfall of a specified duration and a real pattern. It is a powerful tool used for flood calculations.



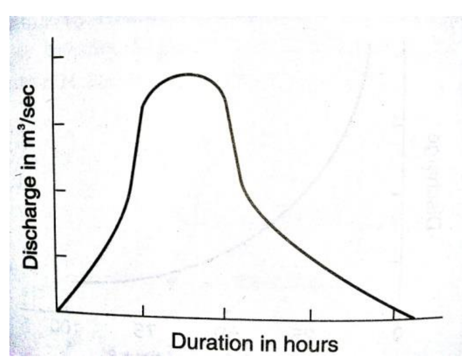


Fig.1.1 A Hydrograph and A Unit hydrograph

- **Mass curve:**
  1. Mass curve is a plot of cumulative volume of water that can be stored from stream flow verses time in days, months or years. As shown in figure below
  2. Maximum intercept between line AB and mass curve is known as reservoir capacity.
  3. Unit used to indicate storage are cubic meter or the day-second-meter (1 m^3 /sec for 1day = 60*60*24 = 86400m^3)
  4. The water stored in dams is called poundage and stored in upstream reservoirs is called storage.
  5. The capacity of the plant is based on capacity of storage, it can be modified as required for generating capacity.
  6. 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.

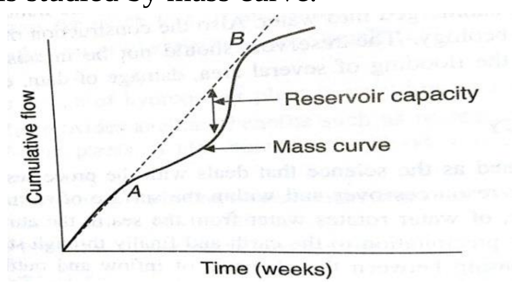


Fig:1.2 Mass curve

- **Flow Duration curve:**
  - It is plot of discharge verses % time for which the discharge is available. It is obtained from hydrograph data.
  - Discharge is expressed in m^3 /sec or /week or the unit of time.
  - The height (h) at which flow is available is known then discharge can be calculated in terms of Power (P) using the following equation.

$$P = \frac{0.736}{75}\ Q\rho hn \quad KW$$

Q= discharge in m^3/sec ,

$\rho =$ density of water = 1000kg/ m^3

n = efficiency

h= meters

- The flow duration curve becomes the load duration curve for the hydroelectric plant and thus it is possible to know the total power available at the site.
- Can be used to know total, maximum and minimum capacity of the plant and to study floods.

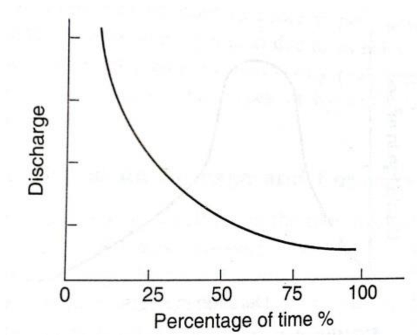


Fig: 1.3 flow duration curve

- **Reservoir capacity:** It is a capacity of a reservoir to store water. Storage can be Natural or artificial storage In other words, it can be said as storage pond. Natural or artificial storage/ Reservoir is created to store water and to generate power as per requirement. Based on storage the power generation capacity can be decided.

Sl.No.	Type of Plant capacity	Capacity in MW
1	very low	up to 0.1
2	Low	up to 1
3	Medium	up to 10
4	High	> 10

Sl.No.	Hydro Plant	Capacity
1	Micro	<100 KW
2	Mini	100KW - 1 MW
3	Small	1MW - few MW
4	Hydro	few MW -1000MW
5	Super Hydro	> 1000MW

- **Dam storage:**
  - Dam built to catch surface runoff and stream water flow in order to regulate the water flow, Storage dams are used to store water for extended lengths of time.
  - The stored water then can be used for irrigation, livestock, municipal water supply, recreation, and hydroelectric power generation.
  - By increasing the capacity of storage more energy production from the plant can be expected.
  - The storage capacity can be calculated using daily hydrograph and also from Mass curve.
  - If a power house is away from the dam storage pond is needed for storage of water for hourly generation of power to meet the load demand. Capacity of poundage is calculated based on stream flow and load.

1.3 Merits and demerits of hydroelectric power plant

- **Merits:**

1. Operation, running and maintenance costs are low.
2. Once the dam is built, the energy is virtually free.
3. No fuel is burnt and the plant is quite neat & clean.
4. No waste or pollution produced.
5. Generating plants have a long lifetime.
6. Much more reliable than wind, solar or wave power.
7. Water can be stored above the dam ready to cope with peaks in demand.
8. Unscheduled breakdowns are relatively infrequent and short in duration since the equipment is relatively simple.
9. Hydroelectric turbine-generators can be started and put "on-line" very rapidly.
10. Electricity can be generated constantly.

- **Demerits:**

1. Very land-use oriented and may flood, large regions.
2. The dams are very expensive to build .However, many dams are also used for flood control or irrigation, so building costs can be shared.
3. Capital cost of generators, civil engineering works and cost of transmission lines is very high.
4. Water quality and quantity downstream can be affected, which can have an impact on plant life.
5. Finding a suitable site can be difficult - the impact on residents and the environment may be unacceptable.
6. fish migration is restricted.
7. fish health affected by water temperature change and insertion of excess nitrogen into water at spillways
8. available water and its temperature may be affected reservoirs alter silt-flow patterns.

1.4 Selection of site

The following points should be taken into account while selecting the site for a hydro-electric power station:

- **Availability of water:** Since the primary requirement of a hydro-electric power station is the availability of huge quantity of water, such plants should be built at a place (e .g, river, and canal) where adequate water is available at a good head. A survey to be carried out regarding minimum and maximum rainfall in previous years, losses and runoff water available.

- **Storage of water:** There are wide variations in water supply from a river or canal during the year. This makes it necessary to store water by constructing a dam in order to ensure the generation of power throughout the year. The storage helps in equalizing the flow of water so that any excess quantity of water at a certain period of the year can be made available during times of very low flow in the river. This leads to the conclusion that the site selected for a hydro-electric plant should provide adequate facilities for erecting a dam and storage of water.

- **Head of the water:** the available water head depends on the land topography. The economical power generation is affected if necessary head is not available.

- **Cost and type of land:** The land for the construction of the plant should be available at a reasonable price. Further, the bearing capacity of the ground should be adequate to with-stand the weight of heavy equipment to be installed.

- **Transportation facilities:** The site selected for a hydro-electric plant should be accessible by rail and road so that necessary equipment and machinery could be easily transported. It is clear from the above mentioned factors that ideal choice of site for such a plant is near a river in hilly areas where dam can be conveniently built and large reservoirs can be obtained.

Distance of power station site from load centers: if it is away from the site, then Cost of transmission line and losses in the line increases the cost indirectly.

1.5 Classification of Hydroelectric power plant

They are classified in three different methods

1. Quantity of water available
2. Available Head
3. Nature of Load

- Quantity of water available:

1. **Run-off river plants with out pondage** : These plants does not store water; the plant uses water as it comes.The plant can use water 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 rate and some quantity of water to go as waste while during low run-off periods, due to low flow rates,the generating capacity will be low.

2. **Run-off river plants with pondage :** In these plants pondage permits storage of water during off peak periods and use of this water during peak periods.Depending on the size of pondage provided it may be possible to meet with hour to hour fluctuations.This type of plant can be used to generate power and meet load as required,and is more useful than a plant with out storage or pondage. When providing pondage tail race conditions should be such that floods do not raise tail-race water level,thus reducing the head on the plant and impairing its effectiveness.This type of plant is comparitively more reliable and its generating capacity is less dependent on avilable rate of flow of water.

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

- Available Head

    1. **Low-Head (less than 30 meters) Hydro electric plants :**"Low head" hydro-electric plants are power plants which generally utilize heads of only a few meters or less and simply use the "run of the river". Run of the river generating stations cannot store water no surge tank, thus their electric output varies with seasonal flows of water in a river. Hydro-electric facilities with a capacity of less than about 25 MW . in such palnts kaplon, francis turbine are used.

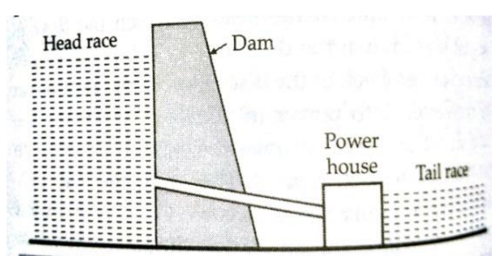


Fig: 1.4 Low Head Plant

2. **Medium-head(30 meters - 300 meters) hydro electric plants :**These plants consist of a large dam which creates a huge reservoir. In these plants, water is carried out from foreby-penstock-power house-tail race. No surge take required forbay acts as a surge tank. For each Penstock turbines are connected and usually Kaplan, Francis and propeller types of turbine are used.

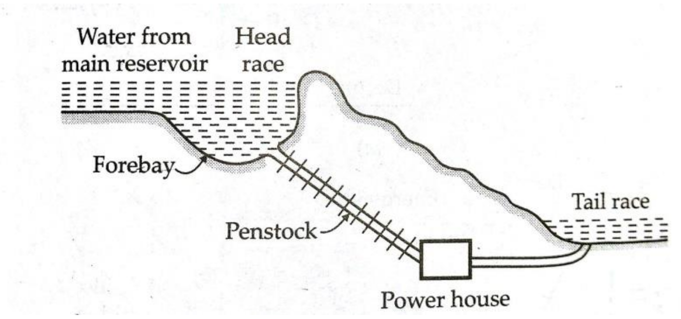


Fig: 1.5 Medium Head Plant

3. **High-head hydroelectric plants >300meters** :"High head" power plants are the most common and generally utilize a dam to store water at an increased elevation. The use of a dam to impound water also provides the capability of storing water during rainy periods and releasing it during dry periods. This results in the consistent and reliable production of electricity, able to meet demand. Heads for this type of power plant may be greater than 1000m. Above 500m Pelton is used and lower than that Francis turbine can be used. Here water flow from reservoir-channel-surge tank- penstock-powerhouse-tailrace.

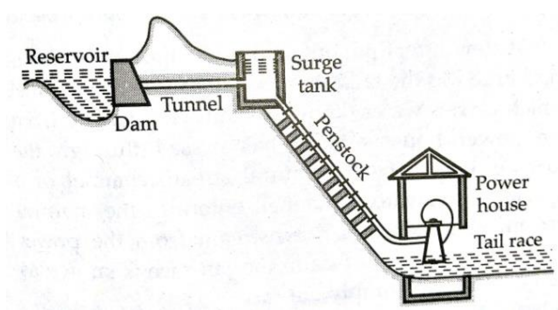


Fig:1.6 High Head Plant

- According to load

1. **Base load plant:** they feed the base load of the system. Thus they supply almost constant load throughout and operate on a high load factor. Run-off river plants without pondage and reservoir plants are used as base load plants. For a plant to be used as base load plant, the unit cost of energy generated by plant should be low.

2. **Peak load plants:** they are meant to supply the peak load of the system. Run off river plants with pondage can be used as peak load plants during lean flow period. Reservoir plant can be used as peak load plants. Peak load plant have large seasonal storage. They store water during off-peak periods and are run during peak load periods. They operate at low load factor.

3. **Pumped storage plants:** it is a special type of plant meant to supply peak loads. During peak load period, water is drawn from the head water pond through the penstock and generates power for supplying the peak load. During the off-peak period, same water is pumped back from tail water pond to head water pond so this water can be used again to generate power again. This operation is usually carried out during night time because light load condition and has high load factor.

1.6 General arrangement of hydel plant

- The essential component for the hydro electric power generation is the continuous flow of water. Water may be available by lakes naturally or artificial reservoir of high head is built by constructing dams across river.

- The water surface in the storage reservoir is known as head race.

- A reservoir know as forebays is also provided in some installations at the head of penstock for storage of water. The purpose of it is to store water and supply water as required for the generation. when reservoir is far away from the power house.

- Water from the reservoir is carried to the turbine through penstocks or canals which is made up of steel or reinforced concrete. It carries water from the reservoir under pressure.

- Water passing through the turbine is discharged to the tail race. Tail race is the channel which carries water to the main stream at the other point.

- The water surface in the tail race is known as tail race level.

- Power house consists of turbine, turbine connected to shaft, shaft to the generator, and 3 phase power is generated.

1.7 Elements of the Plant:

- **Reservoir :** It is a basic requirement of a hydroelectric plant to store water which may be utilized to produce electric power when required. It stores water during rainy season and supply the same during dry season.

- **Forebay:** It is used for storing water temporarily. Based on the loading condition water flow will be increased or decreased to meet the demand. It is a enlarged body provided at the intake.

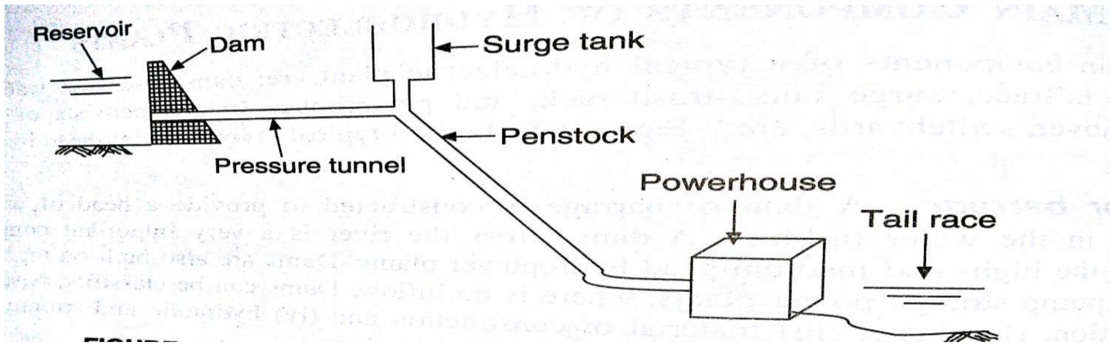


Fig:1.7 general layout and elements of hydro power plant.

- **Dam:** Dam provides the necessary head of water to be utilized in the water turbine. it also increases the reservoir capacity. Dams are classified based on their function, shape, material of construction, hydraulic and structural design.

- **Trash Rack:** It prevents the entry of debris to the turbine nozzles and gates. It is made up of steel and placed across the intake.

- **Surge Tank:** It is the additional storage near the turbine. It is used to provide necessary head, medium head or high head. When water source is away from the turbine to create necessary pressure at the turbine point surge tank is necessary. Surge tank is provided at the intake of the penstock. Surge tank prevent the rapid change in flow of water therefore prevent water hammer effect.

- **Penstock:** It is a conduit which carries water from reservoir/forebays/surge tank to the turbine. There are two types of penstock low pressure and high pressure penstock.

  Low pressure type consists of a canal and a pipe. High pressure pipe consists of steel pipe which carry water under pressure. When the distance from the forebay to the power house is short separate penstock are used for each turbine.

- **Spill way:** It is said as a safety valve for the dam. It discharges the excess water in the reservoir which over the permissible level.

- **Power House:** power house is usually located at the foot of the dam or at the storage reservoir. if the power house is located near the dam then loss due to friction in the penstock is reduced. power hose to be built looking for sufficient head for generations. The power house consist of two major parts sub structure (supports hydraulic and electrical equipments) super structure (Housing to protect equipments). The generating units and exciters are usually located on the ground floor. Turbine rotating on vertical axis are placed below the floor level and rotating horizontal are placed on the ground level along with the generator.

- **Prime Mover:** prime mover is used to convert kinetic energy of water to mechanical energy. Commonly used turbines are Pelton wheel, Francis, Kaplan and Propeller turbines. Prime mover will rotate the shaft of the electrical power generator. Normally water turbine rotate on vertical axis.
- **Tailrace:** it is required to discharge the water leaving turbine, into the river. The design and size of the tailrace should be such that water has a free exit and the jet of water, after it leaves turbine, has unimpeded passage.

1.7.1 Water Turbines:

- Hydraulic turbines convert the energy of water into mechanical energy which drives an alternator.
- They are highly efficient, ease of construction, controlled easily and pick up load in a very short time. It is built in different sizes with variation in speed.
- It is been classified into impulse turbine(high head and low flow) and reaction turbine(medium or low head with medium or high flow of water).
- Hydraulic turbine can be configured horizontally or vertically.

1.7.2 Pelton Turbine

- It is a impulse type of turbine with large head and low quantity of water.
- The potential energy of water is converted to a kinetic energy in a jet of water coming out from nozzle.
- This water jet will hit the buckets which is fixed on the rotor periphery and cause the motion of the rotor. After performing work, water is discharged into tailrace.
- Each buckets are divided into two hemispherical cups and which is rigid at the center.
- The rate of water flow is controlled by the spear.
- Each turbine can have 1- 4 jets.
- Buckets is made up of cast iron, bronze, steel. Rotor is made up of cast steel. Buckets are welded or bolted to the rotor.

- Pelton wheels are usually used in horizontal arrangement, head above 200m and speed 10-50 metric tones.

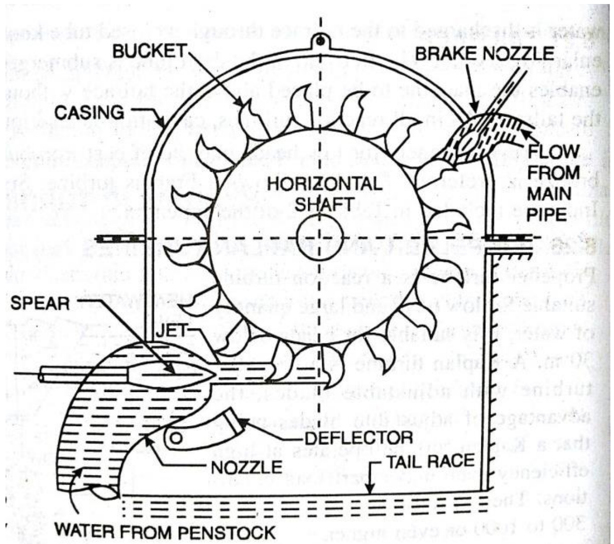


Fig: 1.8 Pelton Turbine

1.7.3 Francis Turbine

- It is a reaction turbine with medium head and medium flow.
- It is built in large size and generally with vertical configuration.
- The turbine develops power due to the velocity of water and the difference in pressure between the front and back of the runner buckets.
- The water, under pressure will enter the runner from the guide vanes radially and will discharge axially.
- The motion of water is controlled by wicket gate, fixed around the runner. The water will pass through a spiral case of a runner.
- The pressure is at the inlet is more than the outlet, the water flows through the closed loop hence water is present in runner always.
- The water after work is discharged from a draft tube which as an enlarging section as runs down to tailrace.
- It is made up of cast iron, bronze or steel
- It is used for the head being 30m-200m with speed 60-300 metric units.

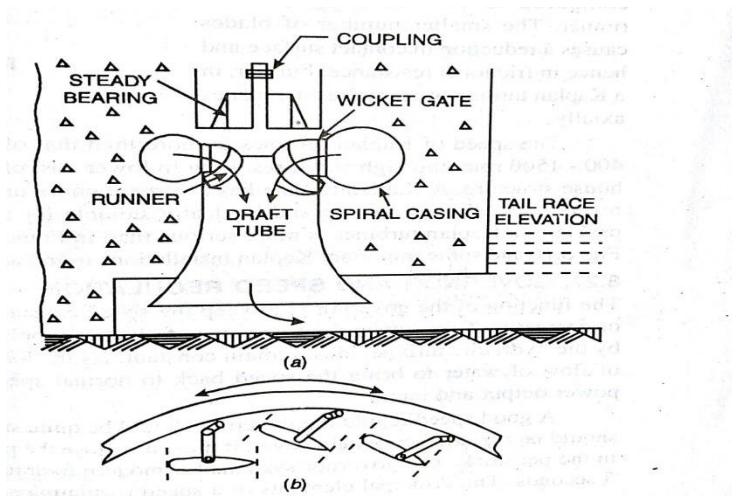


Fig 1.9(a) Francis Turbine (b) Wicket Gates and Shifting ring of a Francis Turbine

1.7.4 Propeller And Kaplan Turbines

- It is a reaction turbine with low head and large quantity of water.
- Kaplon turbine is a propeller turbine with adjustable blades.
- Kaplon turbine has higher efficiency at lighter load also.
- Spiral casing, guide mechanism, draft tube is same as francis turbine. Where in runner is different having lesser blades of 3-6 blades compared to francis turbine with 16-24 blades.
- Water strikes the blades axially.
- It is used for the head being <30m with speed 300-1000metric tones.
- Since speed range from 400-1500rpm, lower cost runner and alternater will cheaper power house structure.

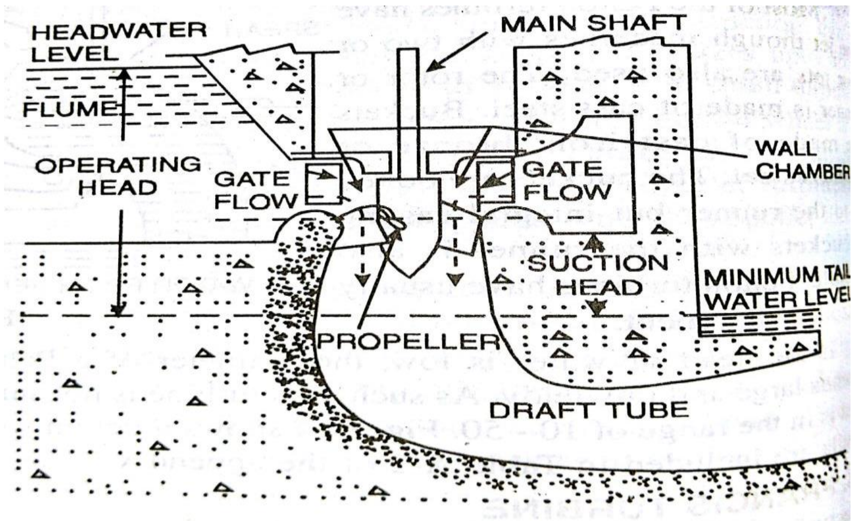


Fig: 1.10 Kaplan Turbine

1.8 CHARACTERISTICS OF TURBINES

- **Head:** based on head turbines are used upto 500m reaction turbine and >500-2000m impulse turbine is used.
- **Efficiency at various load:** impulse turbine as a efficiency of 80-85%, reaction turbine has efficiency or 85-95%. Where in kaplon turbine has a greater efficiency at lighter load also.
- **Specific speed:** it is defined as a speed at which turbine runs to develop 1 metric HP under head of 1 meter.

$$n_s = nP^{1/2} / h^{5/4} \text{ rpm}$$

$$P = Kw$$

- **Turbine Setting:** Pelton wheel turbine to be placed higher level than the tailrace level. Francis turbine to be placed at the tailrace level or below the level.
- **Runaway speed:** it is a maximum speed at which turbine runs under the worst condition of operation with all gates open, maximum head. The generator coupled must be able to with stand the speed of the turbine.

1.9 Governing Of Turbines:

- Hydraulic turbine are directly coupled to electric generators. Generater runs at a constant speed.
- As load on generator varies turbine speed also varies. The speed of the runner will increase or decrease as the load increases and decreases.
- Turbine runner and generator must be maintained at a constant speed. This can be achieved by regulating the water flow through runner.
- Such an operation of speed regulation is known as governing.it is done automatically by means of governor.
- In modern days oil pressure governor are used. The components of governors are

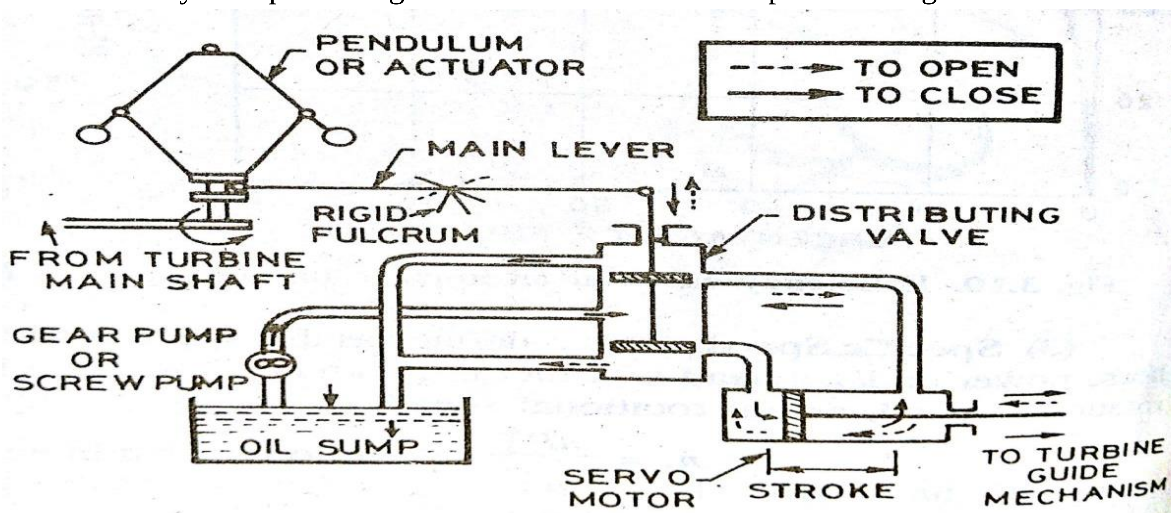


Fig:1.11 Governing of Turbine

1. Servomotor/ realy cylinder
2. Relay valve/ control valve/ distribution valve.
3. Actuator- it is a gear driven from turbine main shaft.
4. Oil sump
5. Oil pump driven by belt connected to turbine main shaft.
6. .oil supply pipes.

- Servo motor as a piston moving which acts under oil pressure.

- The movement of the piston is amplified .
- Distributing valve is actuated and speed of oil to the cylinder is controlled.
- Actuator is a flyball mechanism working as a speed responsive element. It is driven from the turbine main shaft. Oil is pressured from the oil pump.
- If the speed of the turbine falls, the speed of actuator shaft descending cause the main lever to shift the position of distributing valve
- Oil under pressure is sent to one end of the cylinder and piston will be moved to the end by this action.
- If the speed of the turbine is normal all stay at normal positions.

1.10 Selection Of Water Turbine

- **Head of water**

TYPE OF TURBINE	HEAD	SPECIFIC SPEED (metric units)
Pelton	>200m	Oct-50
Francis	30m-200m	60-300
Propeller	<30m	300-1000

- **Specific Speed:** High speed is required where head is low and output is large, on the other hand with greater head low speed is sufficient. Even with low specific speed greater rotational speed can be obtained which can be used in medium capacity plants.
- **Rotational speed:** It is directly proportional to a specific speed. It depends on frequency and number of poles. The specific speed selected must be in a way that it will give the synchronous speed of the generator.
- **Efficiency:** The turbine selected must give the highest overall efficiency for various operating conditions.
- **Part load operation:** Even at part load and full load it should operate at its maximum efficiency. So that it can be very economical.

- **Cavitation:** Installation of reaction type water turbines above the tailrace level is affected by Cavitation. Cavitation factor must be in a way that the turbine will work in a safe zone.

- **Disposition of turbine shaft:** Vertical shaft arrangement is better for reaction type turbine and horizontal arrangement is better for the impulse type turbine**.**

1.11 Underground hydro plant:

- The Underground hydro plant is preferred based on some technical and economical consideration.
- Benefits of underground hydro plant is:
    - If suitable site is not available for outdoor layout, then underground layout can be used.
    - The power plant and auxiliaries are free from danger of falling rocks.
    - Some cases underground layout is cheaper than conventional layout.
    - Penstock may be shorter, which will reduce the cost and head losses.
- The Underground hydro plant can be designed in 2 layout format. Head development and tail development.
- Head development: plant situated at the intake and has a long tailrace tunnel. The cost of intake structure is considerably less, quicker control of turbines is possible.
- Tailrace level: the plant is located at the end of a long pressure tunnel and has a short tailrace.
- In India it is seen in Maharashtra and J&K.

1.12 Small hydro plant:

- Advantages and necessity of small hydro plants:
    - A large size plant is cheaper, but provide a permanent source of energy, but has long construction period.
    - Civil works are simple and can be built using local labour available in a short time.
    - A standardized equipments are available nowadays and a cost of all equipments such as turbine, generator, switch gear etc. are less.
    - The site available for large plant will be less in the future and shortage of fuel for thermal plant are establishing a need for small hydro plant.
    - Small hydro plants are economical and secure.

- Can Supply electricity for a consumer who are at very long distance by setting up a small hydro plant.
- Maintaining regulation for a smaller lines are easier than a long line at the peak load condition.
- Small plants are effective in saving fuels and annual operating time is longer than large plants.
- Simple to operate, reliable and less maintenance.

- Small hydro plant includes mini and micro hydro schemes. The Mini hydro scheme has a capacity of 1-5MW and micro with <1MW.
- Small hydro plant operates under low head.
- India operates around 200MW plant capacity in states like HP, J&k and north eastern states.

1.13 Pumped storage plant:

It is a special type of plant meant to supply peak loads. During peak load period, water is drawn from the head water pond through the penstock and generates power for supplying the peak load. During the off-peak period, same water is pumped back from tail water pond to head water pond so this water can be used again to generate power again. This operation is usually carried out during night time because light load condition and has high load factor. A resent development is a reversible turbine pump. During peak loads, the turbine rotates and alternator will generate electrical energy. During off load generator will run as motor and drives turbine to pumps back water to head water pond. This arrangement reduces capital cost. The reservoir capacity should be such that it should supply power for 4-11 hours without any interrupts.

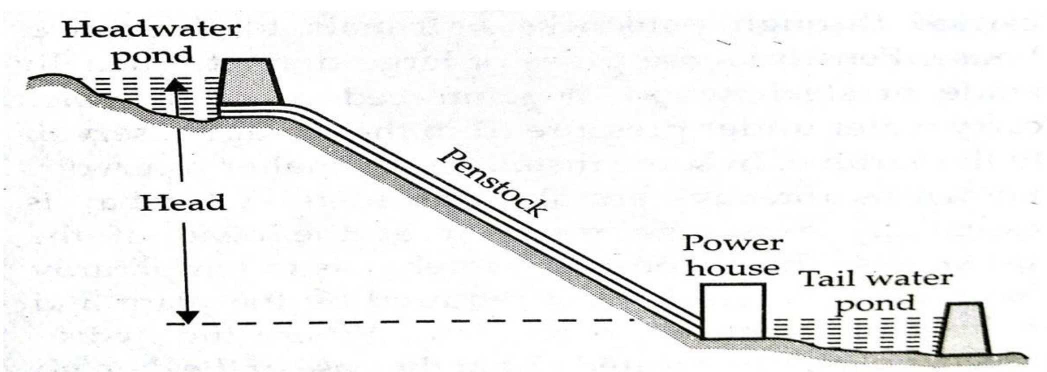


Fig: 1.12 Pump Storage Pond

Advantages

- peak load can be supplied with lesser cost.
- Standby capacity is available for short time.
- Benefit of quick switching on and off.

- They take 2-3 seconds for starting and can be loaded fully by 15 sec.
- During unit failure these storage plant can be used to supply demand which avoids load shedding.
- Reduced maintenance.
- To meet extra demand.
- Avoid spinning reserve requirement of a system.
- Load frequency control can be achieved

Disadvantages:

- Expensive to build.
- Once it's used, you can't use it again until you've pumped the water back up. Good planning can get around this problem.

1.14 Choice of size and number of units:

1.14.1 Size of plant:

- Size of a plant depends on the purpose it is being set up.
- Amount of power required for various section
- Future expansion (5-10 year)
- Based on total load requirement
- Size varies from one plant type to another plant such as emergency plant , industrial plant.
- In hydro power plant depends on water available, additional power available, increase in power in 10-20years.
- Load growth analysis to be done min for 30 years.
- Present day capacity of plant in India is 500MW.

1.14.2 Size of Units:

- Large size units have lower capital cost per KW, need less land area, require less operating labour and have better efficiency.
- As number of unit increases the cost reduces by 5-10%
- The number of size of units in hydro station depends on the available head and water.

- The aim is to achieve the maximum energy at minimum overall cost. Keeping in view the stream flow condition, reservoir storage capacity.
- The largest hydro units in operation now are 250MW.

1.14.3 Plant layout:

- Plant layout is affected by the nature of project
- In low head plant the dam size is small and fixing of turbine and generator is limited
- In high head plant size of area is larger and convenient power station layout can be obtained.
- The size of unit selected will also affect the plant layout.
- In case of vertical arrangement of plant, the spacing between two units is controlled by width of the flume or width of the draft tube mouth or overall diameter of the alternator.
- In case of horizontal arrangement of reaction turbine machine are placed at the right angel to the turbine house. In case of horizontal impulse turbine its placed parallel to longitudinal axis of the turbine house.
- Impulse machines are also fixed on the dimensions of the machine as size and capacity are smaller.
- The vertical arrangement of impulse turbine are very rare. If used axis arranged parallel to turbine house.
- In resent station, each generator has its own step up transformer and is called a unit.
- The transformer will transmit current at extra high voltage at an outdoor switch gear installation from which transmission line originates.
- The generating voltages are 3.3,6.6 and 11KV at 50Hz.
- The grid voltage is 132/220/400KV

1.15 Plant Auxilaries:

1.Switchyard systems

2. Alternating current (AC) station service. Depending on the size and criticality of the plant, multiple sources are often supplied, with emergency backup provided by a diesel generator.

3. Direct current (DC) station service. It is normally provided by one or more battery banks, for supply of protection, control, emergency lighting, and exciter field flashing.

4. Lubrication systems, particularly for supply to generator and turbine bearings and bushings.

5. Drainage pumps, for removing leakage water from the plant.

6. Air compressors, for supply to the governors, generator brakes, and other systems.

7. Cooling water systems, for supply to the generator air coolers, generator and turbine bearings, and step-up transformer.

8. Fire detection and extinguishing systems.

9. Intake gate or isolation valve systems.

10. Draft tube gate systems.

11. Reservoir and tailrace water level monitoring.

12. Synchronous condenser equipment, for dewatering the draft tube to allow the runner to spin in air during synchronous condenser operation. In this case, the generator acts as a synchronous motor, supplying or absorbing reactive power.

13. Service water systems.

14. Overhead crane.

15. Heating, ventilation, and air conditioning.

16. Environmental systems.

1.16 Outcome

Describe the working of hydroelectric power plants and state functions of major equipment of the power plants.

1.17 Further Readings

1. http://www.fayoum.edu.eg/stfsys/stfFiles//243//2512//Ch%204%20-%20Principles%20of%20Power%20system.pdf