NARSIMHA REDDY ENGINEERING COLLEGE
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Department of EEE

UNIT-I

Generation of Electric Power

Subject: Power systems - I

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Power systems - I

Course Outcome

CO1 : Understand the operation of conventional and renewable energy power plants.

CO2 : Apply power generation economics to calculate load factors, demand factors and tariffs.

CO3 : Describe the construction and bus bar arrangements of Air Insulated Substations (AIS).

CO4 : Compare Air Insulated Substations (AIS) and Gas Insulated Substations (GIS) substations.

CO5 : Analyze AC distribution systems and calculate voltage drops.

Topics

- Operation of Hydel plant
  - layout
  - Description of components
  - Choice of site
  - advantages and disadvantages
- Operation of Thermal power plant
- Operation of Nuclear power plant
- Gas Power plant
- solar power plant
- Wind power plant

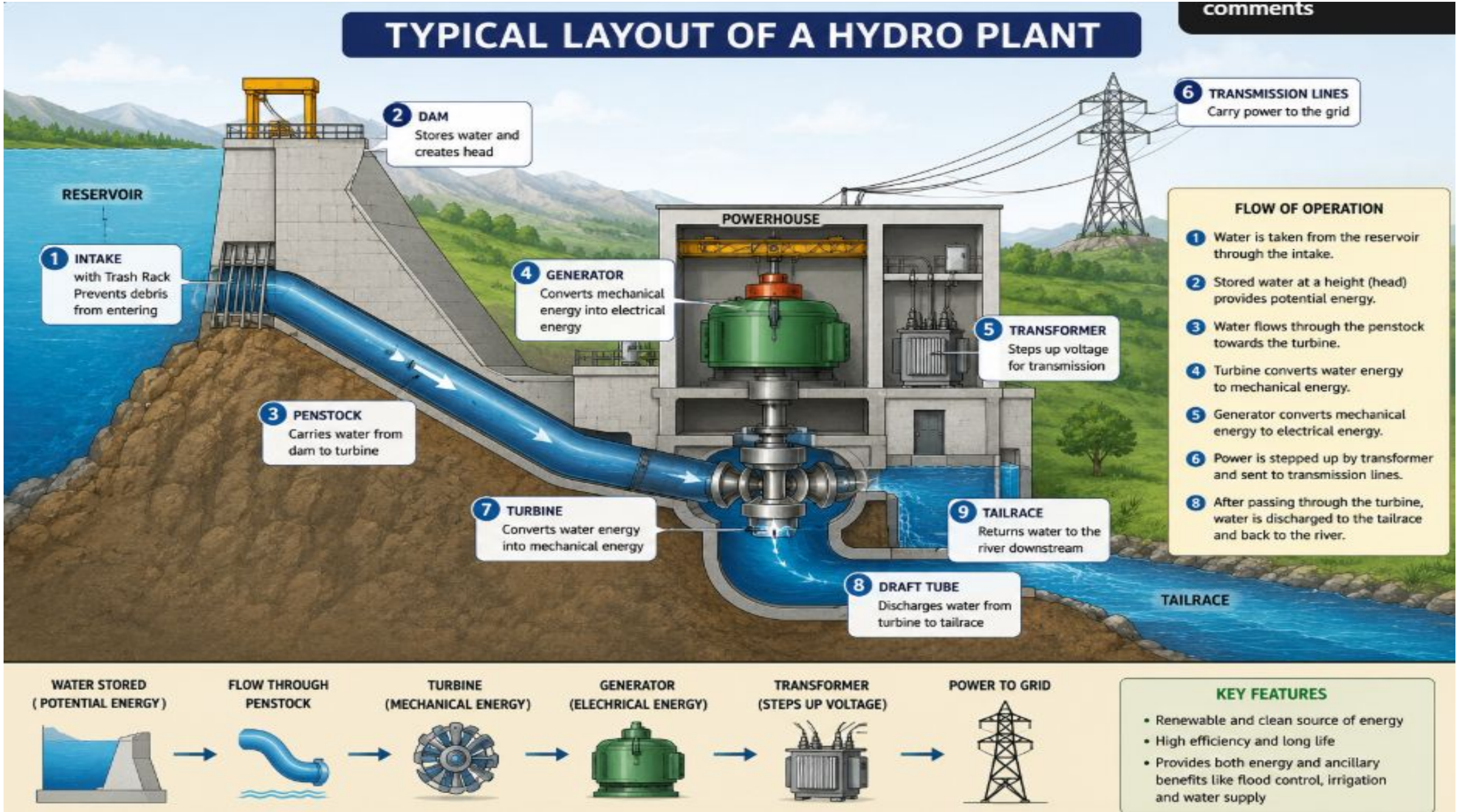
Hydro Station/ Hydroelectric power plant / Hydel power plant:

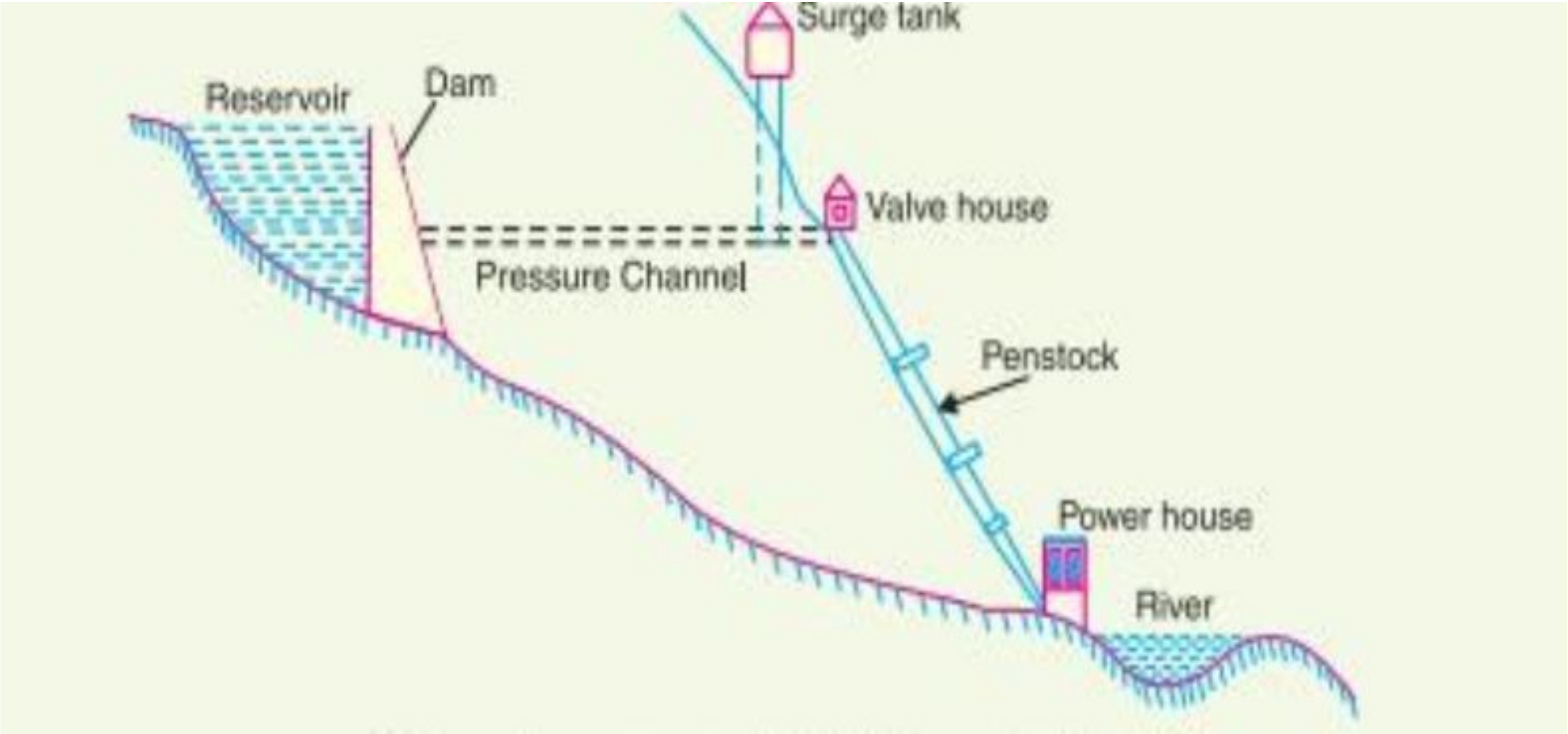
"A generating station which utilises the potential energy of water at a high level for the generation of electrical energy is known as a Hydroelectric power station."

Topics:

- ➢ Operation/ working of hydroelectric power generation.
- ➢ layout
- ➢ Site selection
- ➢ components of a hydel power plant
- ➢ Classification of hydroelectric plants.
- ➢ Advantages, disadvantages
- ➢ Real time examples

Operation/ working of Hydroelectric Power Plant:





A Typical Layout of a Hydro Plant

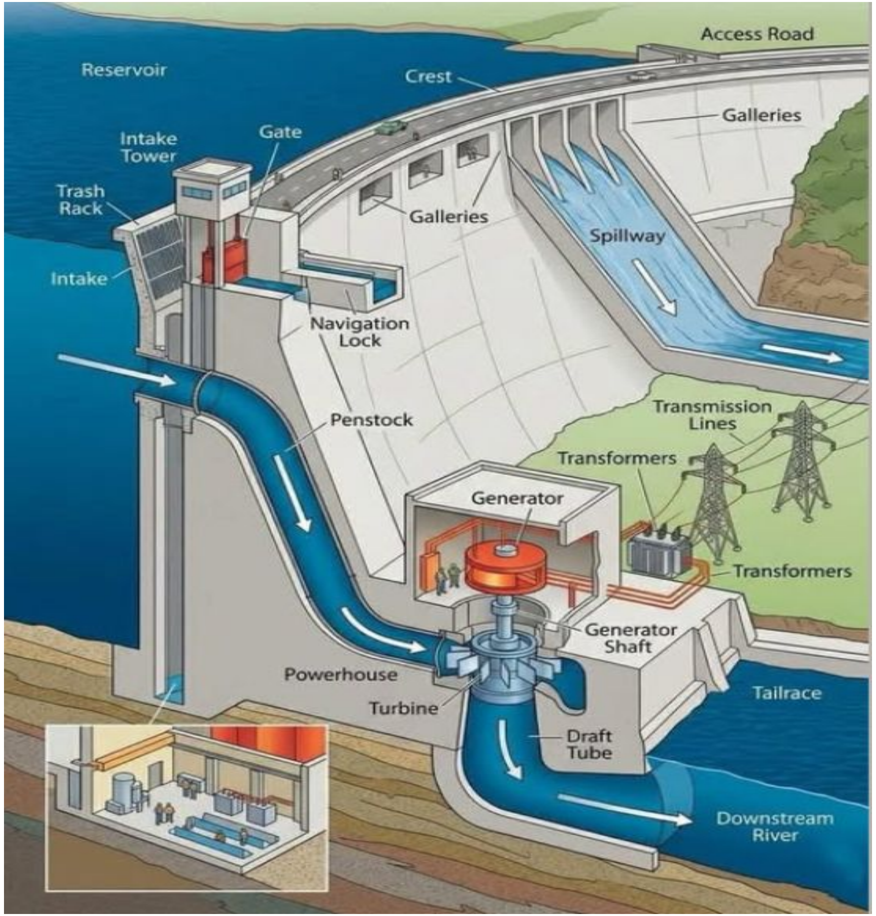
A modern hydroelectric power plant works as follows:

- A dam is built across a river or lake to store water and form a reservoir.
- Water from the reservoir flows through a pressure tunnel to the valve house.
- The valve house contains:
  - Main sluice valves to control water flow.
  - Automatic isolating valves to stop water flow, if the penstock is damaged.
- From the valve house, water travels through a large steel pipe called the penstock to the turbine.
- The water turbine converts the energy of flowing water into mechanical energy.
- The turbine drives an alternator (generator), which converts mechanical energy into electrical energy.
- A surge tank is installed before the valve house and is open at the top.
- It protects the penstock from high pressure when the turbine gates close suddenly.

Components of Hydel power plant:

The main components of the Hydel power plant are as follows:

- ➢ Reservoir
- ➢ Dam
- ➢ Penstock
- ➢ Forebay (Head Pond)
- ➢ Intake
- ➢ Spillway
- ➢ Surge Tank
- ➢ Turbines
- ➢ Power House
- ➢ Draft Tube



1. Reservoir

- A reservoir is a large storage area for water.
- It stores water during the rainy season and supplies it during dry periods.
- It ensures continuous power generation throughout the year.

2. Dam

- A dam is a barrier built across a river.
- It creates a reservoir by storing water.
- It increases the height (head) of water, which helps generate more power.

3. Penstock

- A penstock is a large pipe that carries water from the forebay/ reservoir to the turbine.
- It is usually made of steel or reinforced concrete.

Functions

- Delivers water to the turbine under pressure.
- Controls the flow of water to the turbine.

4. Forebay (Head Pond)

- A forebay is a small water storage area located just before the penstock.
- It acts as a regulating reservoir.

5. Intake

- The intake controls the flow of water into the penstock.
- Screens or trash racks are provided to stop leaves, wood etc.,
- This prevents damage to turbine blades and blockage of water passages.

6. Spillway

- A spillway acts as a safety valve for the dam.
- It releases excess water during floods.
- It prevents the reservoir level from rising above the safe limit.
- It protects the dam from damage due to overflow.

7. Surge Tank

- A surge tank is a water storage tank installed between the dam and the powerhouse.
- It is usually located near the powerhouse.
- It is mainly used in high-head hydroelectric plants.

Functions

1. Regulates water flow.
2. Maintains pressure in the penstock.
3. Reduces water hammer effect.
4. Protects the penstock from pressure fluctuations.

Water Hammer effect

- When turbine gates close suddenly, water pressure increases rapidly.
- This sudden rise in pressure is called **water hammer**.
- Water hammer can damage the penstock.

Working of Surge Tank

When Load Decreases

- Turbine gates partially close.
- Excess water enters the surge tank.
- Water level in the surge tank rises.
- Pressure in the penstock is reduced.

When Load Increases

- Turbine gates open wider.
- Additional water is supplied from the surge tank.
- Water level in the surge tank falls.
- Water flow through the penstock increases.

8. Turbines

A hydraulic turbine is a prime mover connected to a generator. Water flowing through the turbine rotates the turbine shaft, which in turn rotates the generator to produce electricity.

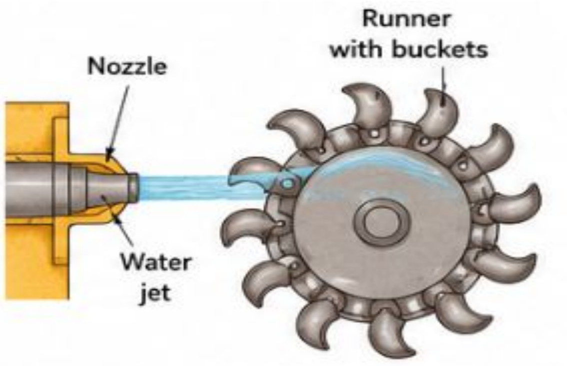
Types of Hydraulic Turbines

(i) Impulse turbines : In impulse turbines, the entire available head of water is converted into kinetic energy in the nozzle and the water strikes the runner blades at high velocity. There is no change in pressure as water passes through the runner.

Main Feature:
Energy at inlet is Kinetic energy alone

Examples: Pelton turbine.

Suitable For:
High head (usually above 250 m) and low discharge.



Pelton wheel turbine

Merits:
- Simple construction.
- Suitable for high head.
- No draft tube required.
- Maintenance is easy.

Demerits:
- Not suitable for low head.
- More space required.

(ii) Reaction turbines:

In reaction turbines, the available head of water is partially converted into kinetic energy and partially remains as pressure energy. There is a change in pressure as water flows through the runner.

Main Feature:

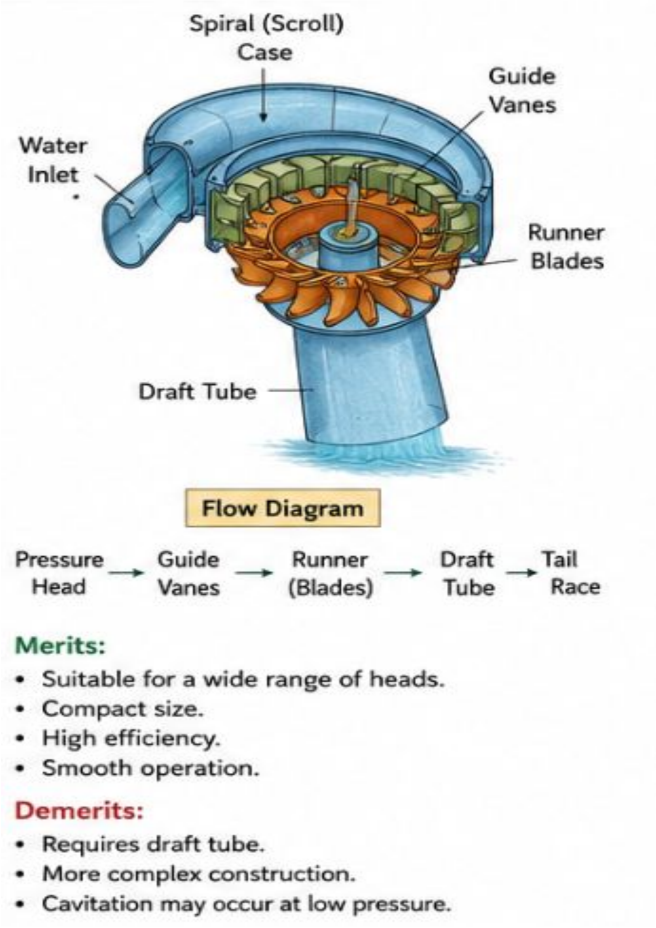
Energy at inlet => Combination of pressure energy and kinetic energy.

Examples:

Francis, Kaplan, Propeller, Deriaz turbines.

Suitable For:

Medium to low head (from about 2 m to 250 m) and medium to high discharge.



9. Power House

- The power house is the main building of a hydroelectric power plant where electricity is generated.
- It contains turbines, generators, transformers, and control equipment.

Parts of a Power House

Substructure

- Located below the ground level and Supports hydraulic and electrical equipment.
- Includes:
  - Foundation
  - Draft tubes
  - Turbine settings

Superstructure

- Located above the generator floor.
- Houses and protects equipment from weather conditions.
- Includes:
  - Generators
  - Switchgear equipment
  - Control equipment

Functions of Power House

- Houses generating equipment.
- Protects equipment from environmental conditions.
- Facilitates power generation and control.

10. Draft Tube

- A draft tube is a gradually expanding pipe connected to the outlet of a reaction turbine.
- It is used in **Francis** and **Kaplan** turbines.

Types of Draft Tubes

1. Straight conical draft tube
2. Elbow-shaped draft tube

Functions of Draft Tube

1. Recovery of Velocity Energy

- Water leaving the turbine still possesses velocity.
- The draft tube converts part of this velocity energy into pressure energy.
- This improves turbine efficiency.

2. Allows Turbine Installation Above Tailrace

- Enables the turbine runner to be placed above the tailrace water level.
- Maintains effective utilization of the available head.

Cavitation

- Cavitation is the formation of air or vapor bubbles in flowing water due to low pressure.
- When these bubbles collapse, they can damage turbine blades.

Effects of Cavitation

- Causes pitting and erosion of turbine runners.
- Reduces turbine efficiency.
- Increases maintenance costs.

Importance of Draft Tube

- Improves overall efficiency of the turbine.
- Reduces energy losses.
- Helps prevent cavitation when properly designed.

CLASSIFICATION OF HYDROELECTRIC POWER PLANTS

1. BASED ON AVAILABILITY OF WATER

TYPE	DESCRIPTION
 **Run-of-River Power Plant (Without Pondage)**	Uses the natural flow of the river directly without significant water storage. Power generation depends on river discharge and varies with seasonal flow.
 **Run-of-River Power Plant (With Pondage)**	A small storage reservoir is provided to store water for a short duration. It helps in meeting daily peak loads and regulating power output.
 **Storage (Reservoir) Power Plant**	A large dam creates a reservoir to store water during rainy seasons. The stored water is used throughout the year to ensure a reliable power supply.
 **Pumped Storage Power Plant**	Water is pumped from a lower reservoir to an upper reservoir during off-peak periods and released during peak demand to generate electricity.

2. BASED ON HEAD OF WATER

TYPE	DESCRIPTION
 **Low Head Power Plant (Head < 30 m)**	Operates with a water head less than 30 m. Large quantities of water are required, and Kaplan turbines are commonly used.
 **Medium Head Power Plant (Head 30 – 100 m)**	Operates with a head between 30 m and 100 m. Francis turbines are generally employed.
 **High Head Power Plant (Head > 100 m)**	Operates with a head greater than 100 m. Pelton wheel turbines are commonly used and require comparatively less water flow.

3. BASED ON LOAD SERVED

TYPE		DESCRIPTION
	Base Load Plant	Operates continuously to supply the minimum demand of the power system.
	Peak Load Plant	Operates during periods of maximum demand. Pumped-storage plants are often used for this purpose.

4. BASED ON CAPACITY

TYPE		DESCRIPTION
	Micro Hydro Plant	Capacity up to 100 kW.
	Mini Hydro Plant	Capacity from 100 kW to 2 MW.
	Small Hydro Plant	Capacity from 2 MW to 25 MW.
	Large Hydro Plant	Capacity above 25 MW.

Selection of the site:

Factors considered for Site Selection of hydroelectric power plant are

1. Location of the Dam

- The dam should be built where the river valley is narrow (neck formation).
- A shorter dam reduces construction cost.
- The upstream area should have a large water storage capacity.
- A site near the meeting point (confluence) of two rivers is preferred because it provides more water storage.

2. Choice of Dam

- Safety and economy are the main considerations.
- The dam should withstand:
  - Earthquakes
  - Sudden changes in water level
  - Heavy floods
- The dam should be located close to the turbines to reduce the length and cost of water conduits.

3. Availability of Water

- Adequate water should be available throughout the year.
- Water availability is determined by measuring river flow over many years.
- A large reservoir is required because rainfall is seasonal and varies from year to year.

4. Accessibility of the Site

- The site should have good transportation facilities.
- Easy access helps in transporting workers, equipment, and construction materials.
- This reduces the overall project cost.

5. Distance from Load Centre

- The power plant should be located as close as possible to the load centre.
- A shorter transmission distance reduces:
    - Transmission cost
    - Power losses

6. Availability of Construction Materials

- Construction materials should be available nearby.
- Skilled manpower and technical expertise should also be available.

Advantages

(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 and requires less maintenance.

(v) It does not require a long starting time like a steam power station. In fact, such plants can be put into service instantly.

(vi) It is robust and has a 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 persons at the time of construction, yet for operation, a few experienced persons may do the job well.

Disadvantages

(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 a high cost of transmission lines as the plant is located in hilly areas which are quite away from the consumers.

First installed Hydel plants

Feature	World First Hydro Plant	India First Hydro Plant
Name	Vulcan Street Plant	Sidrapong Hydroelectric Power Station
Location	Appleton, Wisconsin, USA	Darjeeling, West Bengal, India
Year	1882	1897
Capacity	Small DC Station	130 kW
Importance	World's first hydroelectric central station	India's first hydroelectric power station

Hydel Power plants in India

Power Plant	State	River	Installed Capacity (MW)
Tehri Hydroelectric Project	Uttarakhand	Bhagirathi	1000
Koyna Hydroelectric Project	Maharashtra	Koyna	1960
Srisailam Hydroelectric Project	Telangana & Andhra Pradesh	Krishna	1670
Bhakra Nangal Project	Himachal Pradesh/Punjab	Sutlej	1325
Nathpa Jhakri Hydroelectric Station	Himachal Pradesh	Sutlej	1500
Indira Sagar Project	Madhya Pradesh	Narmada	1000
Sharavathi Generating Station	Karnataka	Sharavathi	1035
Nagarjuna Sagar Project	Telangana & Andhra Pradesh	Krishna	816
Hirakud Hydroelectric Project	Odisha	Mahanadi	347
Idukki Hydroelectric Project	Kerala	Periyar	780

Telangana

Hydro Power Plant	River	Capacity (MW)
Srisailam Left Bank Power House (LBPH)	Krishna	900
Nagarjuna Sagar Main Power House	Krishna	815.6
Lower Jurala Hydroelectric Project	Krishna	240
Jurala Hydroelectric Project	Krishna	234
Pulichintala Hydroelectric Project	Krishna	120
Nagarjuna Sagar Left Canal Power House	Krishna	60
Pochampad (SRSP) Power House	Godavari	36
Singur Power House	Manjira	15
Nizam Sagar Power House	Manjira	10
Paleru Mini Hydel Project	Paleru	2

Andhra Pradesh

Hydro Power Plant	River	Capacity (MW)
Srisailam Right Bank Power House	Krishna	770
Lower Sileru Power House	Sileru	460
Upper Sileru Power House	Sileru	240
Machkund Power House	Machkund	120
Nagarjuna Sagar Right Canal Power House	Krishna	90
Nagarjuna Sagar Tail Pond Power House	Krishna	50
Tungabhadra Dam Power House	Tungabhadra	36
Hampi Power House	Tungabhadra	36
Donkarayi Canal Power House	Sileru	25
Penna Ahobilam Hydel Project	Penna	20
Chettipeta Mini Hydel Project	Local Canal	1

Available Head	Preferred Turbine
High Head (> 250 m)	Pelton Turbine
Medium Head (30–250 m)	Francis Turbine
Low Head (2–70 m)	Kaplan Turbine
Very Low Head (5–10 m)	Propeller Turbine
Medium/Low Head Pumped Storag	Deriaz Turbine

Feature	Pelton	Francis	Kaplan
Type	Impulse	Reaction	Reaction
Head	High	Medium	Low
Discharge	Low	Medium	High
Flow Direction	Tangential	Mixed	Axial
Draft Tube	Not Required	Required	Required
Specific Speed	Low	Medium	High

Steam Power Station (Thermal Station)

A generating station which converts heat energy of coal combustion into electrical energy is known as a **steam power station.**

Arrangement of Steam Power Station

1.Coal and ash handling arrangement.

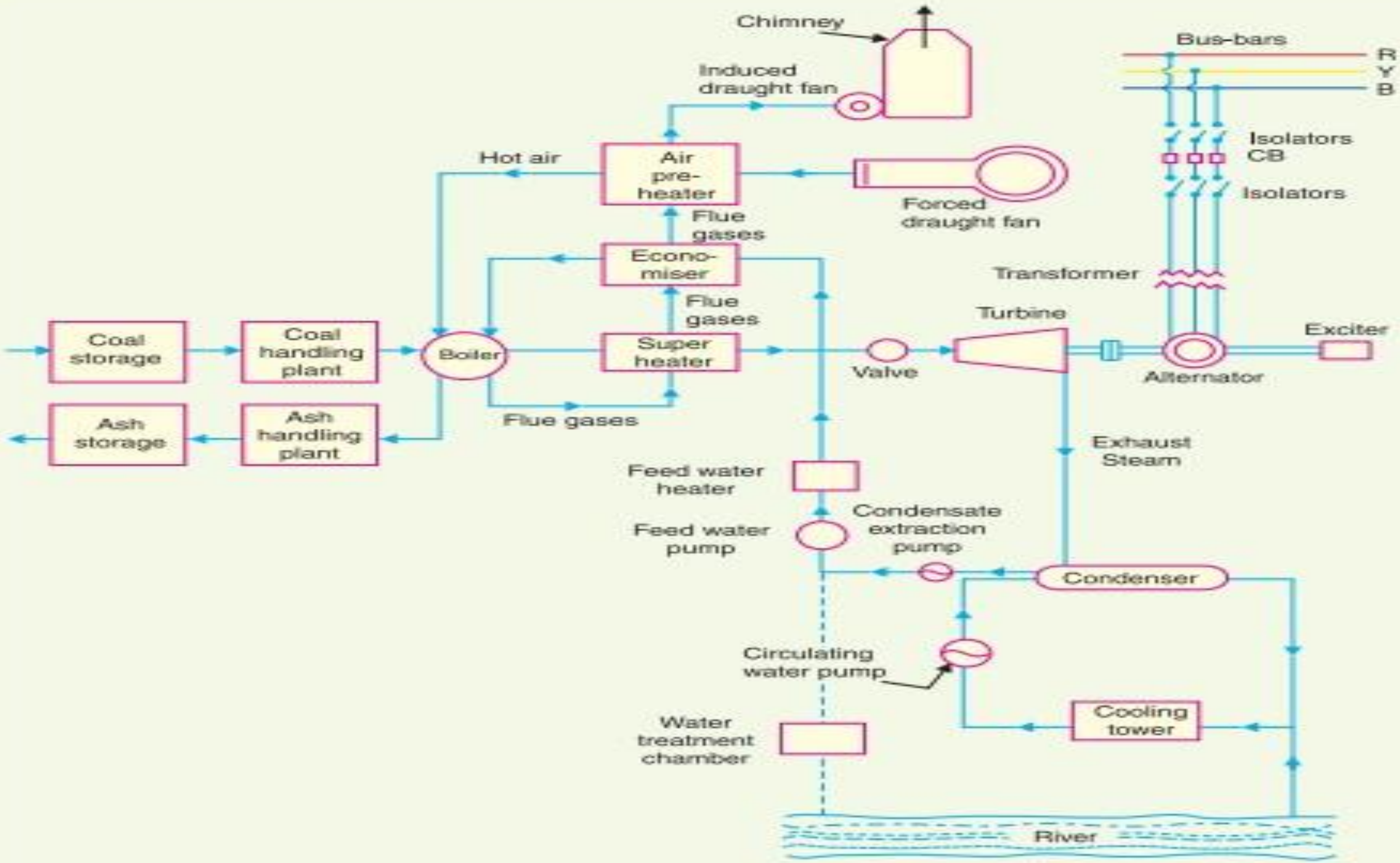
2. Steam generating plant.

3. Steam turbine

4. Alternator

5.Feed water.

6.Cooling arrangement



Schematic arrangement of Steam Power Station

Choice of Site for Steam Power Stations

1.Supply of fuel.

2. Availability of water.

3.Transportation facilities

4. Cost and type of land.

5. Nearness to load centres.

6. Distance from populated area.

Advantages

1.The fuel (*i.e.,* coal) used is quite cheap.

2.Less initial cost as compared to other generating stations.

3.It can be installed at any place irrespective of the existence of coal. The coal

can be transported to the site of the plant by rail or road.

4.It requires less space as compared to the hydroelectric power station.

5.The cost of generation is lesser than that of the diesel power station.

Disadvantages

1.It pollutes the atmosphere due to the production of large amount of smoke and fumes.

2.It is costlier in running cost as compared to hydroelectric plant.

S. No.	Thermal Power Plant	State	Installed Capacity (MW)	Operator
1	Vindhyachal Super Thermal Power Station	Madhya Pradesh	4,760	NTPC
2	Mundra Thermal Power Station	Gujarat	4,620	Adani Power
3	Neyveli New Thermal Power Station	Tamil Nadu	4,400	NLC India Ltd.
4	Mundra Ultra Mega Power Project	Gujarat	4,000	Tata Power
5	Singrauli Super Thermal Power Station	Madhya Pradesh	4,000	NTPC
6	Sasan Ultra Mega Power Project	Madhya Pradesh	3,960	Reliance Power
7	KSK Mahanadi Power Plant	Chhattisgarh	3,600	KSK Energy Ventures
8	Jindal Tamnar Thermal Power Plant	Chhattisgarh	3,400	Jindal Power
9	Tiroda Thermal Power Plant	Maharashtra	3,300	Adani Power
10	Talcher Super Thermal Power Station	Odisha	3,000	NTPC
11	Rihand Super Thermal Power Station	Uttar Pradesh	3,000	NTPC
12	Sipat Super Thermal Power Station	Chhattisgarh	2,980	NTPC
13	Chandrapur Super Thermal Power Station	Maharashtra	2,920	MSPGCL
14	NTPC Dadri Thermal Power Station (Coal + Gas)	Uttar Pradesh	2,637	NTPC
15	Anpara Thermal Power Station	Uttar Pradesh	2,630	UPRVUNL
16	Korba Super Thermal Power Station	Chhattisgarh	2,600	NTPC
17	Simhadri Super Thermal Power Station	Andhra Pradesh	2,000	NTPC
18	Ramagundam Super Thermal Power Station	Telangana	2,600	NTPC
19	Kahalgaon Super Thermal Power Station	Bihar	2,340	NTPC
20	Farakka Super Thermal Power Station	West Bengal	2,100	NTPC

Major Thermal Power Plants in Telangana

S. No.	Power Plant	Location	Installed Capacity (MW)	Operator
1	NTPC Ramagundam	Peddapalli	2,600	NTPC
2	Kothagudem Thermal Power Station	Paloncha, Bhadradri Kothagudem	1,800	TGGENCO
3	Kakatiya Thermal Power Station	Chelpur, Jayashankar Bhupalpally	1,100	TGGENCO
4	Ramagundam Thermal Power Station	Peddapalli	62.5	TGGENCO

Major Thermal Power Plants in Andhra Pradesh

S. No.	Power Plant	Location	Installed Capacity (MW)	Operator
1	Dr. Narla Tatarao Thermal Power Station	Ibrahimpatnam, NTR District	2,560	APGENCO
2	Sri Damodaram Sanjeevaiah Thermal Power Station	Krishnapatnam, SPSR Nellore	2,400	APPDCL
3	Simhadri Super Thermal Power Station	Parawada, Anakapalli	2,000	NTPC
4	Rayalaseema Thermal Power Station	Muddanur, YSR Kadapa	1,650	APGENCO
5	Vizag Thermal Power Station	Visakhapatnam	1,040	Hinduja National Power

Nuclear Power Station

A generating station in which nuclear energy is converted into electrical energy is known as a nuclear power station.

- ➢ In nuclear power station, heavy elements such as Uranium (U235) or Thorium (Th232) are subjected to nuclear fission in a special apparatus known as a *reactor*.
- ➢ The heat energy thus released is utilised in raising steam at high temperature and pressure.
- ➢ The steam runs the turbine which converts steam energy into mechanical energy.
- ➢ The turbine drives the alternator which converts mechanical energy into electrical energy.

Arrangement of Nuclear Power Station

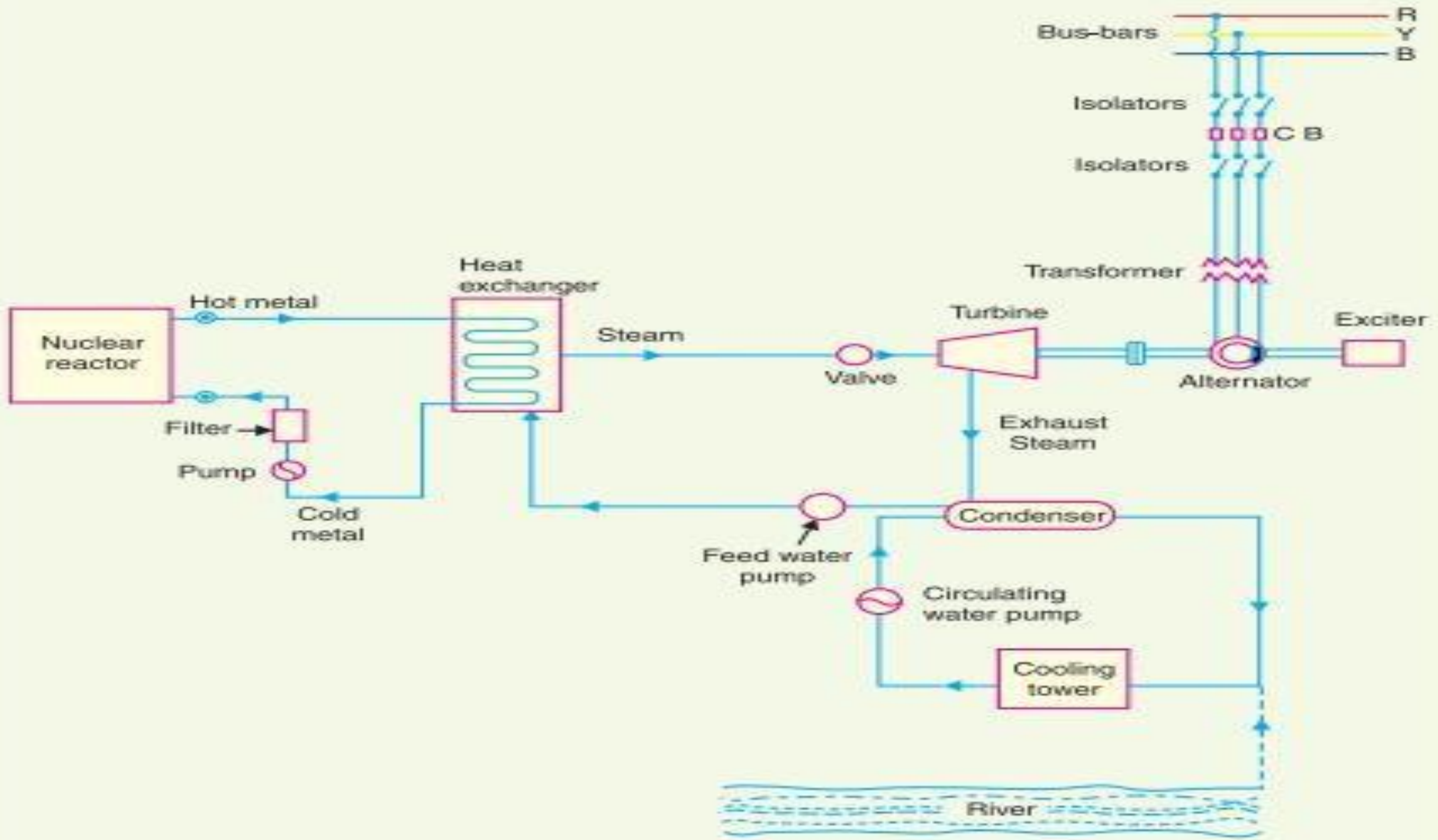
The whole arrangement can be divided into the following main stages :

1.Nuclear reactor.

2.Heat exchanger.

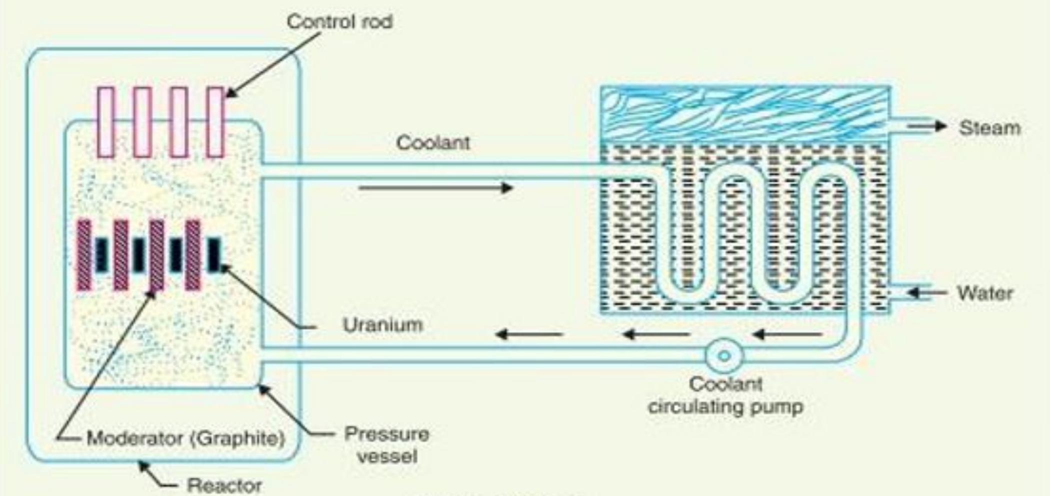
3.Steam turbine.

4.Alternator.



Schematic arrangement of Nuclear Power Station

Fig. 2.7



Nuclear Reactor
Fig. 2.8

Selection of Site for Nuclear Power Station

1. Availability of water
2. Disposal of waste.
3. Distance from populated areas.
4. Transportation facilities

Advantages

1. The amount of fuel required is quite small. Therefore, there is a considerable saving in the cost of fuel transportation.
2. A nuclear power plant requires less space as compared to any other type of the same size.
3. It has low running charges as a small amount of fuel is used for producing bulk electrical energy.
4. This type of plant is very economical for producing bulk electric power.
5. There are large deposits of nuclear fuels available all over the world. Therefore, such plants can ensure continued supply of electrical energy for thousands of years.
6. It ensures reliability of operation.

Disadvantages

1. The fuel used is expensive and is difficult to recover.
2. The capital cost on a nuclear plant is very high as compared to other types of plants.
3. The plant requires greater technical know-how.
4. The fission by-products are generally radioactive and may cause a dangerous amount of radioactive pollution.
5. Nuclear power plants are not well suited for varying loads
6. The disposal of the by-products, which are radioactive, is a big problem.

Gas Turbine Power Plant

A generating station which employs gas turbine as the prime mover for the generation of electrical energy is known as a **gas turbine power plant**

In a gas turbine power plant, air is used as the working fluid. The air is compressed by the compressor and is led to the combustion chamber where heat is added to air, thus raising its temperature. Heat is added to the compressed air either by burning fuel in the chamber or by the use of air heaters. The hot and high pressure air from the combustion chamber is then passed to the gas turbine where it expands and does the mechanical work. The gas turbine drives the alternator which converts mechanical energy into electrical energy

The main components of the gas turbine plant are

1.Compressor

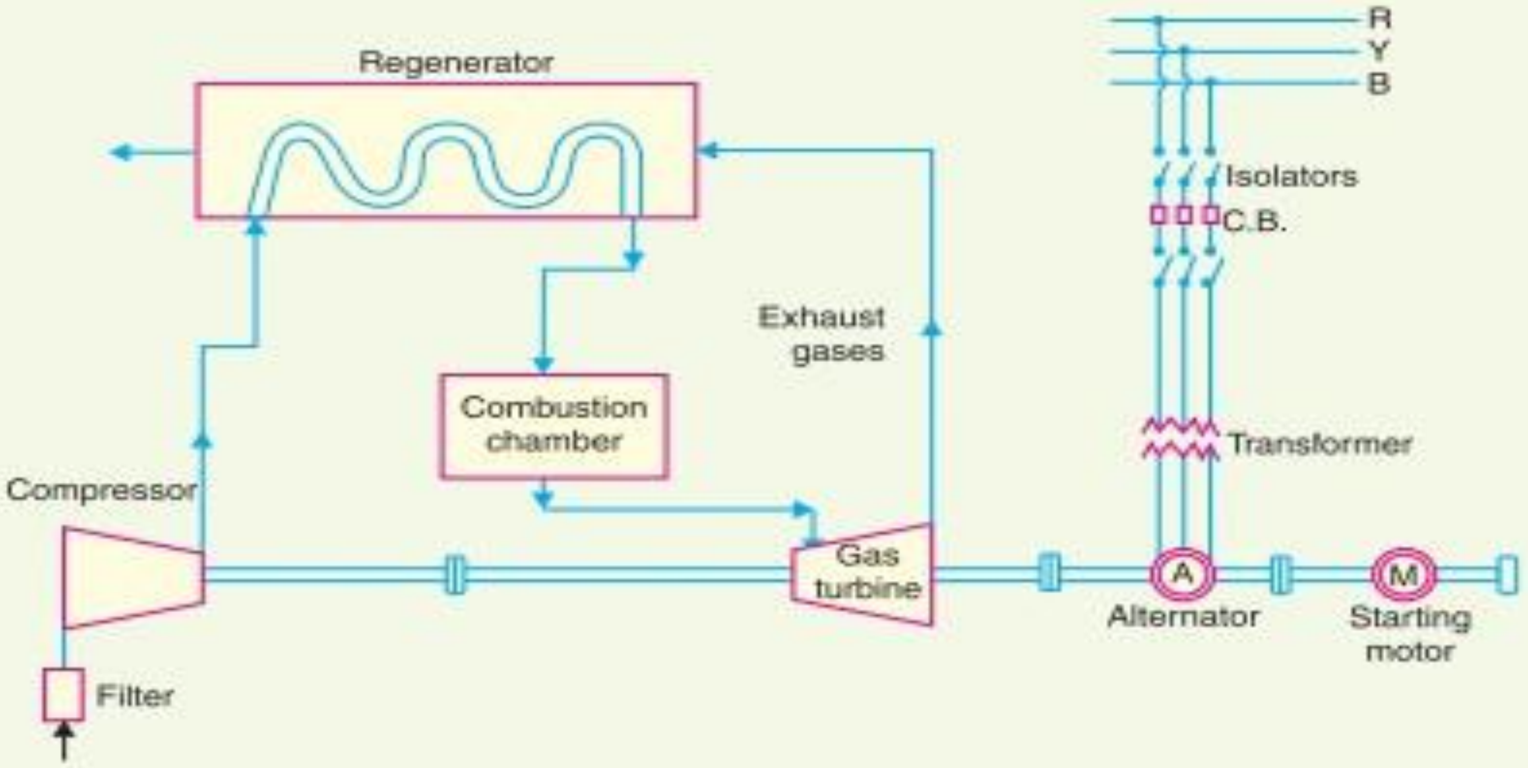
2.Regenerator

3.Combustion chamber

4.Gas turbine

5.Alternator

6.Starting motor



Schematic arrangement of gas turbine power plant.

Fig. 2.9

Advantages

1.Gas turbines are much simpler in construction and operation than steam turbines.

2.It is simple in design as compared to steam power station since no boilers and their auxiliaries are required.

3.It is much smaller in size as compared to steam power station of the same capacity. This is expected since gas turbine power plant does not require boiler, feed water arrangement etc.

4.It requires comparatively less water as no condenser is used.

5.The maintenance charges are quite small.

6.It can be started quickly form cold conditions.

7.There are no standby losses. However, in a steam power station, these losses occur because boiler is kept in operation even when the steam turbine is supplying no load.

Disadvantages

1.There is a problem for starting the unit. It is because before starting the turbine, the com pressor has to be operated for which power is required from some external source. How ever, once the unit starts, the external power is not needed as the turbine itself supplies the necessary power to the compressor.

2.Since a greater part of power developed by the turbine is used in driving the compressor, the net output is low.

3.The overall efficiency of such plants is low (about 20%) because the exhaust gases from the turbine contain sufficient heat.

4.The temperature of combustion chamber is quite high (3000o F) so that its life is comparatively reduced.

Thank you