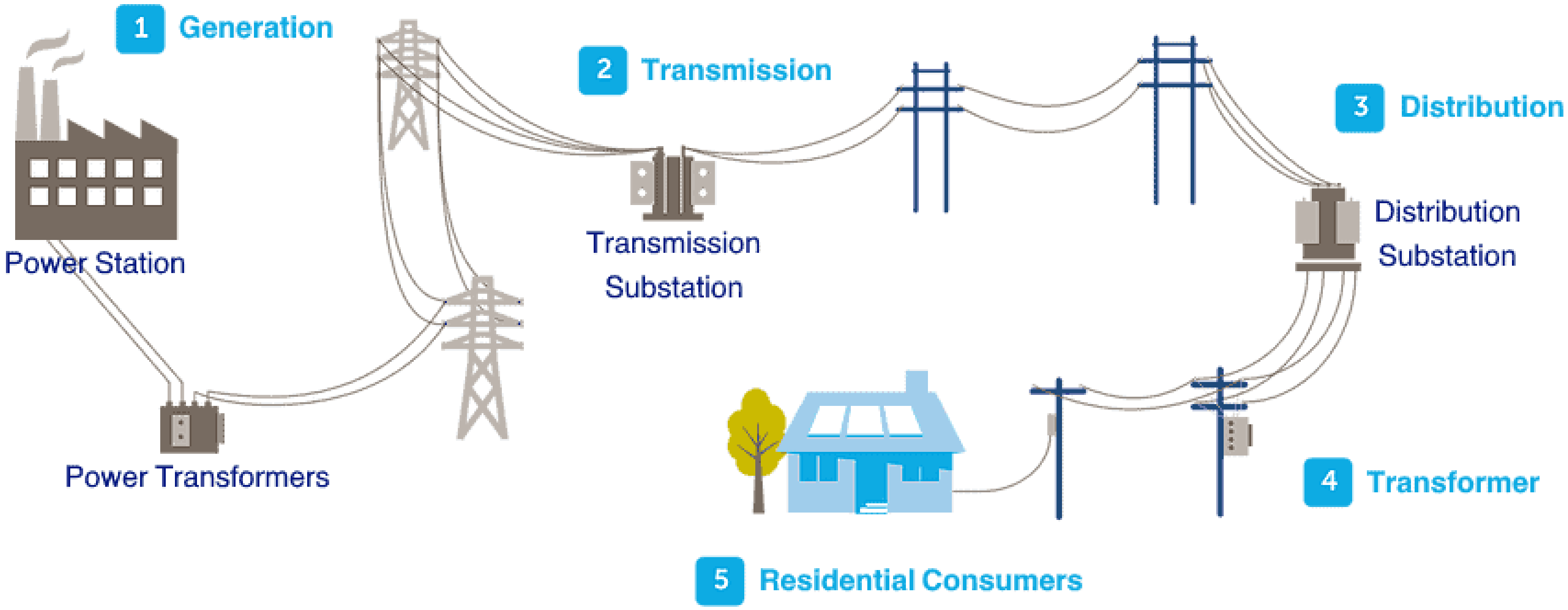
www.mathswithme.in

Course Title:

BEPS (Basics of Electrical Power system)

Course code:20EE11T

POWER SYSTEM LAYOUT



UNIT1

Hydroelectric and Thermal power plants

Power sector scenario including generation, transmission, and distribution scenario of India

India is the world's third largest producer and third largest consumer of electricity.

- The national electric grid in India has an installed capacity of 374.2 GW as of 31 November 2020.
- Renewable (ನವೀಕರಿಸಬಹುದಾದ) power plants, which also include large hydroelectric plants, constitute 36.17% of India's total installed capacity. During the 2018-19 fiscal year
- The gross electricity generated by utilities in India was 1,372 TWh and the total electricity generation (utilities and non-utilities) in the country was 1,547 TWh.
- The gross electricity consumption in 2018-19 was 1,181 kWh per capita.
- In 2015-16, electric energy consumption in agriculture was recorded as being the highest (17.89%) worldwide.
- The per capita electricity consumption is low compared to most other countries despite India having a low electricity tariff.

- India has a surplus power generation capacity but lacks adequate distribution infrastructure.

- To address this, the Government of India launched a program called "Power for All" in 2016.

- Funding was made through a collaboration between the Government of India and its constituent states.

- India's electricity sector is dominated by fossil fuels, in particular coal, which during the 2018-19 fiscal year produced about three-quarters of the country's electricity.

- The government's National Electricity Plan of 2018 states that the country does not need more non-renewable power plants in the utility sector until 2027, with the commissioning of 50,025 MW coal-based power plants under construction and addition of 275,000 MW total renewable power capacity after the retirement of nearly 48,000 MW old coal-fired plants.
- It is expected that non-fossil fuels generation contribution is likely to be around 44.7% of the total gross electricity generation by the year 2029-30.

Importance (ADVANTAGES)of electrical power generation

Energy may be needed as heat, as light, as motive power etc. The present-day advancement in science and technology has made it possible to convert electrical energy into any desired form. In fact, the advancement of a country is measured in terms of per capita consumption of electrical energy.

Electrical energy is superior to all other forms of energy due to the following reasons:

1. Convenient form: Electrical energy is a very convenient form of energy.

2. Easy to control: The electrically operated machines have simple, convenient starting, control and operation.

3.Greater flexibility: Electrical energy can be easily transmitted from one place to another and can be easily converted into other forms of energy like heat, light, mechanical energy, chemical energy, etc.

4.Cheapness: Electrical energy is much cheaper than other forms of energy. Thus, it is overall economical to use electrical energy for domestic, commercial and industrial purposes.

5.Cleanliness: Electrical energy generally does not produce smoke, fumes or poisonous gases. Hence it is non-polluting.

6.High transmission efficiency: Electrical energy can be transmitted conveniently and efficiently from the generating stations to the consumers with the help of transmission lines.

7.Economic development: Energy is the basic necessity for the economic development of a country.

8.Electrical energy can be stored in batteries

Sources of energy available in nature

- Water power
- Solid fuel (coal)
- Liquid fuel (diesel, petrol)
- Gaseous fuel (natural gas)
- Nuclear power
- Solar power
- Wind power
- Tidal power
- Geo thermal power
- Biomass/Biogas
- Magneto hydro dynamic (MHD)

CLASSIFICATION OF SOURCES OF ELECTRICAL ENERGY

i. Conventional sources of energy

ii. Non-conventional sources of energy

Conventional (ಸಾಂಪ್ರದಾಯಿಕ) Sources of Energy- Sources of energy which has been in use from Centuries are called the conventional source of energy. Example Wood, Coal, Petrol, hydro power

Non-Conventional Sources of Energy- Source of energy which we have started using in recent times is called Non-conventional energy sources. Eg Nuclear energy, Geothermal energy, Solar energy, Ocean tides

I. Conventional sources

Conventional sources of energy are the commonly used sources of energy. They include

a) Water power or hydro power
b) Solid fuel (coal)
c) Liquid fuel (diesel, petrol)
d) Gaseous fuel (natural gas)
e) Nuclear power

II. Non-conventional sources

Non-conventional sources of energy are not so commonly used sources of energy. They include

i. Solar power
ii. Wind power
iii. Geo thermal power
iv. Tidal power
v. Ocean thermal power
vi. Biogas/Biomass
vii. Piezo electric, thermo electric
viii. MHD (Magneto Hydro Dynamic)

Renewable and Non-renewable sources of energy

The sources of energy available in nature can also be classified as:

i. Renewable sources of energy
ii. Non-renewable sources of energy

i. Renewable sources of energy: They are inexhaustible (ಅಕ್ಷಯ) sources of energy and they are continuously replenished in nature.

Example: Water power, Solar, Wind, Geo thermal, Ocean thermal, etc.

ii. Non-renewable sources of energy: They are exhaustible sources of energy. Once they are used, they can't be replenished (ಮತ್ತೆ ತುಂಬು) again.

Example: Solid fuel, Liquid fuel, Gaseous fuel, Nuclear power, etc.

Hydro-Electric Power Station.

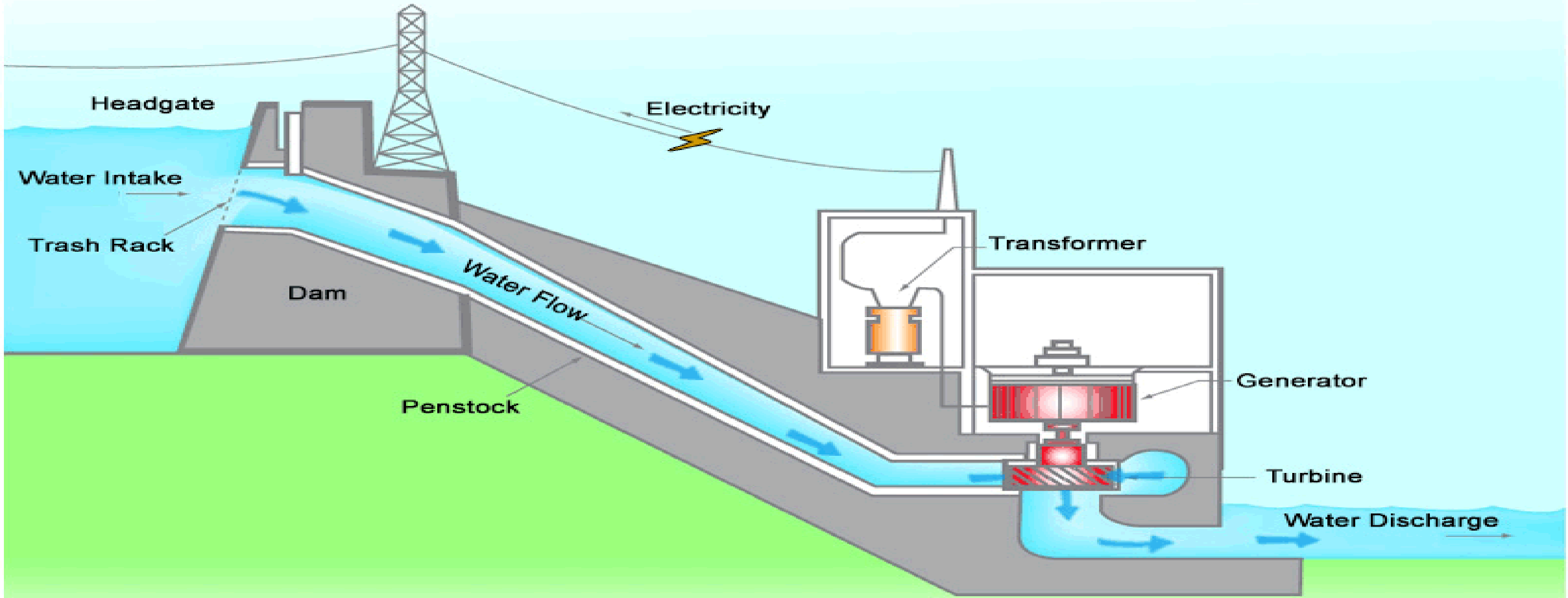
www.mathswithme.in

- Hydro is a Greek Word of Water.

- A Generating Station Which Utilizes the Potential Energy of Water at High Level to Produce Electrical Energy is Called **Hydro-Electric Power Station.**

#HowThingsWork

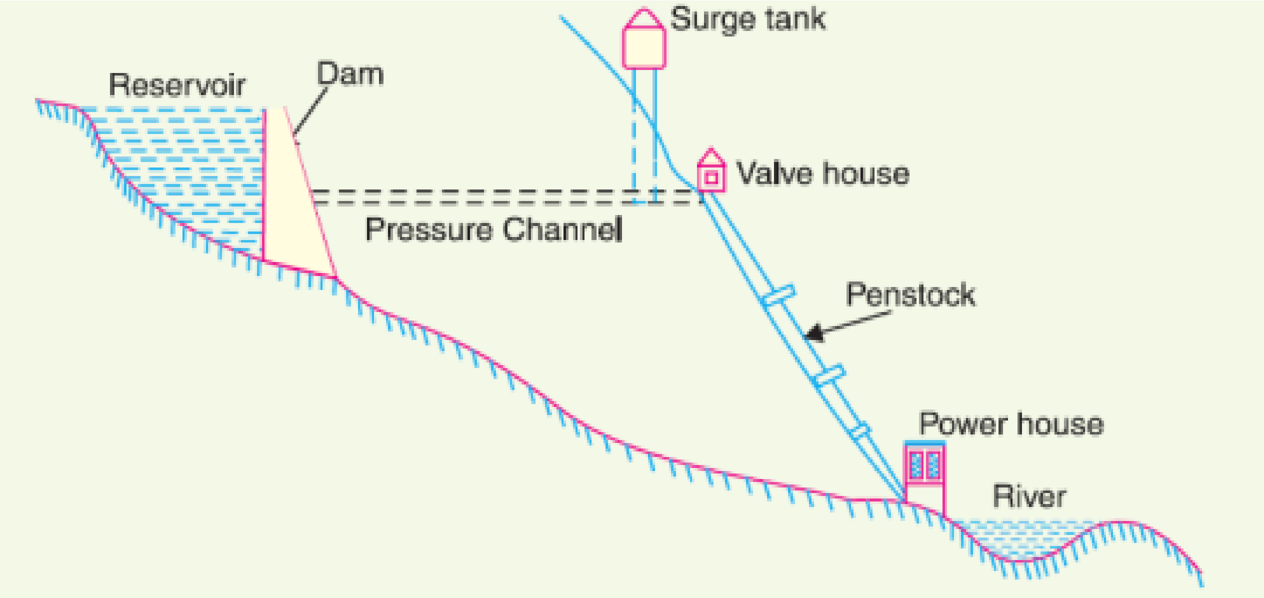
Hydroelectric Power System



Factors to be considered for selection of site

1. **Availability of Water:** Adequate water must be available at good head, because the electricity produce of hydro power station is depends on the height through which the water has to fall to get to the turbine.
2. **Cost and Type of Land:** land should be available at reasonable price. the bearing capacity of the land should be enough to withstand huge structures & equipment.
3. **Storage of Water:** A dam must be constructed to store water in order to deal with variations of water availability during the year.
4. **Transportation Facilities:** the site should be accessible by rail and (or) road for ease in transporting equipment & machinery.
5. **Distance from The Load Centre:** It is important that the power plant should be set up near the load center this will reduce the cost of erection and maintenance of transmission lines.
6. The site should have large. catchment area (ಸಂಗ್ರಹಣಾ ಪ್ರದೇಶ)
7. The site should preferably have high mountains on the two sides of the dam constructed.
8. The land for the construction of plant should be available at low price.
9. The site selected should have less impact on the ecology by the construction of dam.

General layout of hydro power plant



Schematic arrangement of a Hydro-electric plant

www.mathswithme.in

The main components of hydro-electric power plant and their function

1. ***Catchment area:*** The rain water falls on a large area called catchment area.
2. ***Dam:*** The dam is a barrier constructed to trap water and to create water head.
3. ***Reservoir:*** The main function of reservoir is to store water.
4. ***Fore bay:*** Forebay serves as a regulating reservoir. It stores water temporarily when the load on the turbine is reduced and provides water when the load is increased.
5. ***Penstock:*** Penstocks are made of reinforced concrete or steel tubes or pipes which carry water from the reservoir to the turbine of the power house.
6. ***Anchor blocks:*** Anchor blocks hold the penstock and prevent the movement of penstock.

7. ***Surge tank:*** It is an open tank placed at the beginning of the penstock. The surge tank controls the pressure variations in the penstock and prevents water hammering effect. When the turbine is running at steady load, there are no surges in the flow of water through the penstock. When the load on the turbine decreases, the governor closes the gates of the turbine and the water supply to the turbine is reduced suddenly. This causes excess water in the penstock rushes back to the surge tank and the water level in the surge tank increases. Thus, it prevents penstock from bursting. On the other hand, when the load on the turbine increases, excess water is drawn from the surge tank.

8. ***Trash rack:*** Trash rack is provided to stop the entry of debris which might damage the gates and runners of the turbine.

9. ***Spill ways:*** During heavy rain fall, when the water level in the reservoir exceeds beyond the maximum level, the spill way discharges the excess water of the reservoir and acts as a safety valve to the dam.

Component	Function
Dam	Creates a reservoir by blocking the river to store water.
Reservoir	Holds water to provide a constant supply for electricity.
Penstock	Large pipe channels high-pressure water to the turbines.
Turbines	Spins from the water's force, converting it to mechanical energy.
Generator	Converts mechanical energy from turbines into electricity.
Transformer	Increases voltage for efficient long-distance transmission.
Transmission Lines	Carries high-voltage electricity to substations and users.
Control System	Regulates plant operations for safety and efficiency.
Tailrace	Releases water back into the river after passing through turbines.
Auxiliary Systems	Include cooling, safety, and monitoring systems for reliability.

10. ***Prime mover:*** The prime mover also called as turbine converts the potential and kinetic energy of the water into mechanical energy. The prime mover in turn rotates the shaft of the electric generator which generates electricity.

11. ***Alternator:*** It is the AC generator coupled to the turbine. It converts mechanical energy of the turbine into electrical energy.

12. ***Power house:*** The power house is normally located near the foot of the dam. The power house has turbines, alternators, circuit breakers and other control devices.

13. ***Tail race:*** Water after passing through the turbine is discharged into the place called tail race. A tail race is an open channel or a tunnel depending on the power house location. The tail race discharges the water into the original river.

14. ***Draft tube:*** Draft tube is a metal pipe or a concrete tunnel which connects the turbine runner to the tail race. The area at the top of the draft tube is same as that of turbine runner. Its cross-sectional area gradually increases towards the outlet. It helps to mount the turbine above the tail race.

Classification of hydroelectric power plants

1.Based on Head of water:

As per height of water or water head, hydroelectric power plant can be divided into three categories:

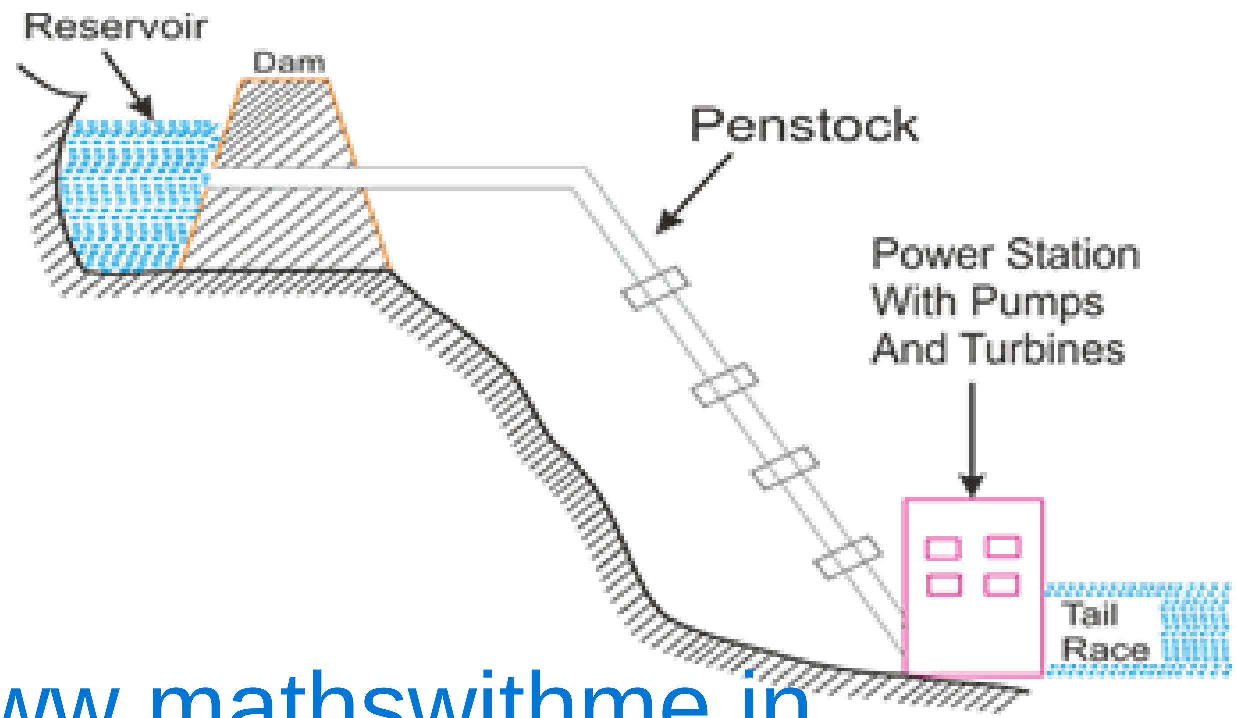
a. Low Head - below 30 meters

b. Medium Head - above 30 meters and up to 300 meters

c. High Head - above 300 meters

www.mathswithme.in

a. Low Head Hydro Electric Power Plant



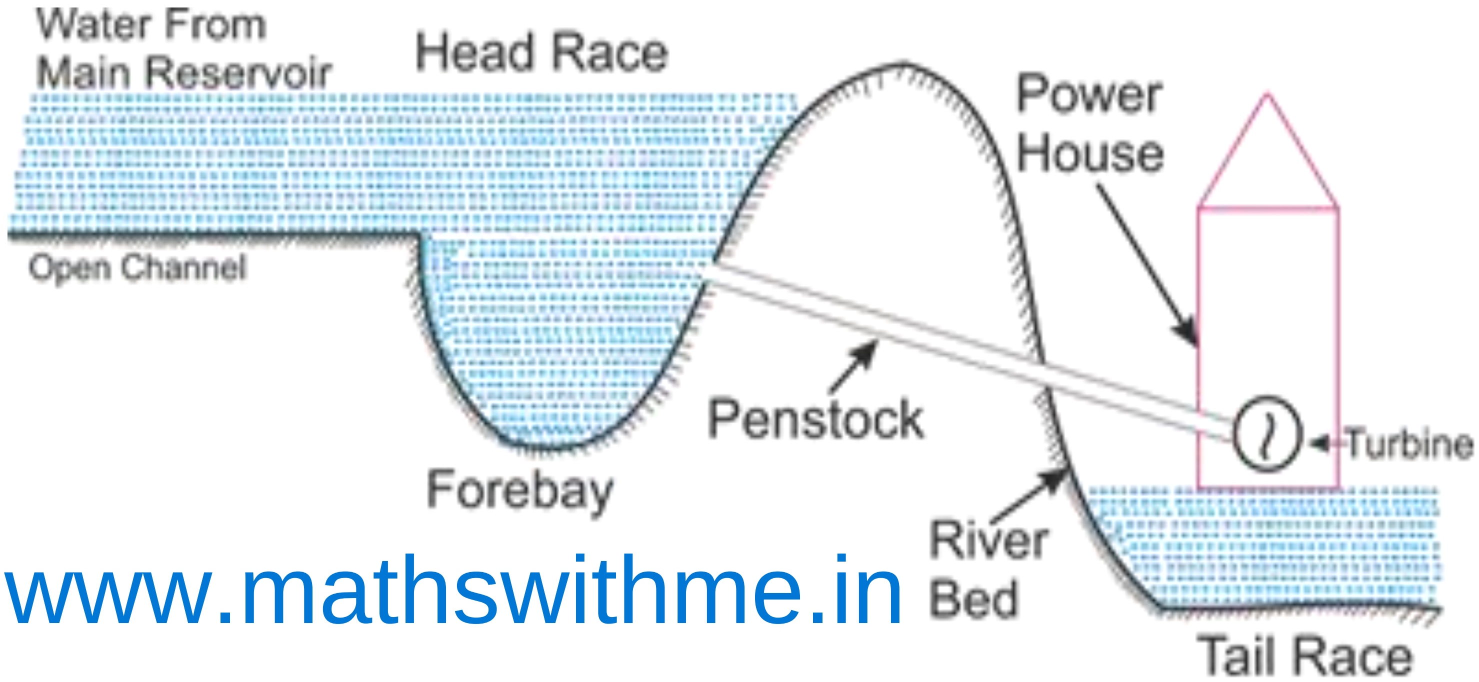
www.mathswithme.in

- Since head is low, huge amount of water is required for the desired output. That's why large diameter and low length pipe is used for this plant. Such types of power plant use low speed and large diameter type generators.
- To create a low head, dam construction is essential.
- Water resource level i.e. river or pond is placed just behind the dam to create a necessary water head level.
- Water is led to the turbine through the penstock.
- **Francis, Kaplan or Propeller turbines** are used for this type of hydroelectric power plant.
- This type of hydro plant is located just below the dam and it creates a useful water level.
- No surge tank is required for this plant, dam itself discharge the surplus water from the river.

FOREBAY

The fore bay is the temporary water storage at one end of the power channel. Its basic purpose is to regulate the water flow and to avoid the turbulence of the water flow before entering into the penstock.

b. Medium head Hydro Electric Power Plant

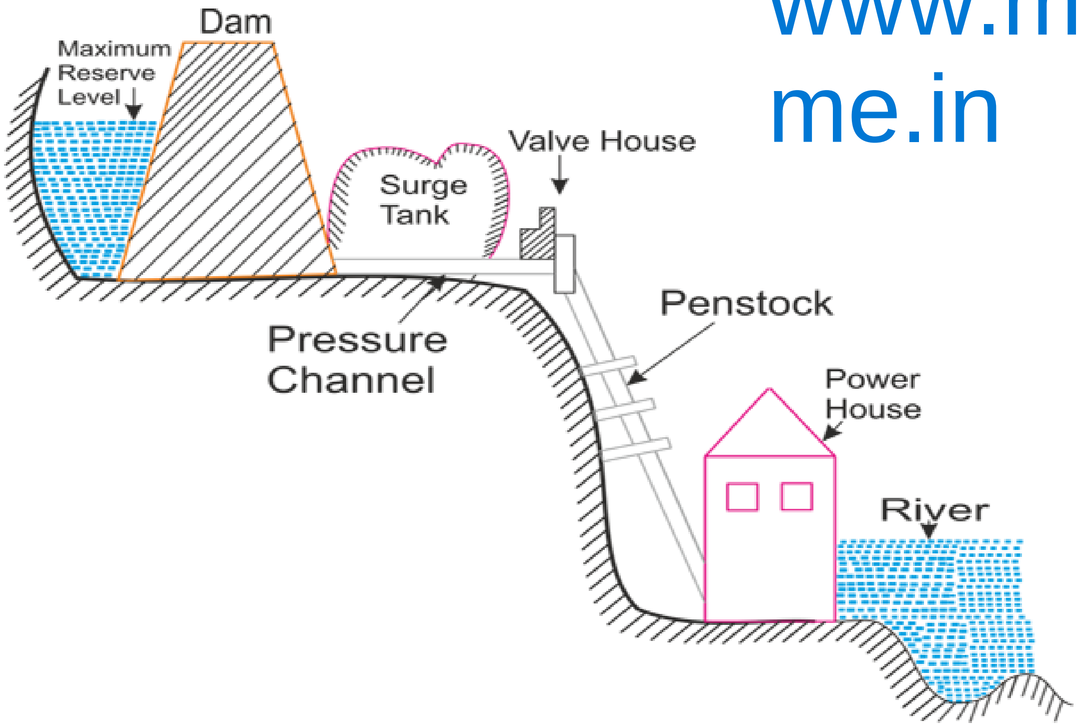


www.mathswithme.in

- In these power plants, the river water is usually tapped off to a forebay on one bank of the river as in case of a low head plant. From the forebay the water is led to the turbines through penstocks. The forebay provided at the beginning of penstock serves as a water reservoir for such power plants.
- A forebay is used for medium head hydroelectric power plant. This forebay works as a surge tank.
- Forebay is tapped with the river and water is led to the turbine via penstock. Forebay is just beginning of penstock. For low head plant forebay itself serves as a surge tank. This plant uses either **Kaplan or Francis turbine**.

C. High head Hydro Electric Power Plant

www.mathswithme.in



c. High head Hydro Electric Power Plant

- The dam is constructed across a river or lake and water from the catchment area collects at the back of the dam to form a reservoir.
- A pressure tunnel is taken off from the reservoir and water brought to the valve house at the start of the penstock.
- The valve house contains main sluice valves and automatic isolating valves. The former controls the water flow to the power house and the latter cuts off supply of water when the penstock bursts.
- From the valve house, water is taken to water turbine through a huge steel pipe known as penstock. The water turbine converts hydraulic energy into mechanical energy. The turbine drives the alternator which converts mechanical energy into electrical energy.
- A surge tank (open from top) is built just before the valve house and protects the penstock from bursting in case the turbine gates suddenly close* due to electrical load being thrown off. When the gates close, there is a sudden stopping of water at the lower end of the penstock and consequently the penstock may burst. The surge tank absorbs this pressure swing by increase in its level of water.

Based on Installed Capacity

1.Micro hydro power plant (upto 0.1MW)

2.Mini hydro power plant (more than 0.1MW and less than 2MW)

3.Small hydro power plant (between 2MW to 25MW)

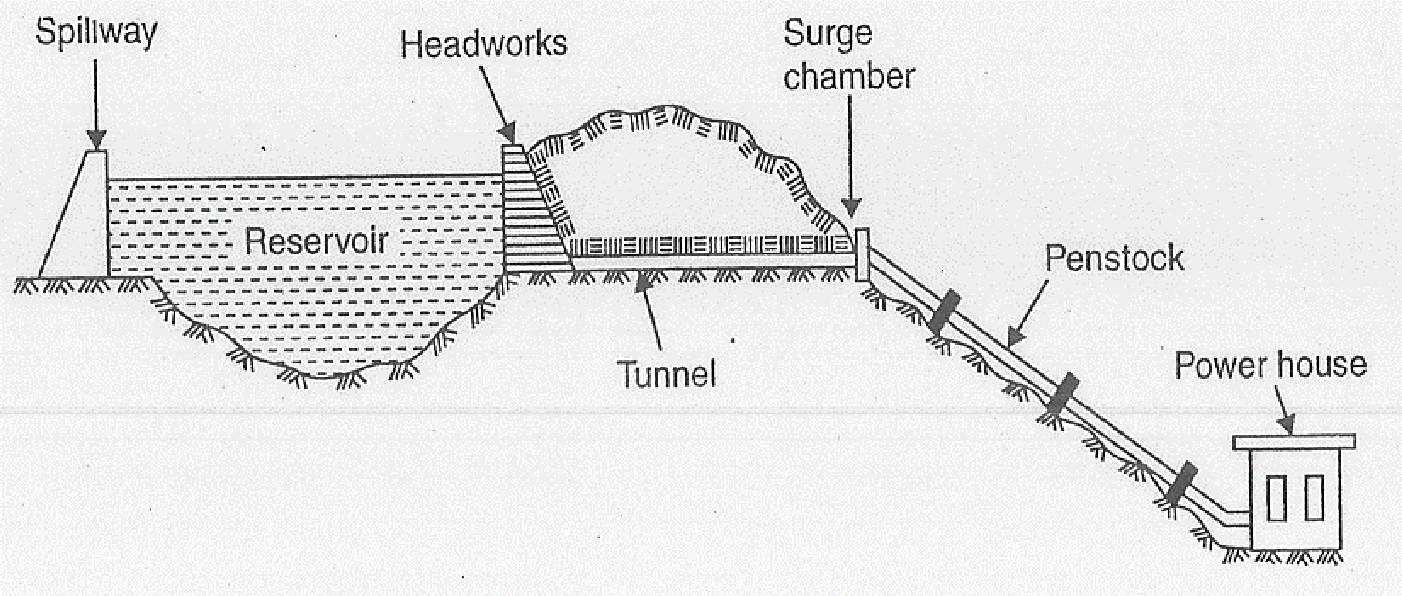
4.Large hydro power plant (between 25MW to 500MW)

5.Mega hydro power plan (more than 500MW)

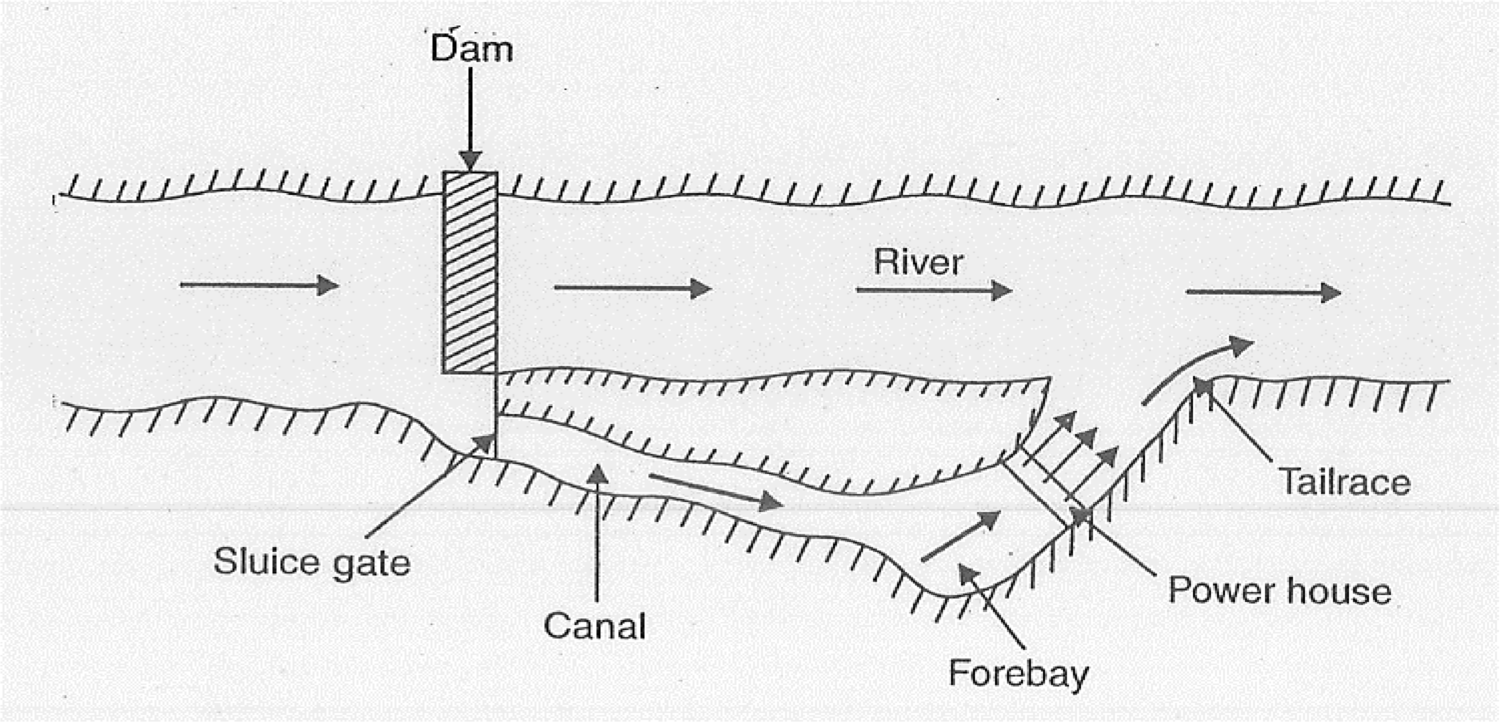
Based on the construction

1.Impoundment hydro power plant (Reservoir plants):

- These plants store water in big reservoir behind the dam.
- Water storage in the reservoir increases the generating capacity of the plant. Most of the hydro electric plants belong to this category.



2.Diversion hydro power plant (Run off river plants without pondage)

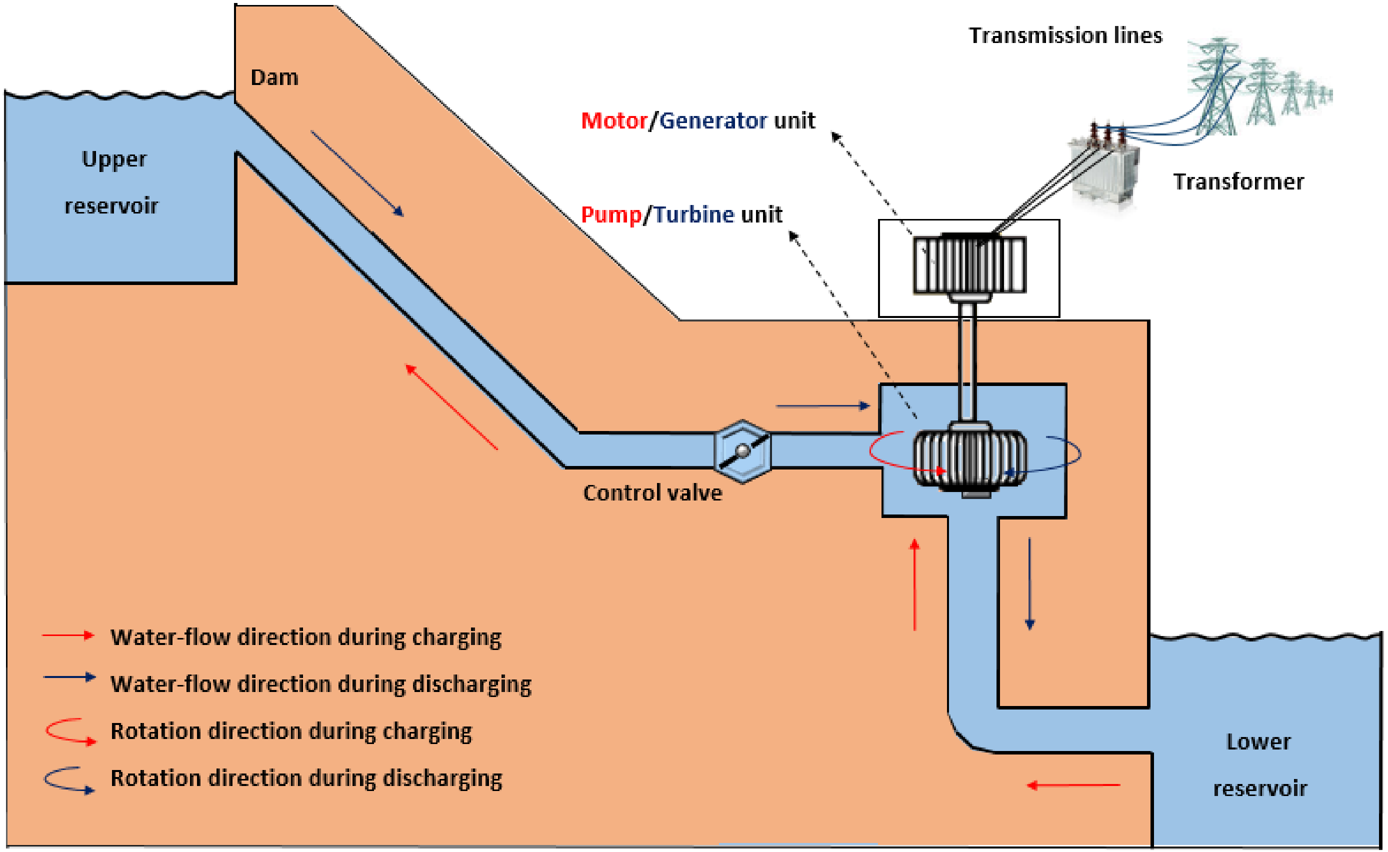


These plants are located such that they use water as it comes without any pondage or storage. In these plants, some quantity of water goes as waste during rainy season. But during low flow periods, the generating capacity of the plant will be low. During periods of high flow, these plants can supply sufficient portion of base load.

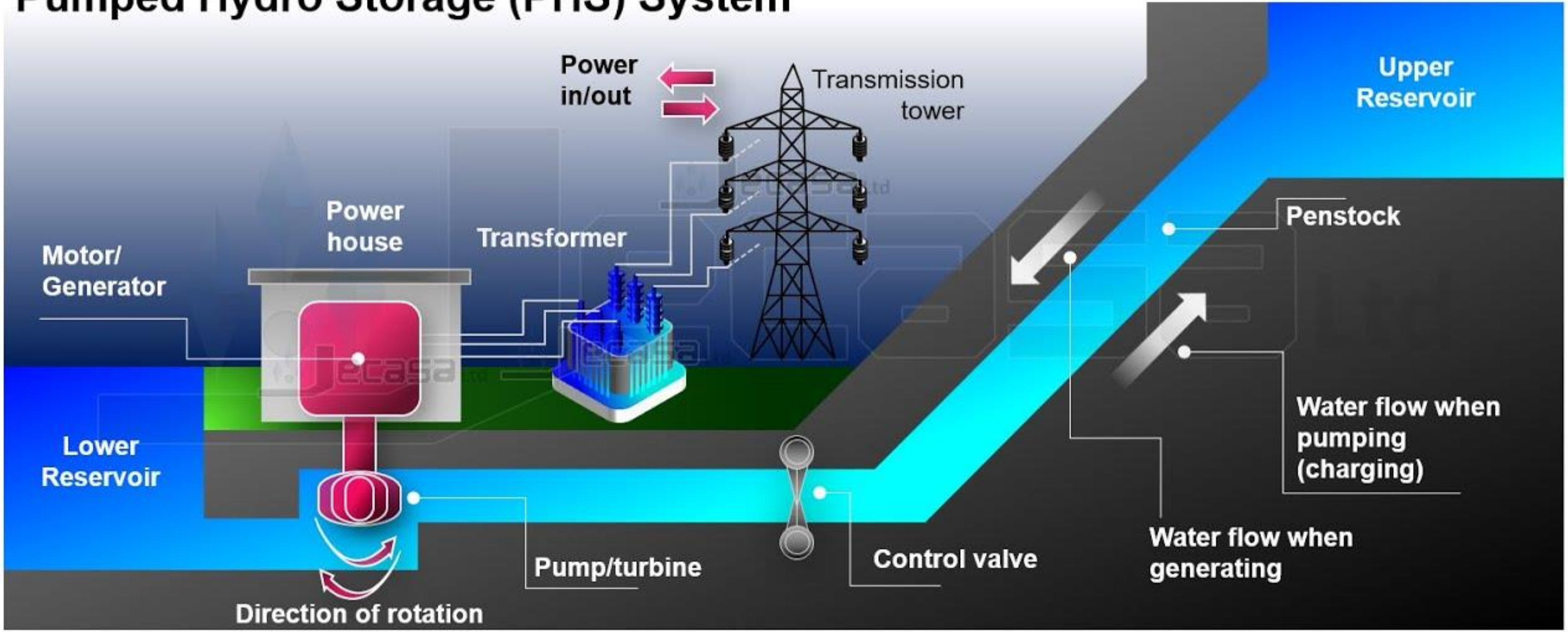
3. Pumped storage plants for the peak load

- This is unique design of peak load plants. Here two types of water pond are used, called upper head water pond and tail water pond. Two water ponds are connected each other by a penstock.
- Main generating pumping plant is lower end. During the off-load period, surplus energy of this plant is utilized to pumping the lower head pond water to upper head pond water. This extra water is used to generate energy at peak load periods.
- By doing this arrangement, same water is used again and again. Extra water is required only to take care of evaporation and seepage.

3. Pumped storage plants for the peak load



Pumped Hydro Storage (PHS) System




Pumped Hydro
Storage Systems

According to the types of load supply

a. Base Load: This is a large capacity power plant. This plant work as a base portion of load curve of power system, that's why it is called base load plants. Base load plant is suitable for constant load.

b. Peak Load: This plant is suitable for peak load curve of power system. When demand is high, the plant is put into operation

Water hammer and its effect

- Whenever the electrical load on the generator drops down suddenly, the governor partially closes the gate which admits water to the turbines.
- Due to this sudden decrease in the rate of flow of water to the turbine, there will be sudden increase of water pressure in the penstock.
- This result in hammering action in the penstock and it is known as water hammer.
- If this water hammer is not prevented it may result in bursting of penstock.
- The surge tank is used to control the pressure variations in the penstock and prevent water hammering effect

Advantages and Disadvantages of Hydroelectric power plant.

Advantages

1. It requires no fuel as water is used for the generation of electrical energy.
2. It is neat and clean since no smoke and ash is produced.
3. It requires low running cost because water is freely available in nature.
4. It is simple in construction and requires less maintenance.
5. It does not require long starting time like thermal power stations. It can be put into service instantly.
6. Overall efficiency of the system is higher as it shows high efficiency over considerable range of load.
7. Besides power generation, it provides additional benefits like irrigation, fishing, and flood control.
8. It is robust and has a long life.
9. It does not need highly skilled persons for operation.
10. It is generally located remote area, hence cost of land is low
11. A single unit of very high output can be used.
12. There is no stand by losses.
13. Use of water helps in conserving coal and other fuels.
14. They offer more flexibility in operation and control.

Disadvantages:

1. It requires high capital cost due to construction of dam.
2. It requires large land area.
3. The duration required for construction is very long (about 10 years)
4. Skilled and experienced personnel are required to build the plant.
5. Power generation depends on weather conditions.
6. Transmission cost and losses are very high because hydro-electric plants are located in hilly areas which are away from load centers.
7. Due to construction of dams and reservoirs, a large portion of area is submerged in water which leads to environmental and social problems.
8. Due to unpredictable rainfall and other weather conditions, there is an uncertainty of water availability thus produces lesser power

Environmental Impacts of Hydro power Plants

1. Demographic Impacts: - Construction of a power plant causes a rapid influx of large construction force in the area. A majority of these workers tend to remain there even after the power plant construction is completed. The area may get urbanized and its population density may increase

2. Public Services:- The increase in the population of the area creates an increased demand for water supply, sewage, waste disposal, educational, medical and transport facilities.

3 Land Use Impacts: Agricultural land gets converted to residential and commercial property.

4. Housing Impacts:-Increased demand for housing, increase in housing values and rents and possibility of out migration of existing residents.

5. Public Safety Impact:- Plant construction creates an increased demand for police, fire protection, legal and judicial services

6. Economic Impacts:- Plant construction increases job opportunities and employment rate of the area.

7 Recreational and Cultural Impacts:- The increase in population causes an increased demand of parks, playgrounds, swimming pools, theatres and other recreational and social centers.

8. Change in Community Structure: - The traditional rural community values may be replaced by urban values and preferences.

www.mathswithme.in

Thermal power plant

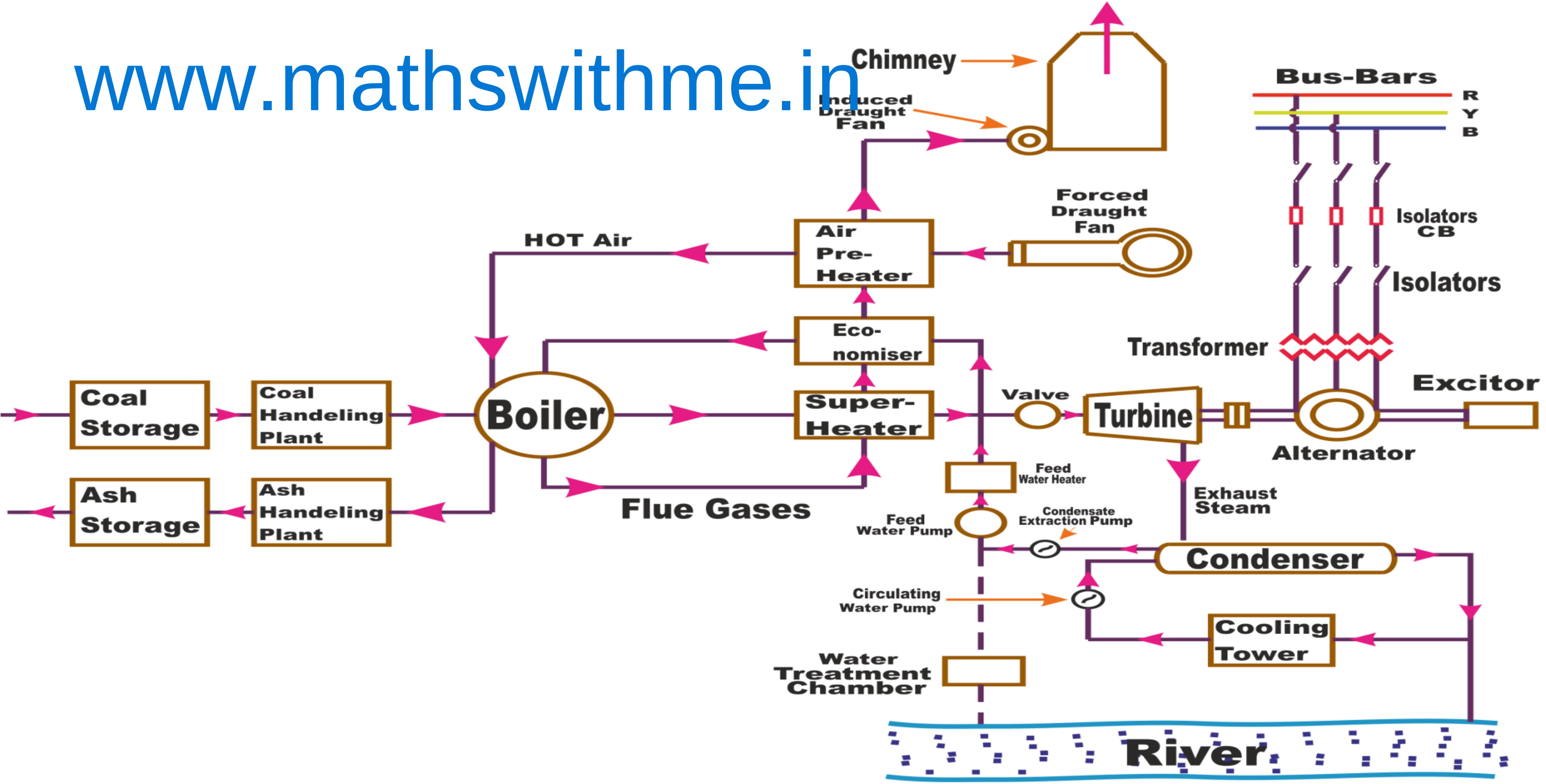
Thermal power plant

A thermal power station is a power station in which heat energy is converted to electrical energy

Factors to be considered for selection of site.

- Availability of coal
- Availability of land
- Ash disposal facilities
- Availability of water
- Transport facilities
- Residential problems
- Space requirement
- Availability of labour
- The initial cost of the plant
- The magnitude and nature of load to be handled
- Probable necessity for future expansion of the plant
- Distance from load center

Lay out of Thermal power plant



Components of thermal power plant

Fuel storage and handling plant

In a thermal power plant process, the first step in process of power generation is that the coal is brought to breaker house with the help of belt conveyor, here light dust is separated and It further goes to the crusher where it is crushed to a size of about 50mm.

Boiler and furnace

A boiler is a pressure vessel which is used to generate high-pressure steam by burning coal in the furnace

Economiser and Air Preheaters

The exhaust gases leaving the boiler are generally at high temperature and this waste heat is extracted by installing an Economiser or Water Preheaters to preheat the feed water to the boiler and Air Preheaters to pre-heat the air coming from the Forced Draft Fan required for the combustion of fuel.

Chimney

flue gases are exhausted off into the atmosphere using a chimney.

Superheater

The Superheater is used to produce superheated steam or to convert the wet steam to dry steam,

generated by a boiler.

Condenser

Condenser condenses the steam which comes from the turbine into water at a very low pressure

Cooling tower

A cooling tower is a heat rejection device, which extracts waste heat to the atmosphere though the cooling of a water stream to a lower temperature.

Turbine

A turbine is a mechanical device which converts the pressure energy of steam into rotational energy

Working of thermal power plant

- First the pulverized coal is burnt in the furnace of steam boiler. High pressure steam is produced in the boiler.
- This steam is then passed through the super heater, where it further heated up.
- This super heated steam is then entered into a turbine at high speed.
- In turbine this steam force rotates the turbine blades that means here in the turbine the stored potential energy of the high-pressured steam is converted into mechanical energy.
- After rotating the turbine blades, the steam has lost its high pressure, passes out of turbine blades and enters into a condenser.
- In the condenser the cold water is circulated with help of pump which condenses the low pressure wet steam.
- This condensed water is then further supplied to low pressure water heater where the low pressure steam increases the temperature of this feed water, it is then again heated in a high pressure heater where the high pressure of steam is used for heating. The turbine in thermal power station acts as a prime mover of the alternator.

Advantages and dis-advantages of thermal power plant

Advantages

1. The cost of the fuel is cheap.
2. The initial cost is less when compared to hydel or nuclear power station.
3. It requires less space when compared to hydro electric plant.
4. Cost of power generation is less than that of diesel power station.
5. Weather conditions will not affect power generation.
6. Large amount of power can be generated by thermal power station.
7. It can be located near the load centers which reduces transmission cost and losses.

Disadvantages

1. Pollutes the atmosphere due to production of ash, dust, fumes and smoke.
2. Running cost is high when compared to hydro electric power station.
3. Maintenance cost is more.
4. The power plant cannot be started instantly.
5. Standby losses in the boiler are more.
6. Losses are more and hence efficiency is less.

Environmental Impact of Thermal power plants

During every energy conversion process, some energy is released into the atmosphere in the form of heat. Some pollutants in the form of gases are also produced during conversion and these gases are also emitted into the surroundings. Both heat and gases can cause degradation of the environment. Some of the pollutants related to thermal power plants are;

I Air pollution: - Air pollution can affect people and other living things. The earth is surrounded by a blanket of air. Air pollution occurs when gases, dust particles, fumes or smoke are introduced in the atmosphere.

The air pollution by thermal plants can be;

a) Stack emissions b) Cooling water emissions.

Types of stack emissions: -Thermal plants using fossil fuels emit a number of harmful substances like Sulphur oxides, nitrogen oxides, particulates, Hydrocarbons, carbon monoxide and traces of organic compounds. Out of these, Sulphur dioxide, nitrogen dioxide and particulates cause the maximum pollution problems. These pollutants are emitted from power plant stacks with flue gases.

Sulphur dioxide impacts: - Many results shown that main health problems created by Sulphur dioxide are related to irritation of respiratory system and the effect becomes more when particulates are also present. Vegetation damage, due to SO2 is characterized by leaf yellowing, reduction in live plant biomass and long-term reduction in crop growth and yield. Presence of SO, in air also increases the corrosion rate of steel.

Nitrogen oxide impacts: -It causes respiratory and cardiovascular diseases and form acid in lungs.

Air borne particulates impacts: - Flue gases emitted from stacks of coal fired plants contains substantial quantity of particulates. The amount of particulates depends on ash content of coal. The ash content of Indian coal being high, the particulates pose a serious problem. The hazards include bronchitis, respiratory diseases and excessive death rate.

UNIT2

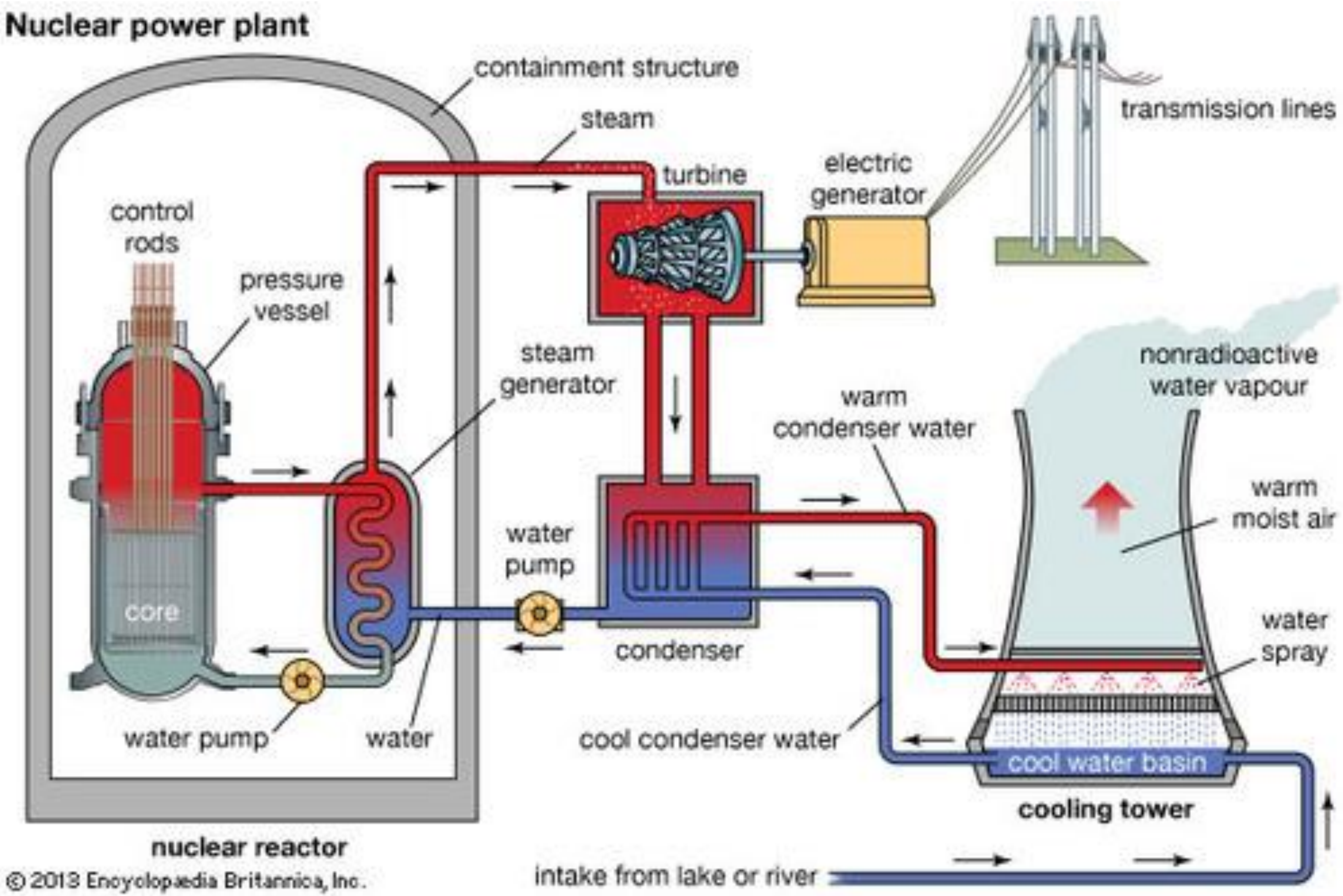
NUCLEAR,DIESEL &GAS TURBINE POWER PLANTS

Nuclear power plant

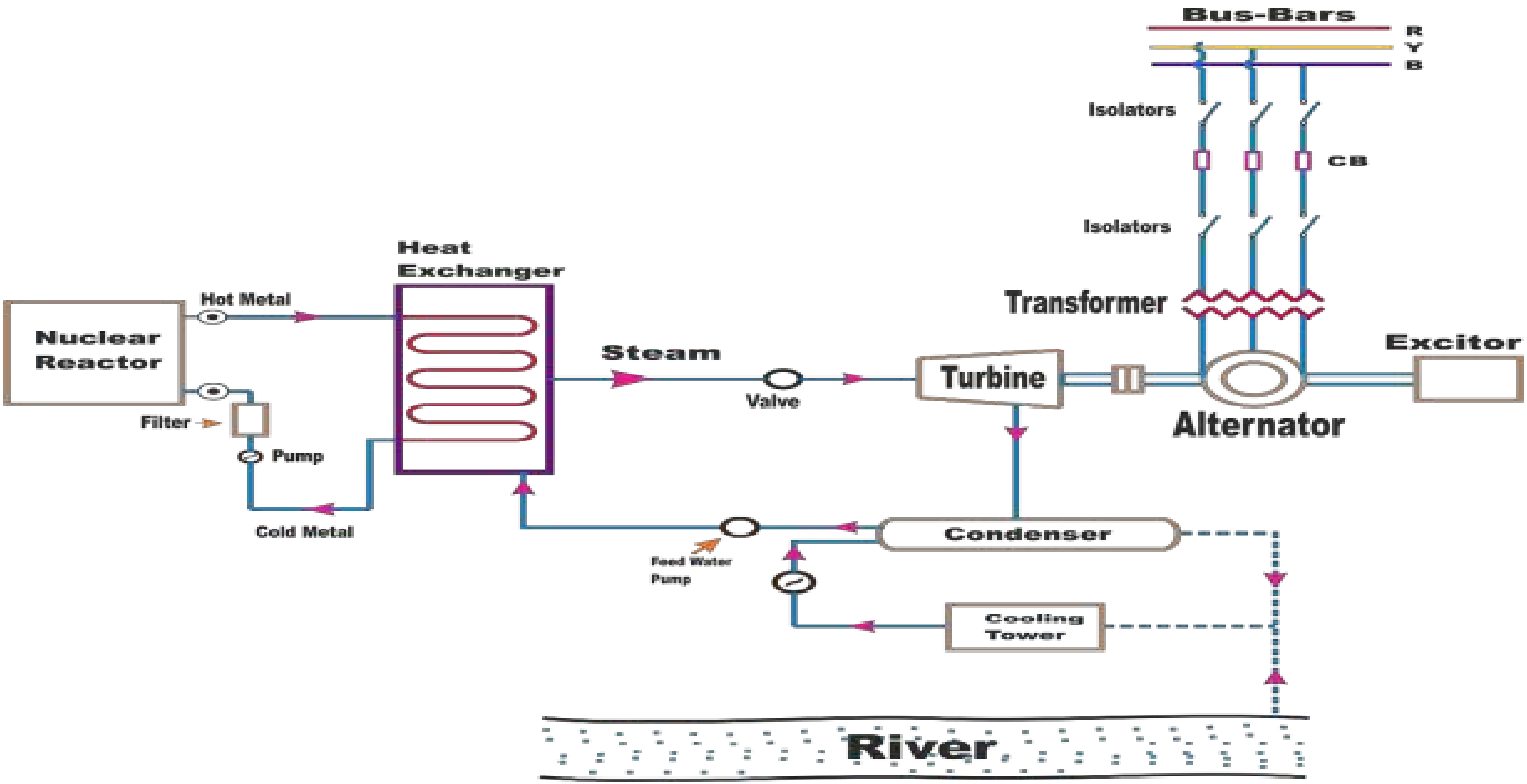
The Power Plant which uses nuclear energy of radioactive material (Uranium or Thorium) converted into Electrical Energy is known as Nuclear Power Plant.

Factors to be considered for selection of site

1. Availability of water
2. Disposal of Waste
3. Distance from Populated Area
4. Transportation
5. Availability of skilled manpower to run & handle the plant also good public transport should also be present at the site.
6. Near to Load Centre
7. Storage of Nuclear Material:- the nuclear materials are radioactive, which are dangerous to health to overcome this drawback a separate arrangement provided for storage of material
8. Geographical Condition:- The radioactive material are very dangerous to human health & all living organisms, and the location should be free from earthquakes.


Nuclear power plant
containment structure
steam
turbine
electric generator
transmission lines
control rods
pressure vessel
steam generator
nonradioactive water vapour
warm condenser water
warm moist air
water pump
core
condenser
water spray
water pump
water
cool condenser water
cool water basin
cooling tower
nuclear reactor
intake from lake or river

Schematic diagram of nuclear power plant.



Construction and working of Nuclear power plant.

- Fuel rod –it is a rod filled with pellets of uranium
- Moderator-used to reduce the speed of neutron. Graphite, heavy water or beryllium is used as a moderator
- Shield- give protection from radiations
- Control rods-controls the chain reaction during the operation of reactor. Cadmium or boron is used
- Reflector-it completely surrounds the reactor core and bounce back the escaping neutrons into

  the core
- Coolant- transfer heat produced in the reactor to heat exchanger
- Heat exchanger- heat exchange takes place to generate steam
- Steam turbine- Steam energy is converted into rotational energy
- Alternator- rotational energy of turbine is converted into electrical energy
- Cooling system or condenser-steam from turbine is converted into water which is again fed to

  the heat exchanger

Nuclear power plant impacts such as Health physics

The emissions, from a nuclear power are ‘heat' and 'radioactivity'. Therefore, the radiations from the nuclear power plants have to be monitored and safety should be ensured under all conditions of operation.

Health physics: Nuclear radiations can cause danger to living cells by ionization process. Radiations enter our body through breathing, eating, drinking or cuts. Some radiations are specially excreted while others remain in the body cause damage. The damage may take the form of sudden death or illness such as leukemia, anemia, cancer or congenital abnormalities.

The work of health physics organization in a nuclear installation as under.

a. Environmental control: - Checking of radiation levels periodically inside the plant and in the surrounding areas, specifying precautionary measure estimating the probable exposure of staff to radiation, analyzing the dangers of radiation, marking of zone etc.

b. Personnel Monitoring: - Measuring and recording, the radiation dose received by plant staff. Photographic films which are sensitive to radiations are used for this purpose.

Nuclear wastes and nuclear waste disposal.

Nuclear wastes associated with nuclear power plant

- Solid radio active waste (solid fission products)
- Pieces of discarded fuel elements cans
- Splitters
- Control rods
- Sludge from cooling ponds
- Gaseous effluents

Nuclear waste disposal

1.Solid fission products can be stored in boro silicate glass and storing this glass in leak tight

capsules. These capsules can be stored in deep salt mines. Sometimes containers filled with nuclear waste are sunk to the bottom of sea. Sludge from the cooling ponds is diluted enormously before discharging to sea.

2.Gaseous effluents are filtered and discharged into atmosphere

3.Biological monitoring: -Carrying out routine checks or medical conditions of workers.

Comparison between thermal power plant with nuclear power plant

	Thermal power plant	*Nuclear power plant*
1	Huge quantity of fuel is required	Less quantity of fuel is required
2	Transportation and storage of fuel becomes problem	There is no problem of transportation
3	These plants require large area for the same size of nuclear plants	Require less area
4	The fuel used is of less cost	The fuel is expensive
5	Low initial cost	High initial cost
6	Easy erection and commissioning	Erection and commission require greater technical skill
7	Heavy atmospheric pollution due to fuel combustion	No atmospheric pollution a there is no combustion
8	Disposal of thermal waste can be made easily	Disposal of nuclear waste requires greater care and skill
9	Well suitable for varying loads	Not suitable for varying loads
10	Output cannot be raised suddenly from zero to max level	Output can be raised suddenly from zero to max level
11	High operating cost	Less operating cost

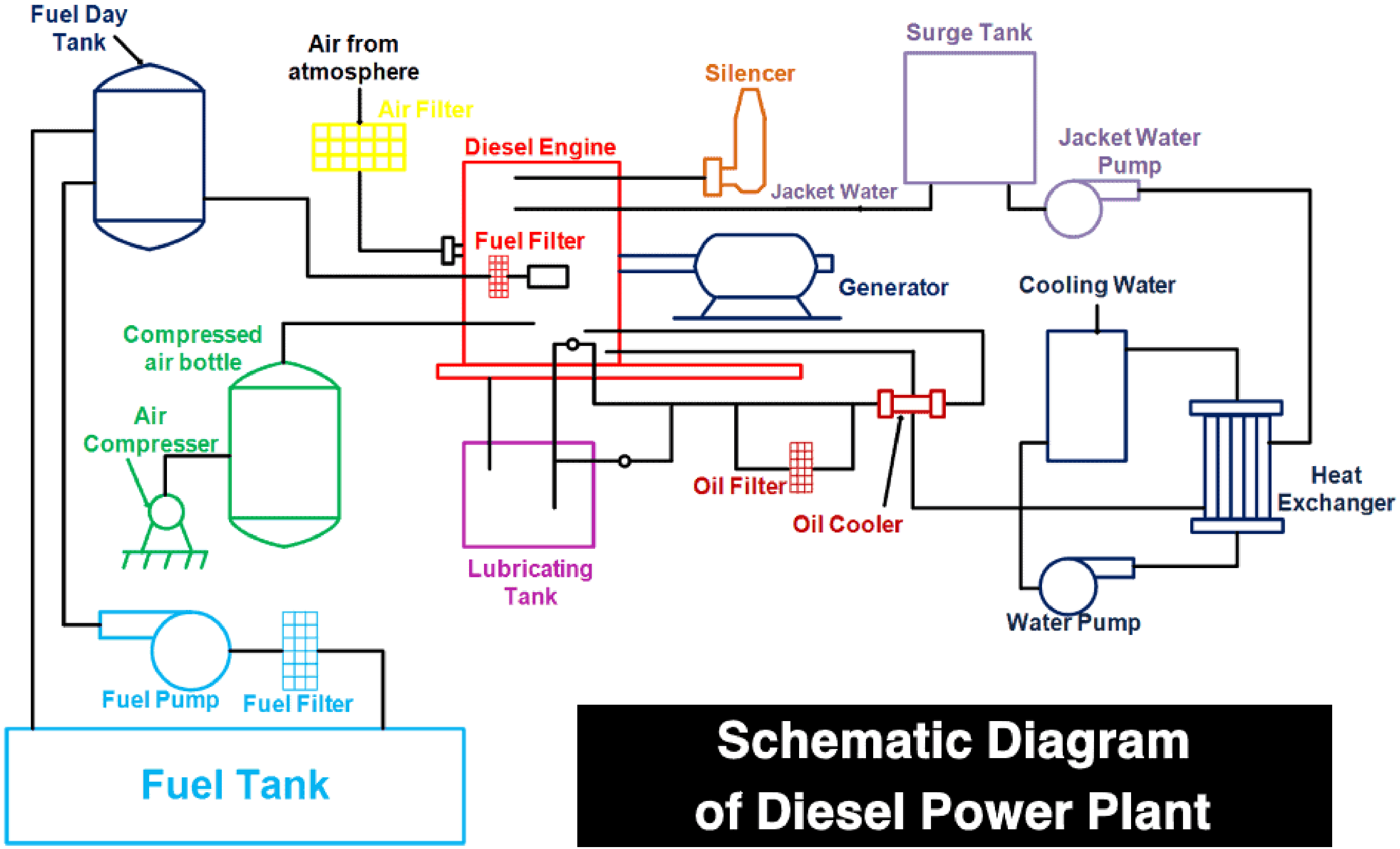
Comparison between thermal power plant with nuclear power plant.

	Thermal power plant	Nuclear power plant
1	Huge quantity of fuel is required	Less quantity of fuel is required
2	Transportation and storage of fuel becomes problem	There is no problem of transportation
3	These plants require large area for the same size of nuclear plants	Require less area
4	The fuel used is of less cost	The fuel is expensive
5	Low initial cost	High initial cost
6	Easy erection and commissioning	Erection and commission require greater technical skill
7	Heavy atmospheric pollution due to fuel combustion	No atmospheric pollution a there is no combustion
8	Disposal of thermal waste can be made easily	Disposal of nuclear waste requires greater care and skill
9	Well suitable for varying loads	Not suitable for varying loads
10	Output cannot be raised suddenly from zero to max level	Output can be raised suddenly from zero to max level
11	High operating cost	Less operating cost

DIESEL POWER PLANT

Generating station in which the diesel engine is used as a prime mover for generation of electricity is known as diesel power plant

DIESEL POWER PLANT



Schematic Diagram of Diesel Power Plant

Main Components of Diesel Electric Power Plant

1 Diesel Engine

It is the main component used in diesel electric power plant for developing mechanical power. This mechanical power is used to run the generator & produce electrical energy

2 Engine Fuel Supply System

It consists of Fuel Storage Tank, Fuel Filter or Strainer, Fuel Transfer Pump, Day Tank, Heaters & Connecting Pipes. First with the help of transportation facility available (road, rail etc.) the diesel fuel is stored in storage tank. Then this diesel fuel is transferred to day tank. Diesel required for 24 hours is stored in day tank. If the day tank is full or overflow occurs, then excessive diesel returned to storage tank. The filter or strainer is used to purify diesel. With the help of fuel transfer pump, the diesel is transferred to day tank.

3. Engine Air Intake System

This System includes air filters, air tank, compressor & connecting pipes. The air filters are used to supply the fresh air to diesel engine for the purpose of combustion. The compressor or Supercharger is used to increase the pressure of the air supplied to the engine. This will help to increase the output power.

4. Engine Exhaust System

These systems consist of silencers & connecting ducts. As the temperature of the exhaust gases is sufficiently high, it is used for heating the fuel oil or air supplied to the diesel engine. The exhaust gas is removed from engine, to the atmosphere by means of an exhaust system. A silencer is normally used in this system to reduce noise level of the engine.

5. Engine Cooling System

The Diesel Engine Cooling System Consist of coolant pumps, water cooling towers or spray pond, water treatment or filtration plant & Connecting Pipe Works. The heat produced due to internal combustion, drives the engine. But some parts of this heat raise the temperature of different parts of the engine. High temperature may cause permanent damage to the machine. Hence, it is essential to maintain the overall temperature of the engine to a tolerable level. Cooling system of diesel power station does exactly so.

6.Engine Lubrication System.

Engine lubrication system consists of lubricating oil pump, oil tanks, filters, coolers, purifiers & connecting pipes. This system provides lubricating oil to moving parts of the system to reduce the friction between them wear & tear of the engine parts.

7.Engine Starting System.

The function of starting system is to start the engine from stand still or cold conditions by supplying compressed air. For starting a diesel engine, initial rotation of the engine shaft is required. Until the firing start and the unit runs with its own power. For small DG set, the initial rotation of the shaft is provided by handles but for large diesel power station. Compressed air is made for starting.

Alternator(Alternator)

It converts mechanical energy into electrical energy

Advantages of Diesel Power Station

1. This is simple in design
2. Requires very small space.
3. It can also be designed for portable use.
4. It has quick starting facility
5. It can also be stopped as when required
6. Cooling is easy and required smaller quantity of water in this type power station.
7. Initial cost is less than other types of power station.
8. Thermal efficiency of diesel is quite higher than of coal.
9. It requires fewer operating staff.
10. The overall cost is much less than that of steam power station of same capacity.

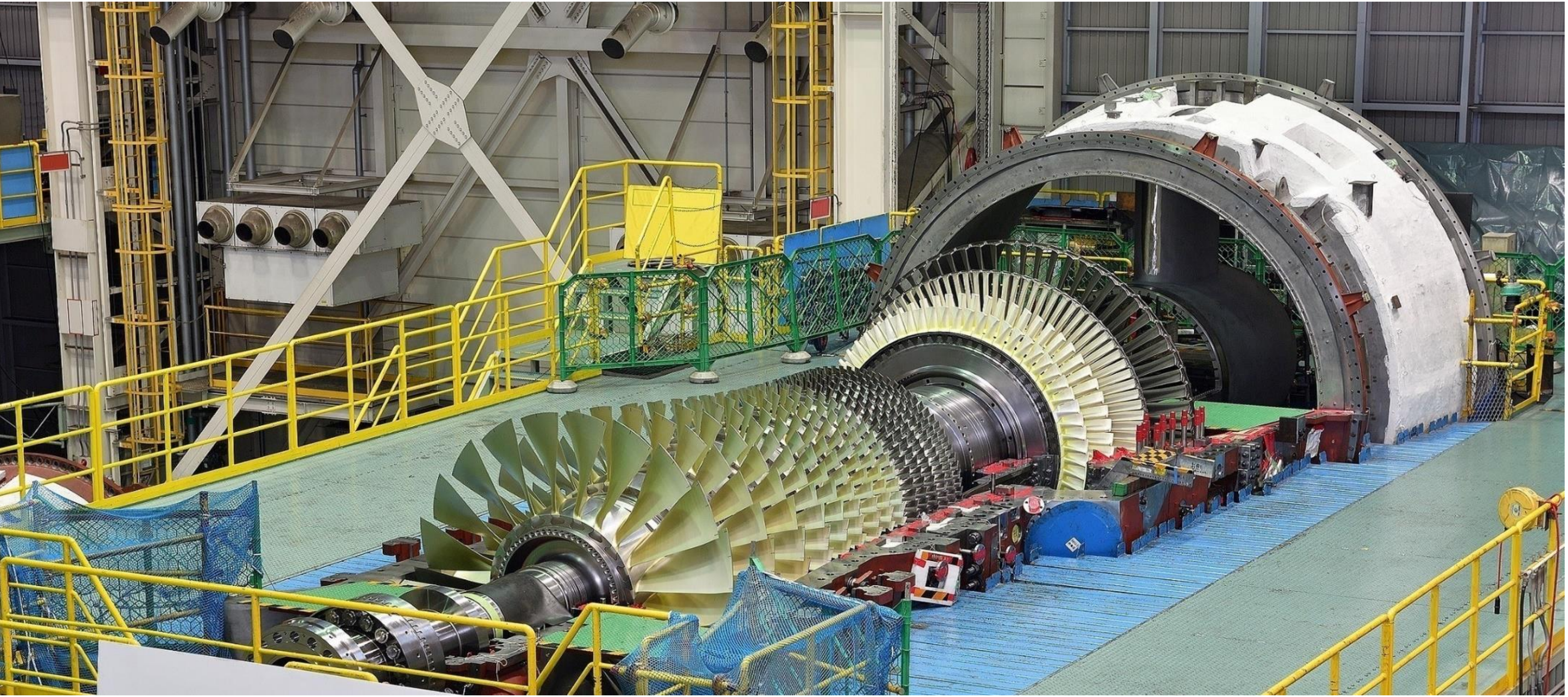
Disadvantages of Diesel Power Station

1. The cost of diesel is very high compared to coal.
2. Running cost of this plant is higher compared to steam and hydro power plants
3. Cost of lubricants is high.
4. Maintenance is quite complex and costs high.
5. The plant doesn’t work satisfactorily under overload conditions for a longer period.
6. The cost of lubrication is generally high.
7. The maintenances charges are generally high

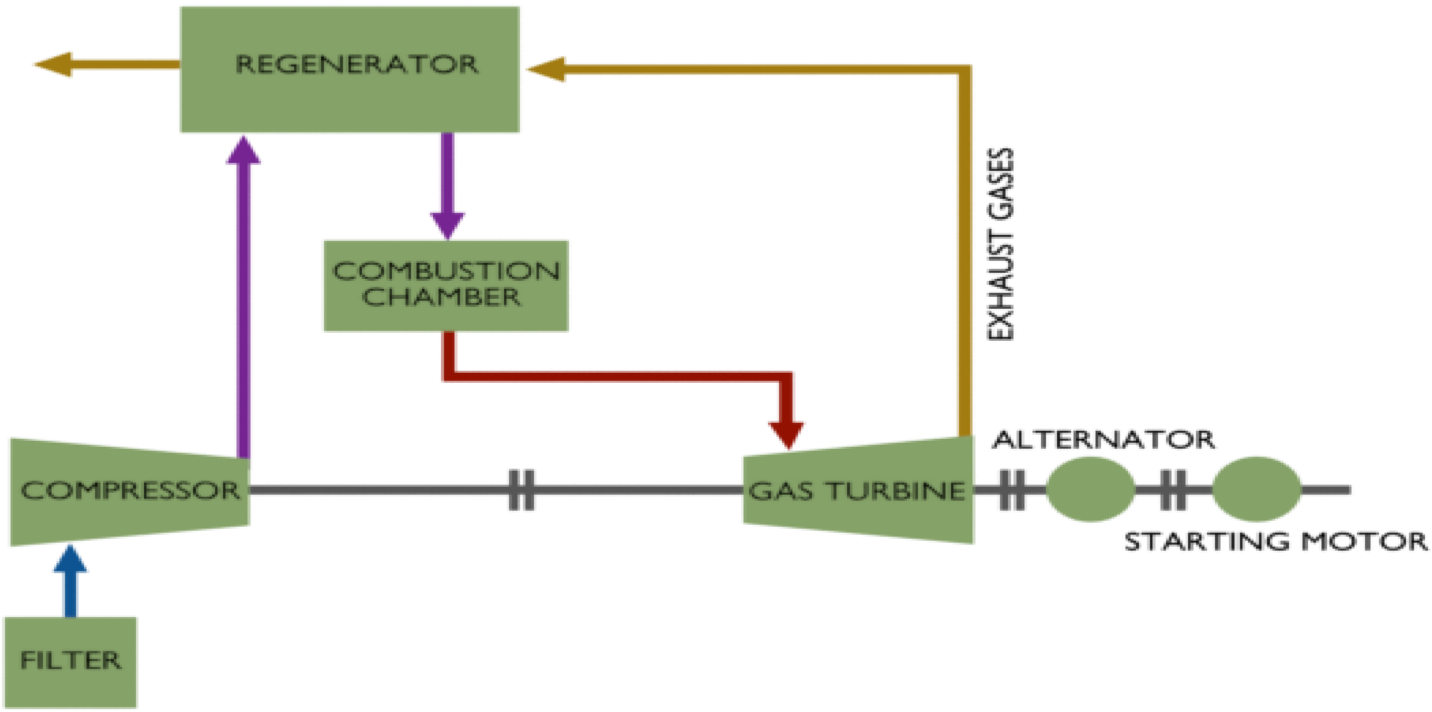
Gas turbine power plant

Generating station which uses gas turbine as the prime mover for generation of electrical energy is known as a gas turbine

Gas turbine power plant



Schematic diagram of a Gas turbine power plant.



Components of gas turbine power plant

1. compressor

The air at atmospheric pressure is drawn by the compressor via filter which removes dust from air. The air at high pressure is available at the output of the compressor

2. Regenerator

It is a device which recovers heat from the exhaust gases of the turbine and heat the compressed air form the compressor before entering the combustion chamber

3. Combustion chamber

In combustion chamber heat is added to the air by burning oil to increase the pressure of air.

4.Gas turbine

Gases at high pressure are passed to the gas turbine blades causing blade to rotate

5.Alternator

The alternator converts mechanical energy of gas turbine to electrical energy

6.Starting motor

Before staring the turbine, compressor has to be started. For this purpose, an electric motor operated by batteries is used

Advantages of Gas turbine plant

- Simple in design as compared to steam power plant
- For the same capacity the gas turbine power plant is much smaller in size
- Initial and operating cost is lower
- Requires less quantity of water
- Maintenance cost is less
- Can started quickly from cold conditions
- No stand by losses

Disadvantages of Gas turbine plant

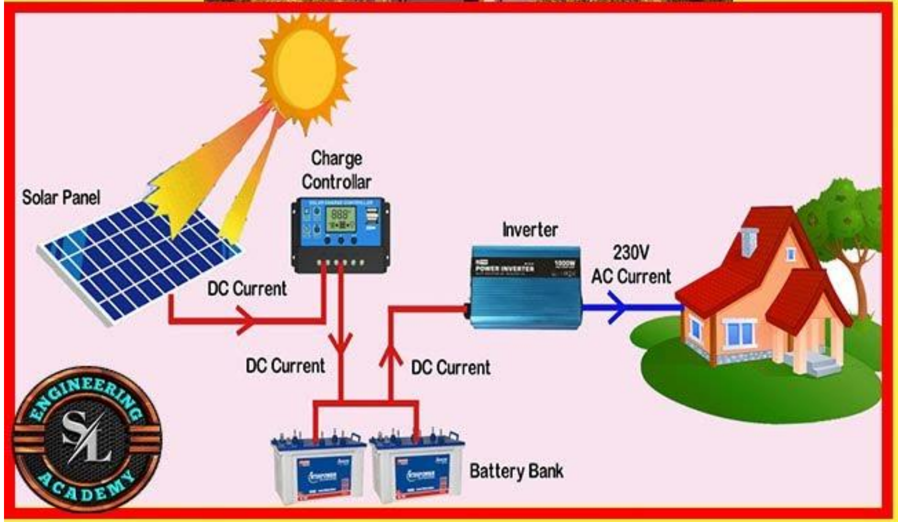
- There is problem of quick starting
- Efficiency is less
- The temperature of combustion chamber is high so life is comparatively reduced
- Lot of power developed by the turbine is used in driving the compressor hence the net output is low

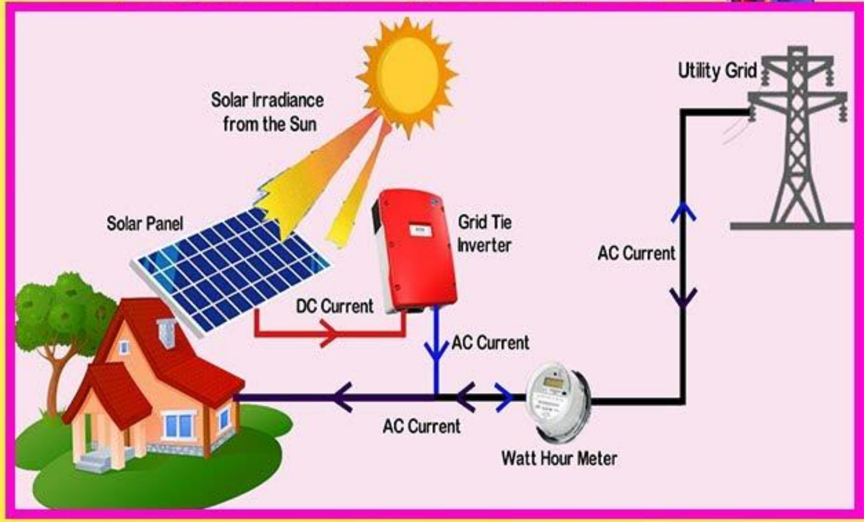
UNIT-3

- SOLAR PHOTOVOLTAIC SYSTEM
- WIND POWER PLANTS

Solar Panel Systems

Basic Knowledge





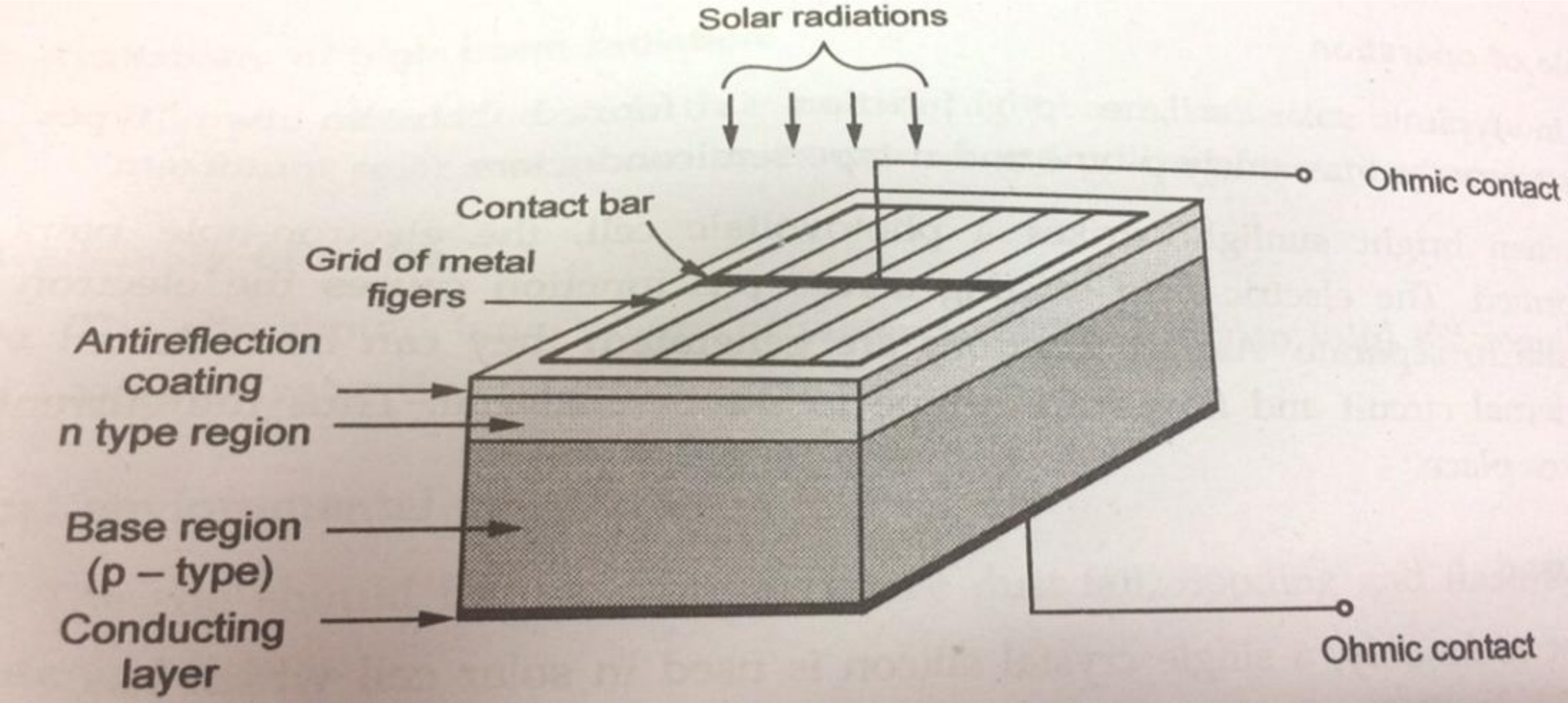
Solar Photovoltaic System

- In photovoltaic type of solar power plant, the light energy of the sun is directly converted into electrical energy.
- It uses a principle called photovoltaic effect for energy conversion.
- The photovoltaic effect is the creation of voltage or electric current in a material upon exposure to light.

Solar cell

The energy conversion device that converts sunlight into electricity by the use of photovoltaic effect is called as solar cell. A solar cell is also known as photovoltaic cell or photo electric cell.

Solar cell



Solar radiations
Ohmic contact
Contact bar
Grid of metal figers
Antireflection coating
n type region
Base region (p – type)
Conducting layer
Ohmic contact

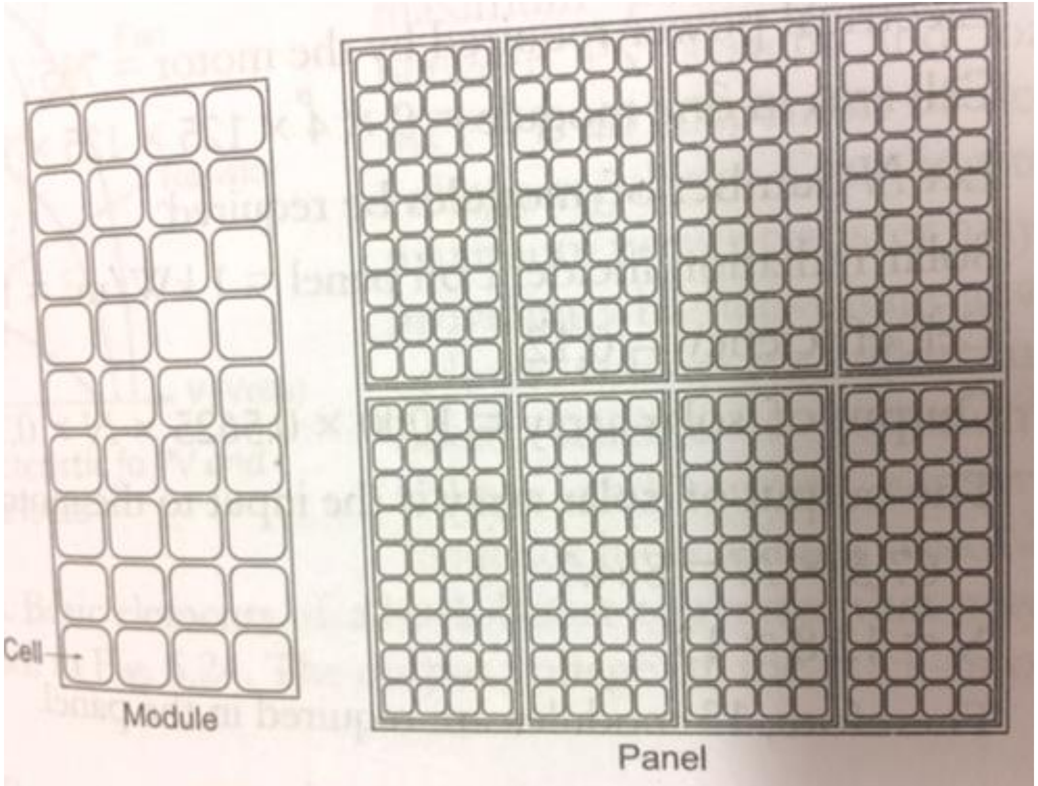
Construction of Solar cell

- Solar cell consists of a **pn** semiconductor junction.
- The **pn** junction of the solar cell is formed by diffusing a thin layer of n-type dopant on p- type base material using diffusion furnace.
- At the bottom of the cell, a metallic conducting layer is formed and a terminal is taken out.
- At the top of the cell, a metallic grid is formed and another terminal is taken out.
- The entire cell is encapsulated to protect from atmospheric degradations.

Working of Solar cell

- When a bright sunlight strikes the photovoltaic cell, the photons of the sunlight penetrate the junction and create electron-hole pairs.
- The barrier field existing across the **pn** junction causes the electron hole pair to separate.
- The free electrons thus created move towards the n-side and the holes move towards the p-side.
- So a voltage is set up which is known as photo voltage.
- When the cell is connected to an external circuit, the free electrons diffuse from n-side to p-side causing the electric current to flow.

Solar photovoltaic module

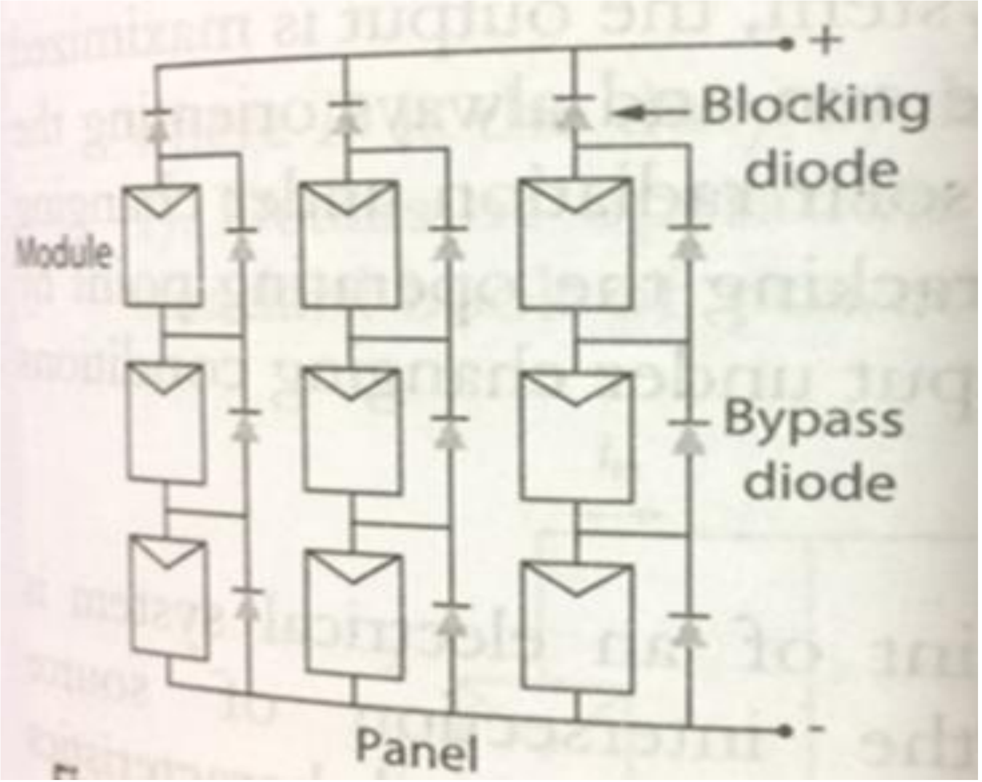


Cell, module and panel

Solar photovoltaic module

- The output voltage of a single cell is very small and is about 0.3 to 0.5V.
- To increase the voltage level, several cells are interconnected to form a photovoltaic module.
- The number of cells in a module depends on the module voltage.
- A 12V solar module consists of 33 to 36 cells. These cells are mounted on a durable back cover and are sealed with a transparent top cover to protect against dust, moisture, mechanical shocks and other outdoor conditions.

Solar photovoltaic array



Solar photovoltaic array

Several solar modules are interconnected in series and parallel to form solar arrays.

These modules are connected in series to increase the voltage and they are connected in parallel to increase the current output.

Materials Used in Solar Cell

- Silicon.
- GaAs (Gallium Arsenide)
- CdTe (Cadmium Telluride).
- $CuInSe_2$ (Copper Indium Diselenide)

Applications of Solar PV System

.

1. Terrestrial Applications

Water pumping sets for irrigation and drinking water supply.

- Rural electrification.
- Radio beacons for ship navigations at ports.
- Weather monitoring
- Railway signaling equipment
- Battery charging
- Street lighting

2. Agricultural applications

- Heating and cooling of commercial green houses.
- Drying grains, soybeans, peanut, tobacco, onions, fruits.

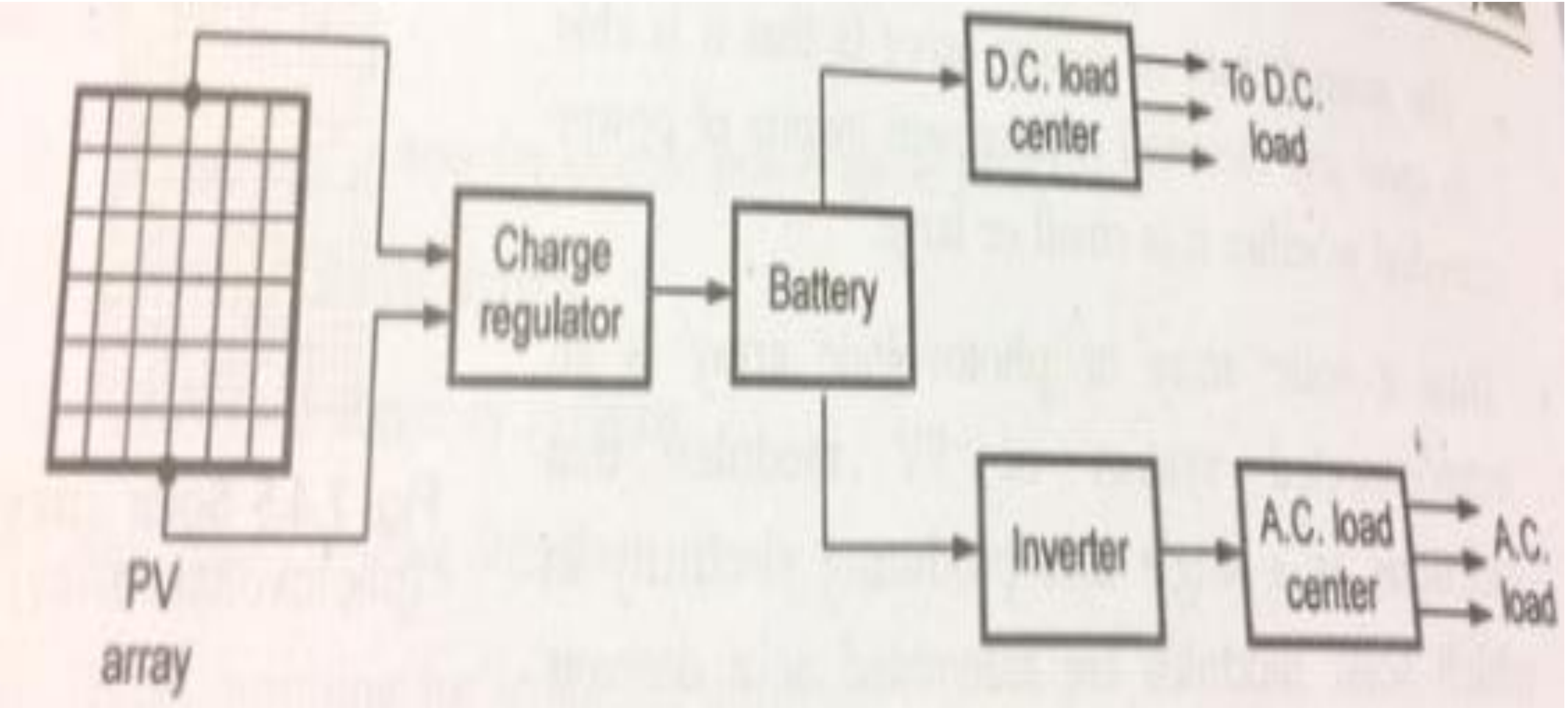
3. Industrial applications

- Distillation of water.
- Laundries, fabric drying, textile dying, paper industries, etc.,
- Food processing.
- Laminating and drying glass fibers.
- Picking in steel industries.
- Generation of electric power.

Classification of solar photovoltaic systems

- Stand alone solar photovoltaic system
- Grid interactive solar photovoltaic system
- Hybrid solar photovoltaic system

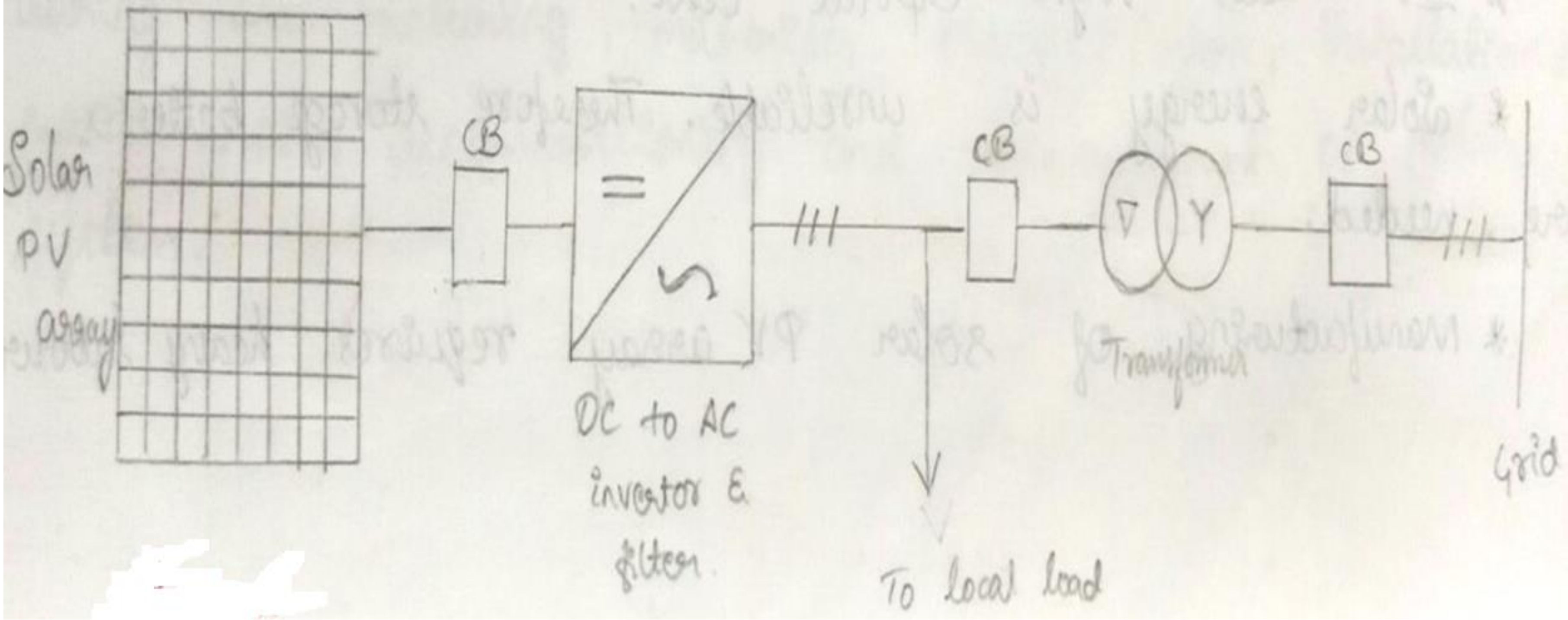
Stand alone solar photovoltaic system



Stand alone solar photovoltaic system

- It consists of photo voltaic array, charge regulator, battery, inverter, DC load centre and AC load Centre.
- The DC output of the PV array is connected to the battery through the charge regulator unit. The charge regulator consists of a blocking diode in series with the photovoltaic array.
- It prevents the battery from being discharged through the PV array at night when there is no sunshine.
- The blocking diode also prevents overcharging and discharging of battery and also protects the battery from short circuits.
- The battery gets charged from the DC output of the PV array.
- Battery output can be directly connected to the DC loads.
- For AC loads, the battery output is first connected to an inverter which converts DC to AC and then it is connected to AC load centre.

Grid interactive solar photovoltaic system



Grid interactive solar photovoltaic system

- In grid interactive solar photovoltaic system, all the excess power is fed to the central power grid.
- In this system, battery is not required because the supply of power is maintained from the grid during night when there is no sunshine.
- The DC power from the PV array is first converted to AC by the inverter
- AC power is fed to the grid after adjusting the voltage level using transformer.
- The circuit breakers are provided to disconnect the PV system from the grid during failure of utility supply.

Advantages of PV systems

- Solar energy is freely available in nature
- Direct conversion of sun light into electricity
- Absence of moving parts
- Low maintenance cost
- No environmental pollution
- Long life and highly reliable
- It can be easily started as no starting time is required
- It can be installed at load centers and hence saves cost of transmission and distribution

Disadvantages

- Solar power plants require large area of land
- It needs high capital cost
- Solar energy is unreliable and therefore storage batteries are needed
- Manufacturing of solar array requires heavy labour

Environmental impacts of solar photovoltaic system

- Unlike fossil fuel power generating systems, solar power systems have very low emissions of air pollutants such as Sulphur dioxide, nitrogen oxides, carbon monoxide and carbon dioxide during their operations.
- However, there are some negative impacts of solar power plants on the environment associated during construction, operation, and decommissioning.
- The following are the negative impacts of solar power plants
- **Land Use Impacts:** Solar power plants require relatively large area of land to generate electricity at utility scale. Such solar power plants result in land degradation. They may also affect vegetation, wildlife and result in habitat loss.
- **Impacts to Soil and Water Resources:** Construction of solar power plants requires clearing of large area of land. This results in alteration of drainage facilities, soil erosion and increased runoff.
- **Other Impacts:** The PV cell manufacturing process includes a number of hazardous materials. Workers in the manufacturing unit face risk of inhaling silicon dust. There can also be environmental contamination if the solar panels get damaged or improperly disposed upon decommissioning.
- **Global Warming Emissions:** Though there are no global warming emissions associated with generating electricity from solar energy, but there are global warming emissions during manufacturing, materials transportation, installation, maintenance, decommissioning and dismantlement of solar system.

WIND POWER PLANTS

What is Wind Energy ?

- Kinetic energy of air in motion is known as wind energy. The movement of air is caused because of uneven heating of earth's surface by the sun.

- Wind energy having speeds 7m/sec to 10m/sec is converted into mechanical energy with the help of wind turbines. By coupling generators to wind turbines electricity is generated.

Importance of wind energy

- Wind energy is clean, cheap and eco-friendly renewable source of energy. The only disadvantage of wind energy is that, it is dispersed, erratic and location specific.
- With modern blade materials, the life of wind turbine has exceeded 20 years. The installation cost is also less than conventional thermal power plant. Due to these reasons, the wind energy is gaining importance and is competing with conventional power sources.

Importance of wind energy

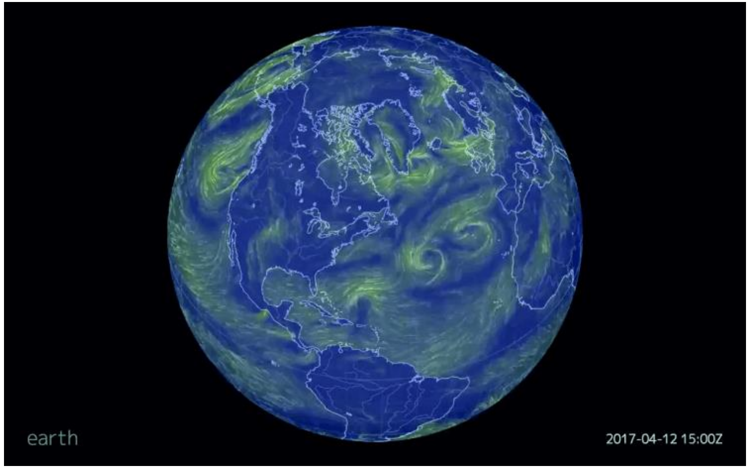
- Wind power generation capacity in India has significantly increased in recent years.
- India has total installed wind power capacity was 38.124 GW. It is the fourth largest installed wind power capacity in the world.

Eco friendly Electricity generation

Types of winds

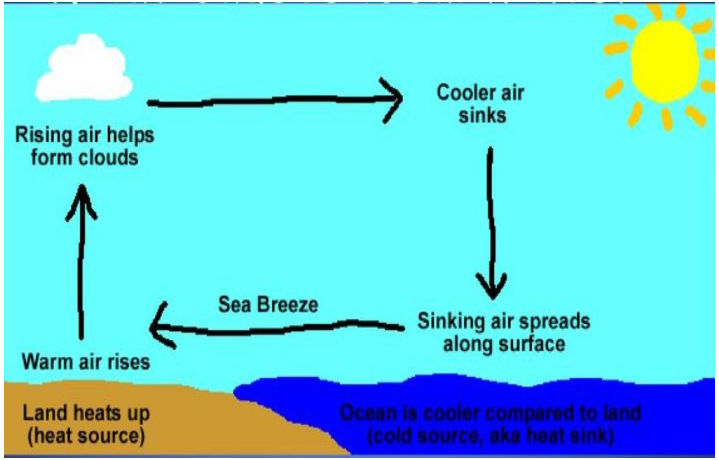
Wind is caused by uneven heating of earth's surface by the sun. There may be widespread circulation of wind called global winds and small area circulation called local winds.

Global winds



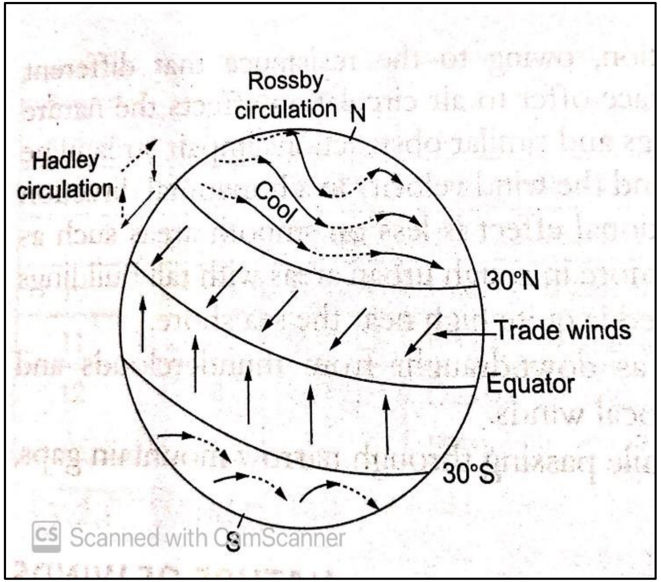
Courtesy:- https://www.thecoli.com/threads/a-mesmerizing-animated-interactive-map-visualizing-global-wind-patterns-in-calming-blues-and-greens.632537/

Local Winds



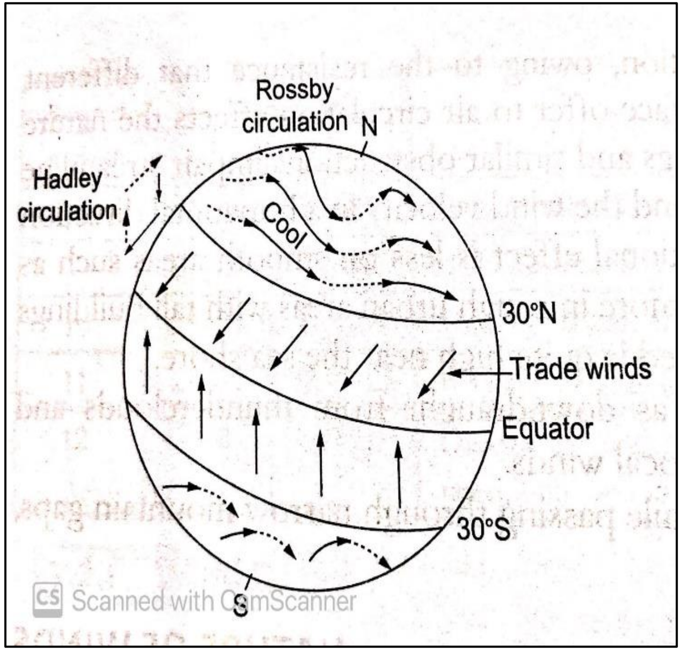
Courtesy:-https://slideplayer.com/slide/14854048/

Global winds



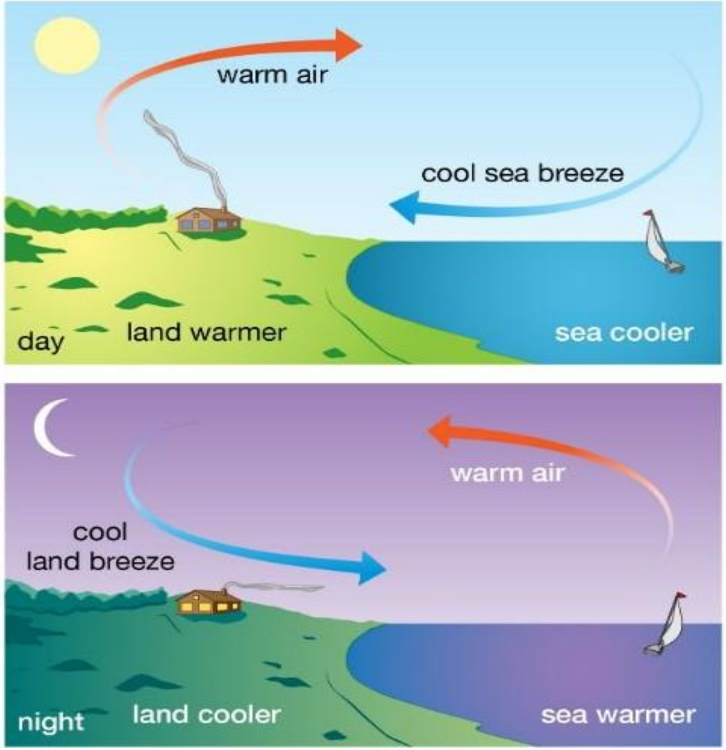
- Global winds are produced due to difference in heating of the earth at equator and polar regions.
- The solar radiation causes temperature at equator to be more than that of polar region.
- The hot air over the equator starts moving towards the poles and the cold air from the poles move towards the equator.
- This is known as Hadley circulation

Global winds



- Earth's rotation about its axis creates a force called Coriolis Force. This force causes the air current to bend towards west. These air currents are also known as trade winds.
- These winds form wavelike circulation near poles while transferring heat from hot air to cold air. This pattern is called as Rossby Circulation.

Local winds

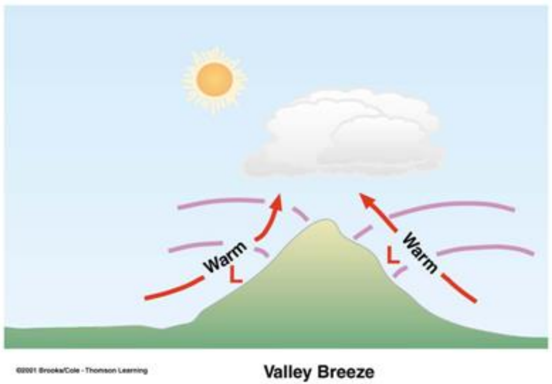


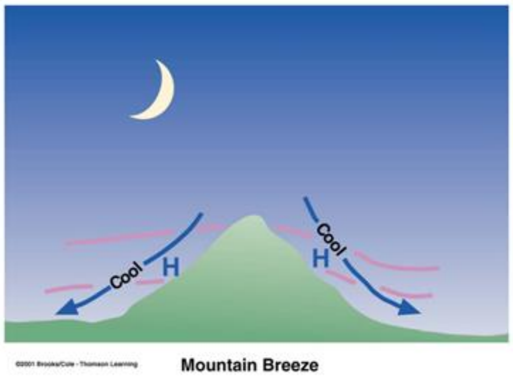
Local winds are produced due to uneven heating of land surface, water bodies and the hill slopes during day and night.

During the day, land becomes hotter than water. As a result cool heavier air blows from water bodies to the land.

At night, land cools rapidly than water. This causes cool air to blow from land to water bodies. This results in local winds.

Local winds





- Similarly, there is a difference in heating between land and hill slopes.
- During day, hill slopes heat up more than that of land. This causes cool air to blow from land to the hill slope.
- At night, hill slopes cool rapidly than land. This causes cool air to blow from hill slopes to land. This also results in local winds.

Revision

The following is (are) the classification of winds

(A) Global wind
(B) Local wind
(C) Both (A) and (B)
(D) None of the above

Ans. C. Winds are classified as Global and Local Winds.

Revision

Global Cold wind move from

(A) Polar to equatorial region
(B) Equatorial to polar region
(C) Equatorial to oceanic region
(D) Oceanic to Equatorial region

Ans. A. Global cold wind move from polar to equatorial region

Revision

____ force is responsible for forcing the global winds towards westernly direction.

(A) Coriolis
(B) Gravitational
(C) Centripetal
(D) Centrifugal

Ans. A. Coriolis force is responsible for forcing the global winds towards western direction

Revision

Uneven heating occurs on land surface and water bodies due to _____

(A) Air Currents

(B) Solar radiation

(C) Lunar eclipse

(D) None of the above

Ans. B. **Uneven heating occurs on land surface and water bodies due to solar radiation**

Nature of Wind

The Beaufort scale gives the description of the nature of the wind. The description of wind based on Beaufort numbers is given in table

Beaufort number	**Wind speed (m/s)**	**Wind description**	**Wind effect**
1	0.4 – 1.8	Very light	Smoke moves
2	1.8 – 3.6	Light	Leaves move
4	5.8 – 8.5	Moderate	Small branches and turbine vanes start moving
7	14 - 17	Strong	Whole tree moves
8	17 – 21	Very strong	Tree branches break

Factors to be considered for site Selection of wind power plant

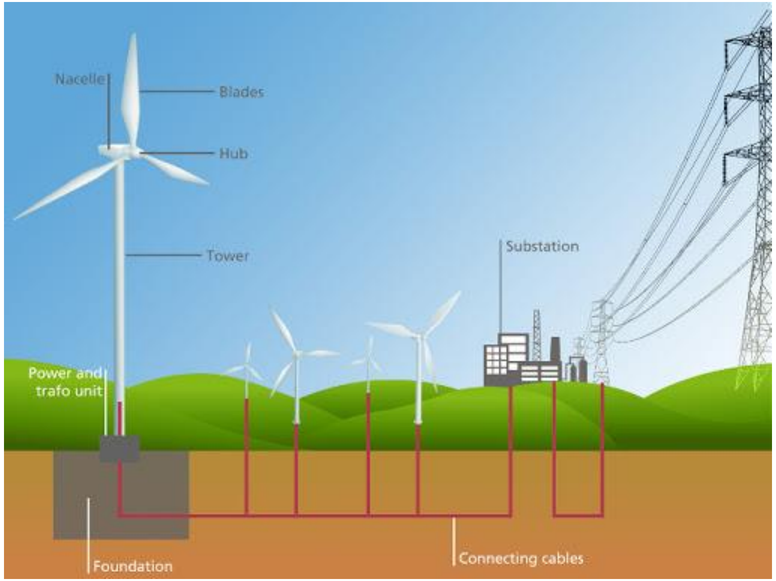
- The site selected for wind power plant should have an average wind speed of 7 to 10 mts/sec.
- It is desirable to install wind power plant at higher altitudes because the wind tends to have higher velocities at higher attitudes.
- The land cost should be low.

Factors to be considered for site Selection of wind power plant

- The ground condition of the site should be such that strong foundation for tower is possible.
- Icing problem, salt spray or blowing dust should not be present at the site as they affect the turbine blades.

Factors to be considered for site Selection of wind power plant

- The land should be accessible by road or rail.
- The site should be near the load center to reduce transmission cost and losses.



The following factor(s) affects the distribution of wind energy

(A) Mountain chains

(B) The hills, trees and buildings

(C) Frictional effect of the surface

(D) All of the above

Ans. D. All of the above

Revision

The wind intensity can be described by

(A) Reynolds number

(B) Mach number

(C) Beaufort number

(D) Froude number

Ans. C Beaufort number

Revision

What type of energy is wind energy?

(A) Renewable energy

(B) Non-renewable energy

(C) Conventional energy

(D) Commercial energy

Ans. A. Renewable energy

WIND TURBINE

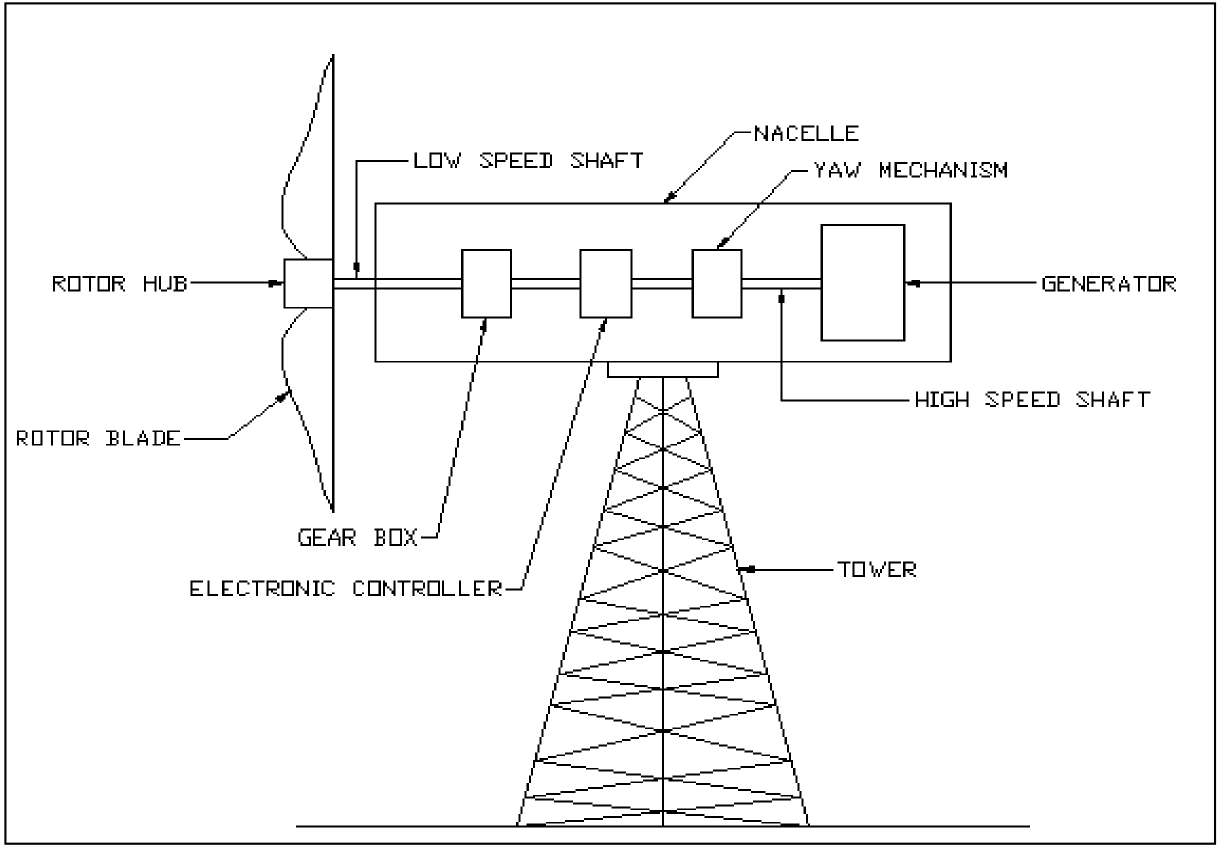
Classification of wind turbine generator

Wind turbine generators are classified as:

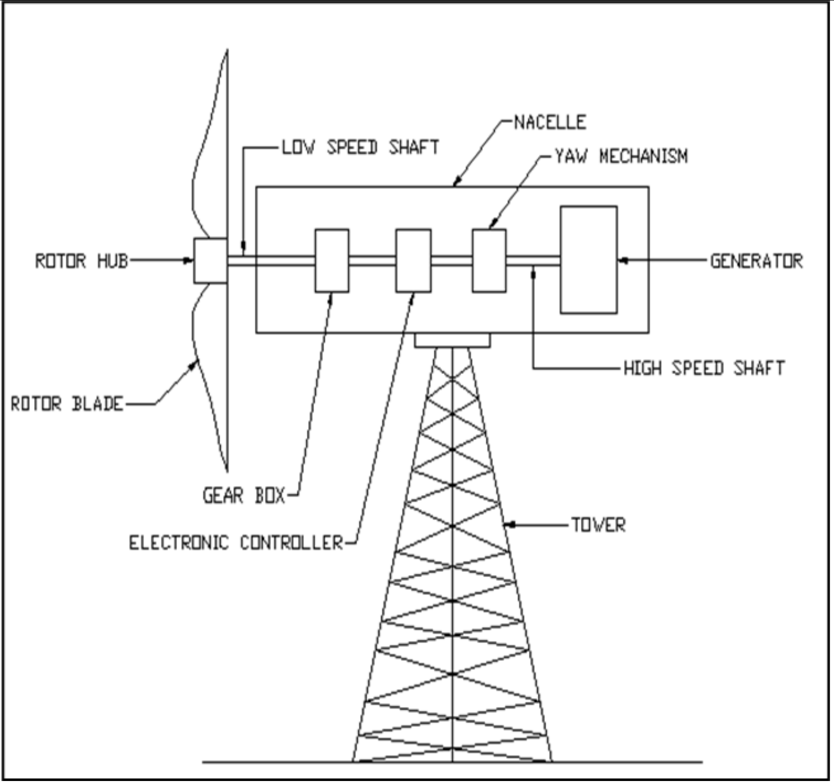
A. Horizontal axis wind turbine generator.
B. Vertical axis wind turbine generator.

HORIZANTAL AXIS WIND TURBINE

Horizontal axis wind turbine generator:

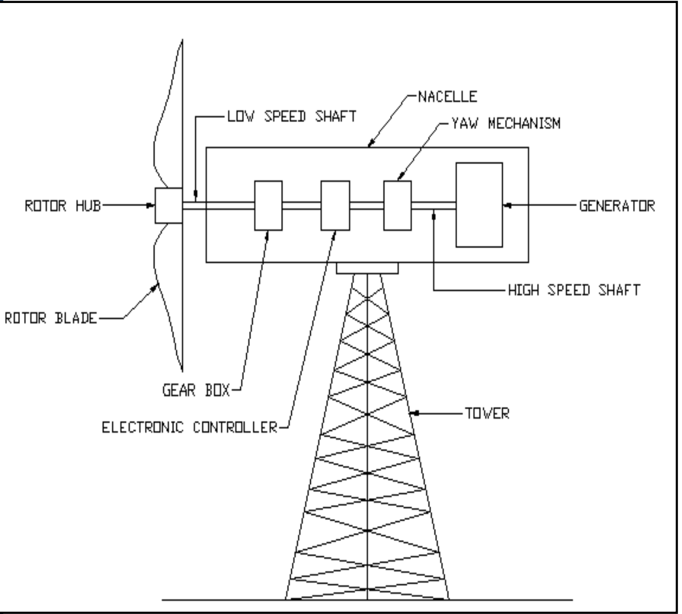


Horizontal axis wind turbine generator



- Horizontal axis wind turbine is the commonly used type of wind turbine.
- In this turbine shaft is mounted horizontally parallel to the ground.
- All the components are mounted on a tower of about 80m height.

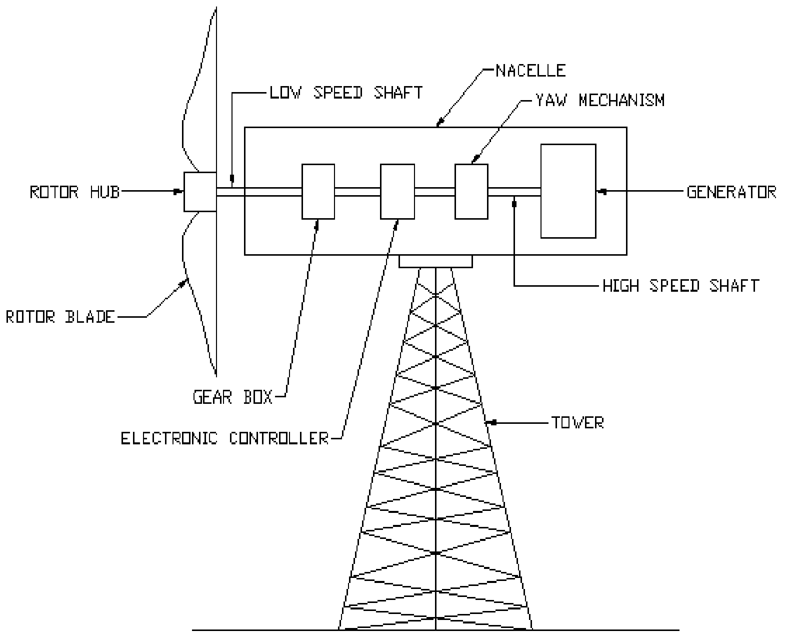
Horizontal axis wind turbine generator



Rotor blades: Rotor blades are used to convert the kinetic energy of wind into mechanical energy. These blades are made up of fiber glass-reinforced polyester or wood-epoxy. About 2 or 3 blades are mounted on the rotor hub.

Nacelle: A housing which contains all the components which are essential to operate the turbine is called a nacelle. It is fitted at the top of a tower and includes the gear box, low- and high-speed shafts, generator, electronic controller, yaw mechanism and brakes.

Horizontal axis wind turbine generator:

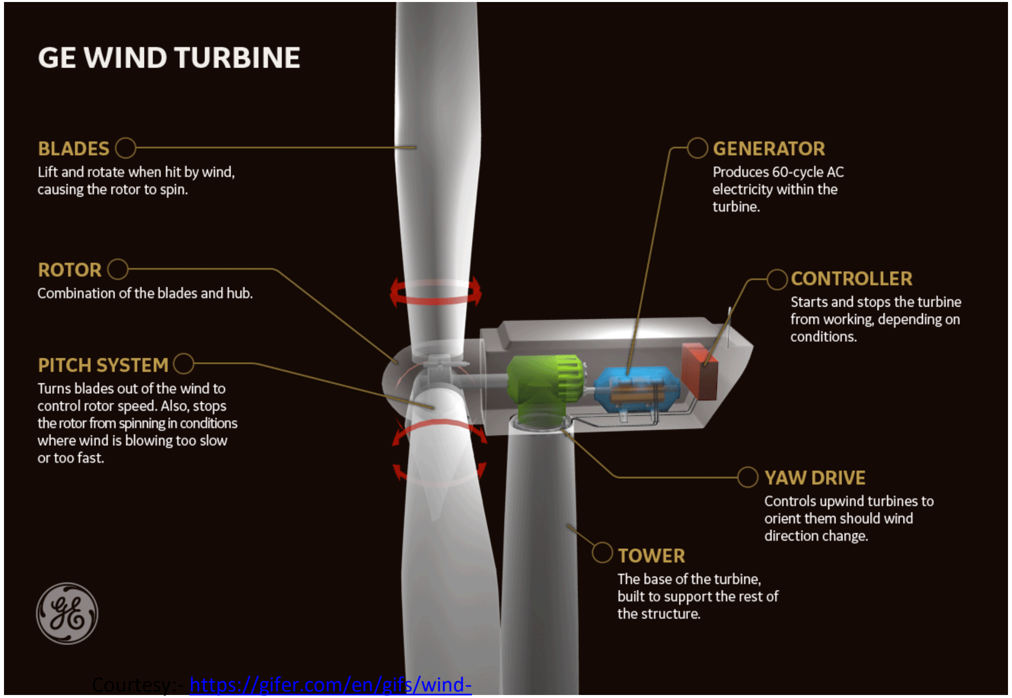


Shaft: Rotational energy of the wind turbine is transferred to the electric generator using shaft.

Gear box: Gear box increases the speed of the turbine shaft from 30 – 60 rpm so that it matches with generator speed of about 1000 – 1800 rpm.

Horizontal axis wind turbine generator

Yaw mechanism: Yaw mechanism aligns the rotor with the direction of wind to capture maximum wind energy.



Courtesy:- https://gifer.com/en/gifs/wind-turbine

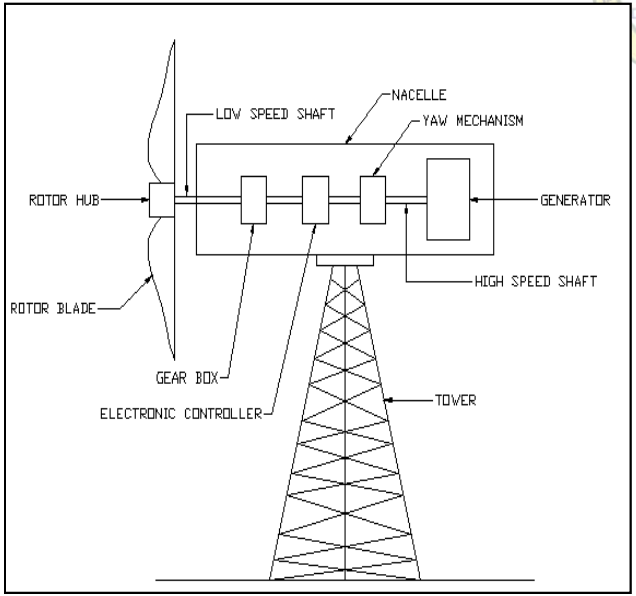
Horizontal axis wind turbine generator:

Brakes: Brakes stop the rotation of shaft in case of overload or system failure.

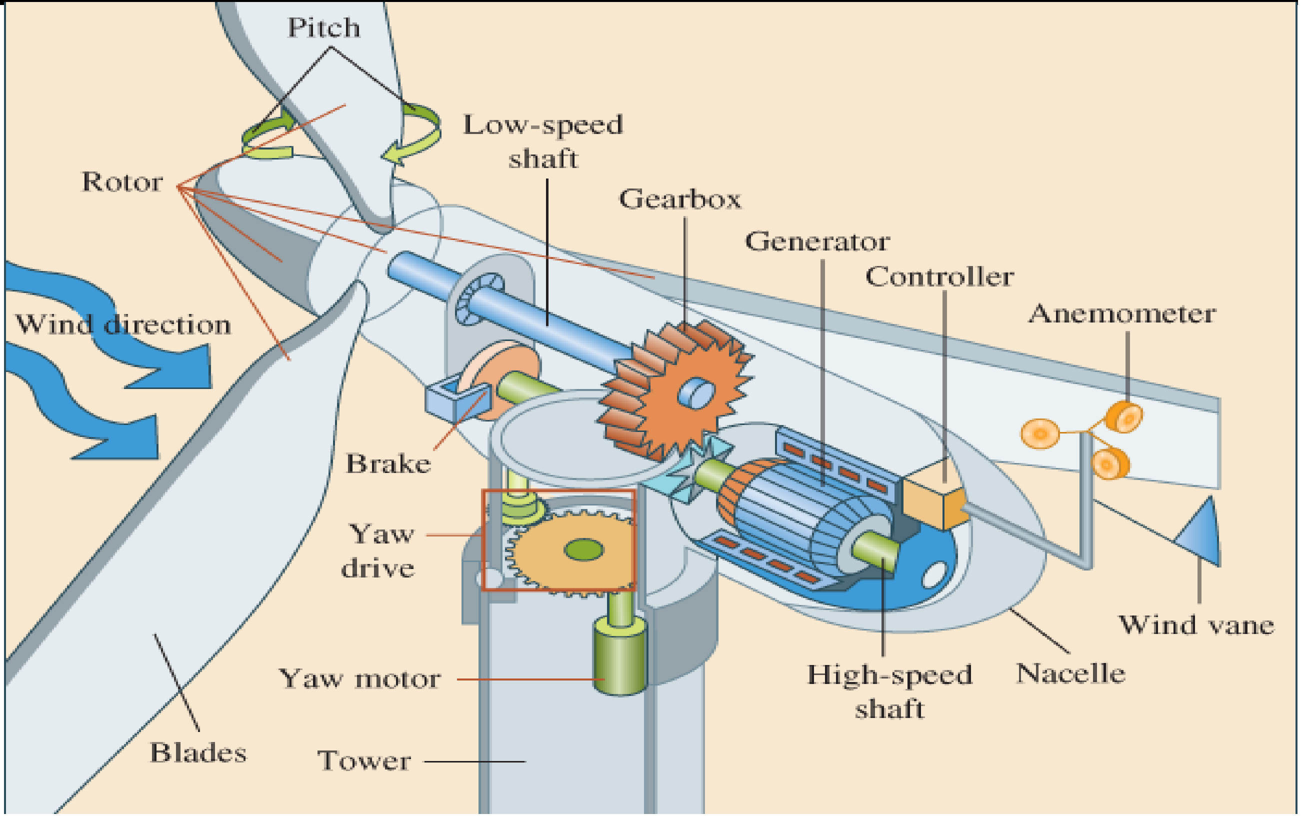
Electronic controller: It controls the yaw mechanism by sensing the wind speed and wind direction. It also gives signal to the brakes to shut down the turbine in case of malfunction.

Generator: Generator converts rotational energy of the shaft into electrical energy.

Tower: Tower supports the entire set up at higher elevation so that blades can freely rotate away from the ground.



Horizontal axis wind turbine generator

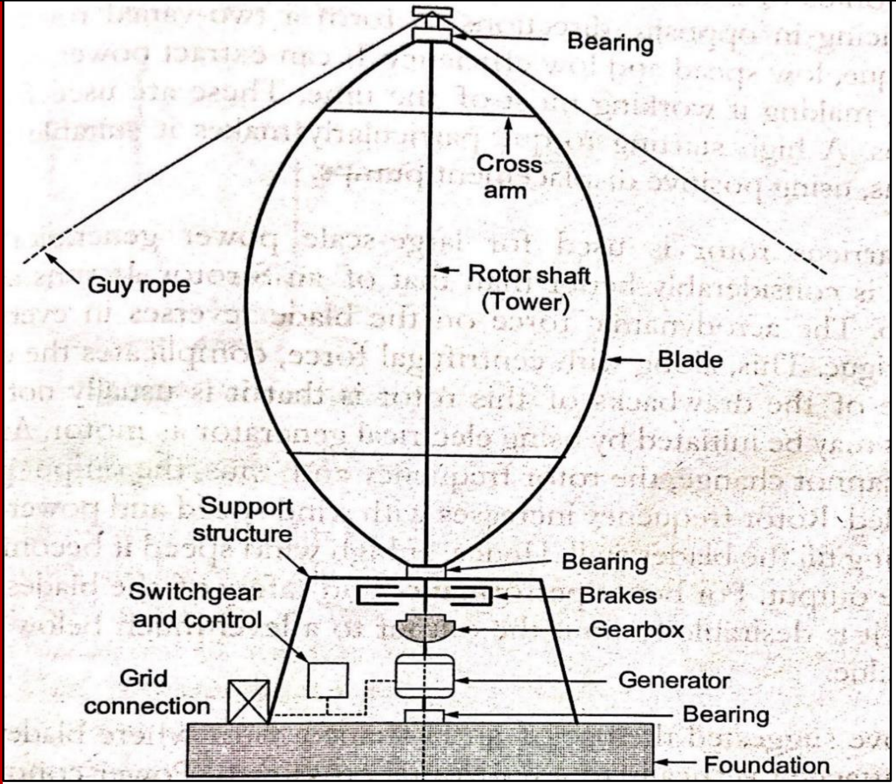


Courtesy:- https://gifer.com/en/gifs/wind-turbine

Vertical axis wind turbine generator

. In this turbine, the rotor turbine is perpendicular to the ground.

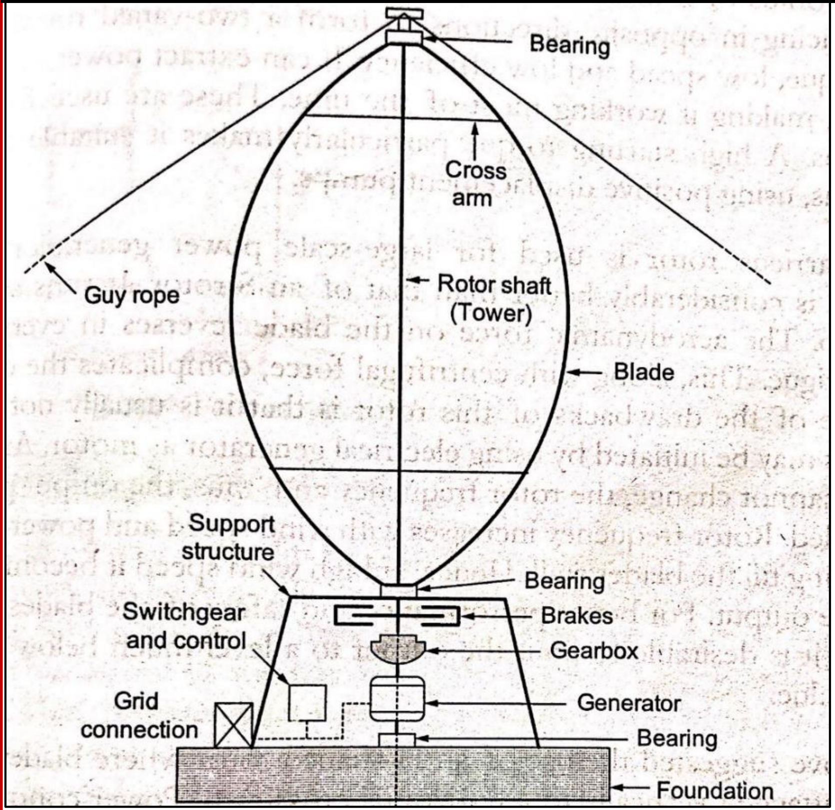
Vertical axis wind turbine generator



Rotor shaft: The vertical rotor shaft is mounted between the top and bottom bearings above the support structure. The upper part of the rotor shaft is supported by guy wires. The height of the rotor shaft is around 100m.

Blades: The rotor shaft has two or three thin curved blades which converts wind energy into mechanical energy. The blades can accept wind from any direction and therefore it does not require yaw mechanism.

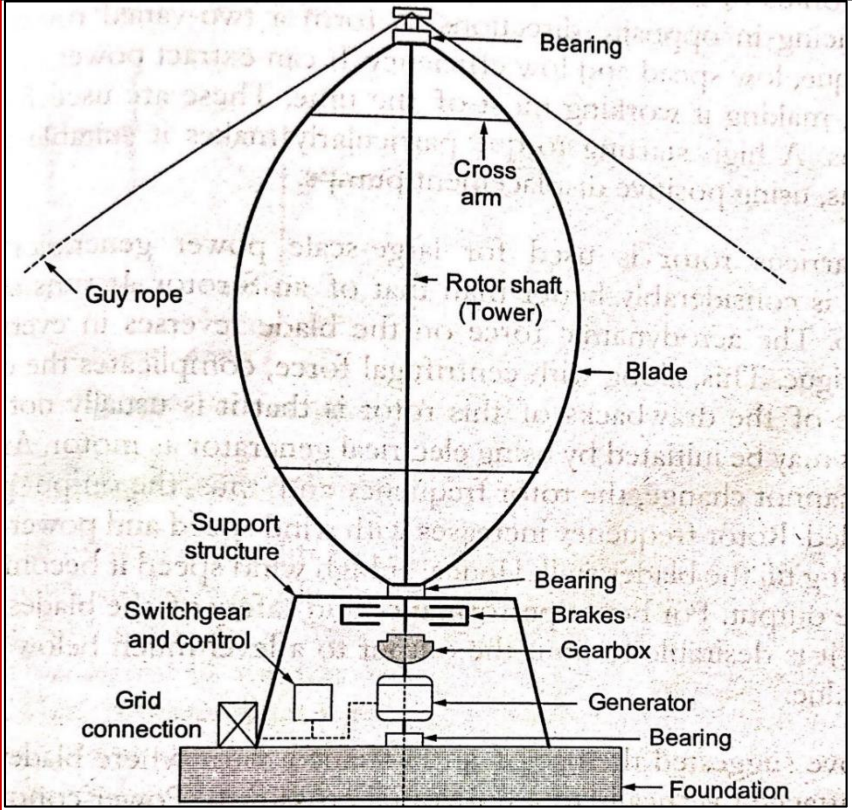
Vertical axis wind turbine generator:



Support structure: The support structure is provided at the ground and it has gear box, brakes, generator and switch gear controls.

Gear Box: The gear box increases the speed of the turbine shaft from 30-60 rpm to match with generator speed of 1500-1800 rpm.

Vertical axis wind turbine generator:



Brakes: Brakes stop the rotation of shaft in case of overload or system failure.

Generator: Generator converts rotational energy of the shaft into electrical energy. The electrical energy is fed to the grid through switch gear control.

Revision

The function of Yaw mechanism is to

(A) Aligns the rotor with the direction of wind

(B) Protect the turbine

(C) Decide the Beaufort number

(D) Act as the support structure

Ans. A Aligns the rotor with the direction of wind

Revision

What is the function of the gear box?

(A)To stop the rotation of the shaft in case of overload

(B) To increase the speed of the turbine shaft.

(C) To decrease the speed of the turbine shaft.

(D) Commercial energy

Ans. (B) To increase the speed of the turbine shaft.

Comparison between horizontal axis and vertical axis wind turbine generator

Sl No	Horizontal axis wind turbine	Vertical axis wind turbine
1	In this turbine, the shaft is mounted horizontally parallel to the ground.	In this turbine, the shaft is mounted on a vertical axis perpendicular to the ground.
2	It uses tower for support.	It uses guy wires for support.
3	Gear box and generator are mounted above the ground on a tower.	Gearbox and generator are mounted at ground level.
4	Installation and maintenance are difficult as the equipments are at height.	Easy installation and maintenance as all the equipments are at ground level.

Comparison between horizontal axis and vertical axis wind turbine generator

Sl No	Horizontal axis wind turbine	Vertical axis wind turbine
5	Yaw mechanism is required to align the blades to face the wind.	Yaw mechanism is not needed as the rotor rotates for any wind direction.
6	Turbine rotor is at higher elevation, so higher wind speed and higher efficiency.	Turbine rotor is almost at ground level, so lower wind speed and lower efficiency.
7	It takes little ground space.	It takes larger ground space.
8	Energy output is more.	Energy output is less.

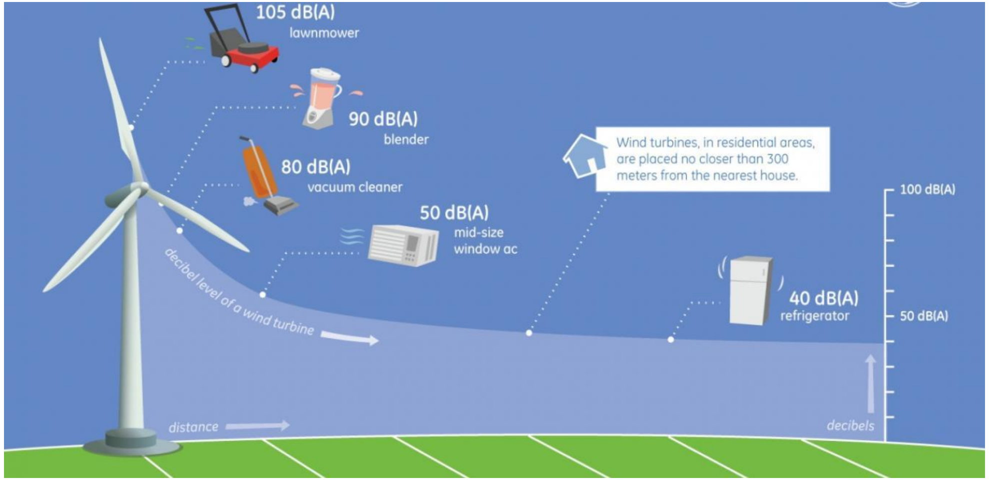
Environmental Impacts of Wind Power Plant:

Land use impact: Wind turbine installations use a large land area. About one acre of land per megawatt is permanently disturbed. The remaining land can be used for other purposes like livestock grazing, agriculture, highways, etc.

Environmental Impacts of Wind Power Plant:

Noise impact: Noise from wind turbines is caused from two sources:

- Mechanical noise caused by the gearbox and generator
- Aerodynamic noise caused by interaction of the turbine blades with the wind.



Environmental Impacts of Wind Power Plant:

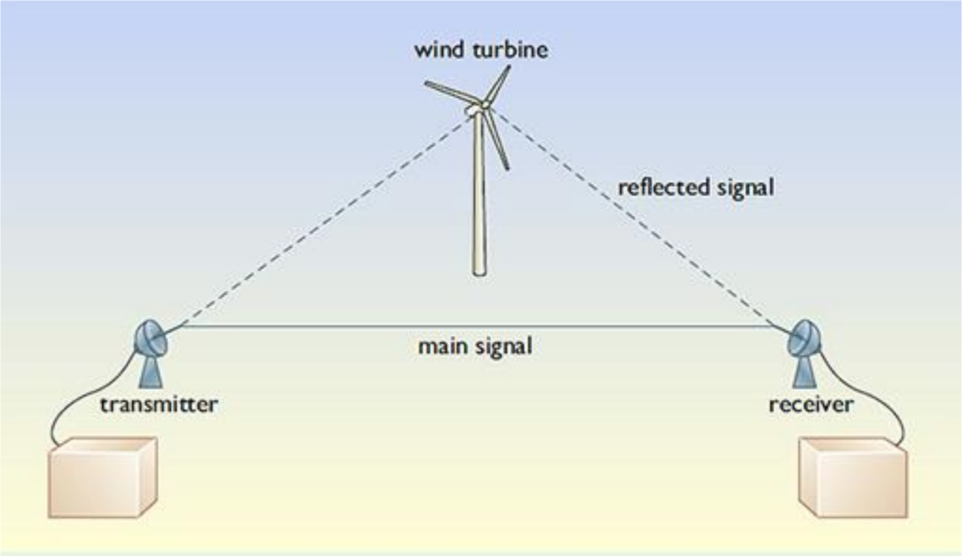
Visual Impacts: Due to their height, wind turbines are highly visible structures in any landscape. They may result in aesthetic impacts to the landscape.

Environmental Impacts of Wind Power Plant:

Bird and bat mortality: Bird and bat deaths by colliding with rotor blades are one of the most biological impacts of wind turbines. The risk of bird collisions can be reduced by increasing the visibility of rotor blades and by keeping the bird migration paths free.

Environmental Impacts of Wind Power Plant:

Interference with communication: Another impact of wind turbines is that they interfere with radar and telecommunication facilities.



Environmental Impacts of Wind Power Plant:

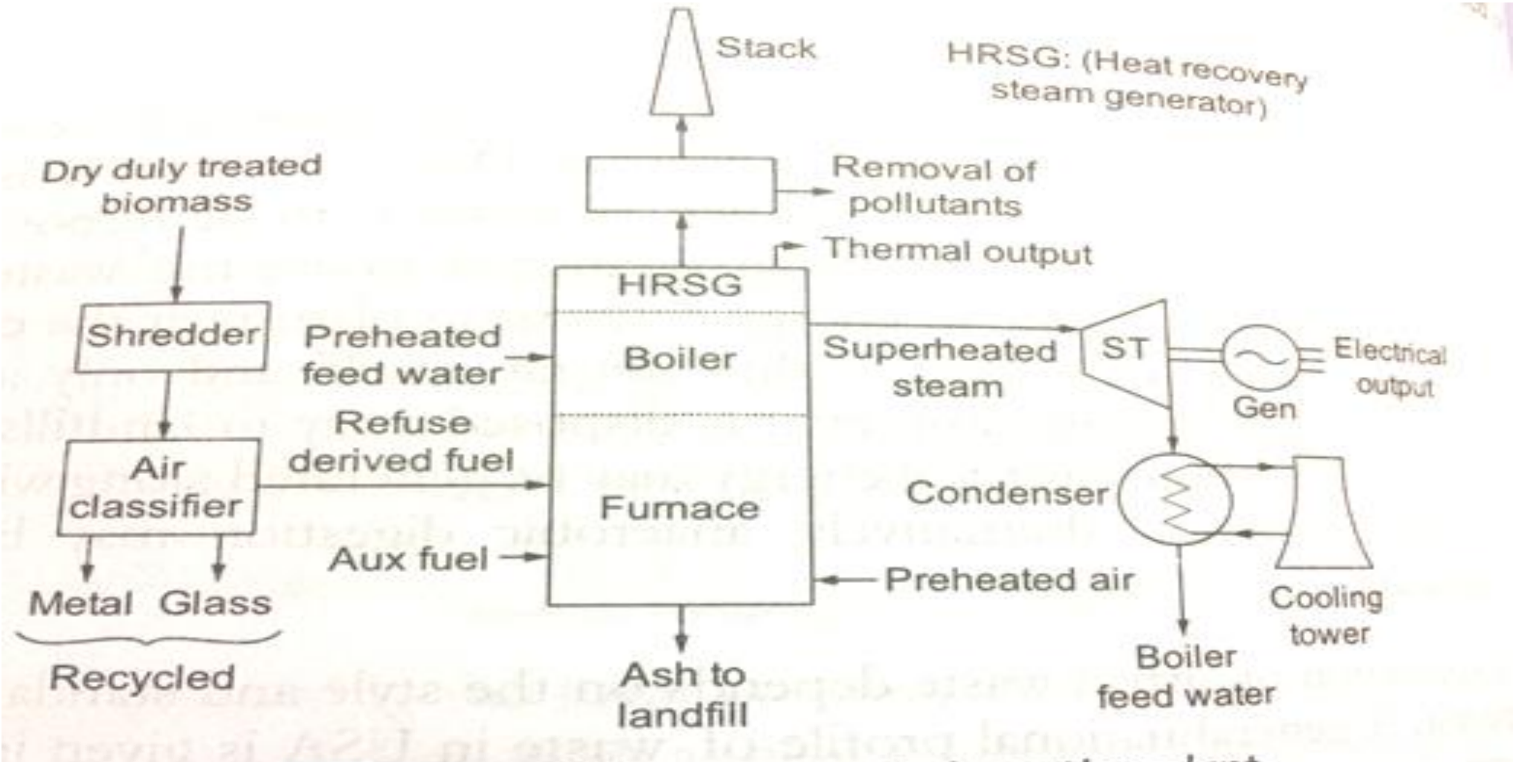
Other impacts: Wind turbines do not produce global warming emissions during operation. But there are certain emissions produced during manufacturing of turbines, transportation, commissioning, maintenance and decommissioning.

UNIT 4
Biomass Power, Fuel cell and Hybrid PV systems

Urban waste to energy conversion- Block diagram municipal solid waste (MSW) to energy incineration plant

- Municipal Solid Waste (MSW) is a solid waste generated by households, commercial and industrial operations.
- Disposal of MSW is major problem in big cities, where large quantity of waste has to be disposed far away from city centres.
- The solution for this problem is to use MSW incineration plant.
- Here the waste biomass is used as an energy source for electricity generation for the city itself.
- The small residue of used biomass (ash) can be disposed in the landfills.

Block diagram municipal solid waste (MSW) to energy incineration plant



MSW to energy incineration plant

Municipal solid waste (MSW) to energy incineration plant

- The dry biomass is torn (shredded) into small pieces of 2.5 cm in diameter.
- The air stream separates the lighter refuse derived fuel (RDF) from the heavier metal and glass pieces.
- These glass and metal pieces can recycled and reused.
- The RDF thus obtained is burnt in a furnace at about 1000^0C to produce steam in the boiler.
- The combustion process may be assisted by using auxiliary fuel if needed.
- The superheated steam thus obtained from the boiler is used to run steam turbine coupled with an alternator to generate electricity.
- The heat recovery steam generator (HRSG) extracts maximum possible heat from the flue gases to form thermal output. The flue gases are then discharged into atmosphere through the stack after removing pollutants such as particulate matter and oxides of nitrogen and sulphur.
- The ash is removed and disposed in the landfills.

Bio Energy-biomass and sources, conversion process.

Sources

Biomass is a renewable energy resource derived from the carbonaceous waste of various human and natural activities.

It is derived from numerous sources, including the by-products from the timber industry, agricultural crops, raw material from the forest, major parts of household waste and wood.

conversion process

Biogas is produced by the anaerobic digestion or fermentation of biomass in the presence of microorganisms and moisture and in the absence of oxygen at temperature of 35-70^{0}C.

.

Importance of biomass energy and its scope

- Biomass is a renewable energy resource derived from the carbonaceous waste of various human and natural activities. It is derived from numerous sources, including the by-products from the timber industry, agricultural crops, raw material from the forest, wastE and wood.

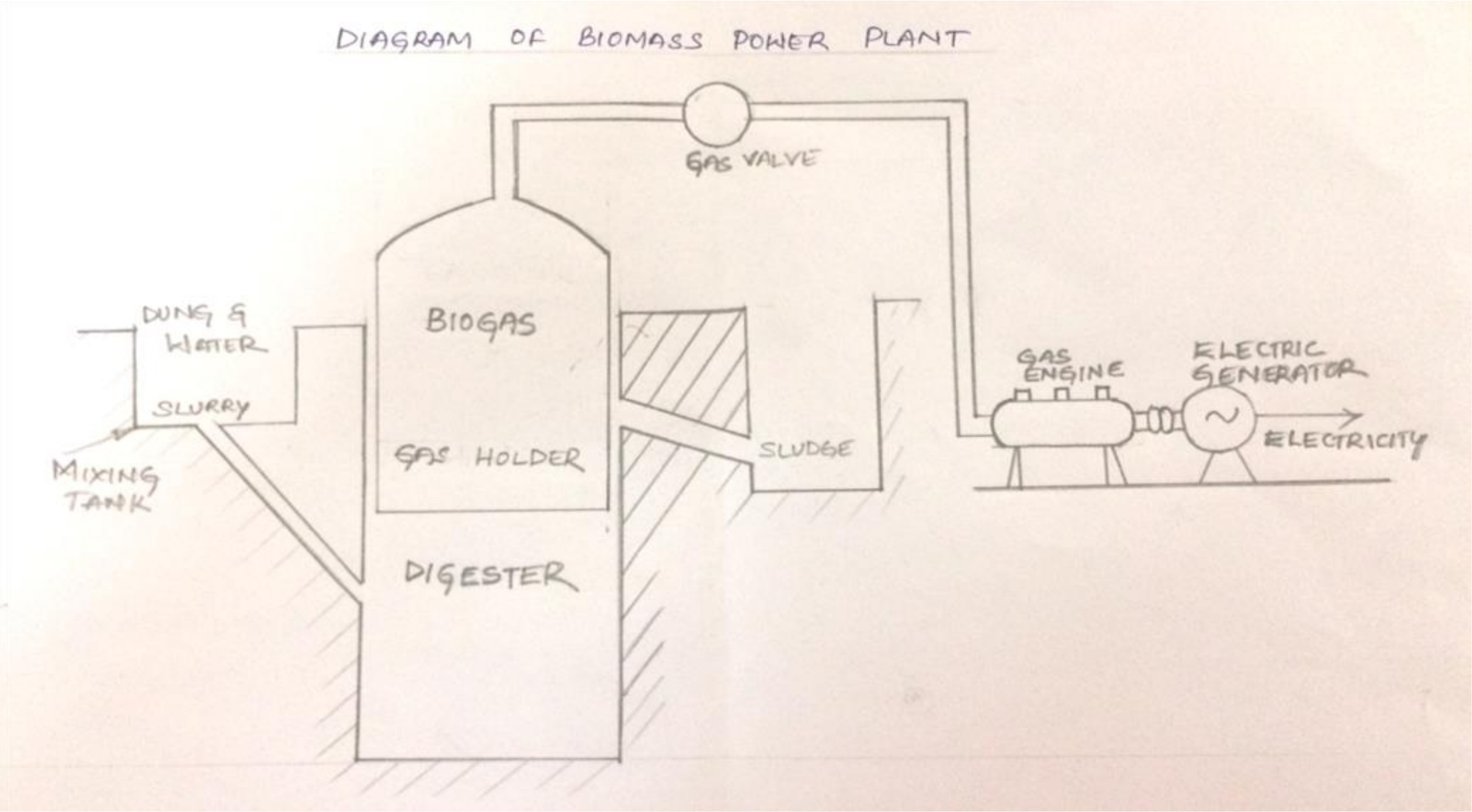
- Biomass is a renewable energy resource and it does not add carbon dioxide to the atmosphere. It can be used to generate electricity with the same equipment or power plants that are now burning fossil fuels. In India, biomass fuel is the most important fuel used in over 90% of the rural households and about 15% of the urban households. Biomass can be used directly as fuel instead of coal in the traditional furnaces or it can also be converted into a more convenient-to-use gaseous form of fuel called biogas.

Factors to be considered for site selection.

- **Distance:** The distance between the plant and the site of gas consumption should be less in order to pump the gas economically and to minimize gas leakage. For a gas plant capacity of $2m^3$, optimum distance is 10m.

- **Minimum gradient:** For conveying the gas a minimum gradient of 1% must be available in the line.
- **Open space:** The sunlight should fall on the plant as temperature between 15^oC and 30^oC is essential for the gas generation at good rate.
- **Distance from wells:** The seepage of fermented slurry may pollute the well water. Hence a minimum of 15m should be maintained from the wells.
- **Space requirement:** Sufficient space must be available for day to day operation and maintenance.
- **Availability of water:** Plenty of water must be available as cow dung slurry with a solid concentration of 7% to 9% is used.
- **Source of cow dung:** The distance between the cow dung source and the gas plant should be less to reduce the transportation cost.

Line diagram of biogas plant



Components of biogas plant

- **Mixing Tank:** It is used to mix dung and water to produce slurry to the digester
- **Digester:** Digester is an underground chamber where anaerobic digestion of slurry takes place to produce biogas. In this area, the bacteria and other microorganisms transform the slurry into compost and this slowly decays over time to produce biogas. The entire process takes place in the absence of oxygen, at atmospheric pressure and temperature of 35 to 70^0C.
- **Gas holder:** After the required amount of biogas has been produced, the biogas digester moves the gas into a chamber known as gas holder. This holds the biogas and makes it available for further use.
- **Sludge holder:** The waste sludge after digestion of slurry is fed to the sludge holder.
- **Gas Engine and Generator:** The gas from the gas holder drives the gas engine. The gas engine in turn drives the electrical generator to generate electricity

Benefits of biomass.

Biogas is a renewable fuel that can be used to produce heat, power and as a vehicle fuel

Biogas plants use waste to generate energy.

Biogas plants considerably reduce the greenhouse effect by recycling waste.

Digested slurry of the biogas plant can be used as fertilizer.

They do not cause pollution.

Running cost is low because they use biological waste as fuel which is free of cost.

Types of biogas plants.

i) Batch type and ii) Continuous type.

Continuous type plants are further classified as

a) fixed dome type and b) floating drum type

Fuel cell

Fuel cell is an electrochemical energy conversion device that converts chemical energy of the fuel directly into DC electrical energy. Fuel cell mainly uses hydrogen as fuel. Sometimes hydro-carbons such as natural gas are also used as fuel. Similar to a primary cell, the fuel cell consists of two electrodes with an electrolyte between them. The fuel is supplied to the negative electrode called anode and the oxidant is supplied to the positive electrode called cathode. Each fuel cell generates an average DC voltage of about 0.7V. Several cells are connected in seriesparallel combination to increase the current and voltage.

Classification of fuel cell Based on the type of electrolyte used, fuel cells are classified as:

- Phosphoric Acid Fuel Cell (PAFC)
- Alkaline Fuel Cell (AFC)
- Polymer Electrolytic Membrane Fuel Cell
- (PEMFC)Molten Carbonate Fuel Cell (MCFC)
- Solid Oxide Fuel Cell (SOFC

Applications of fuel cell

1. They are used for central power generation.
2. They are used for residential power of 5 to 10 KW
3. They are used in space flights and in remote site applications.
4. They are used to power electric vehicles for road and rail transport.
5. They are used in communication systems. 6. They supply combined heat and power to commercial buildings, hospitals, military installation and airports.

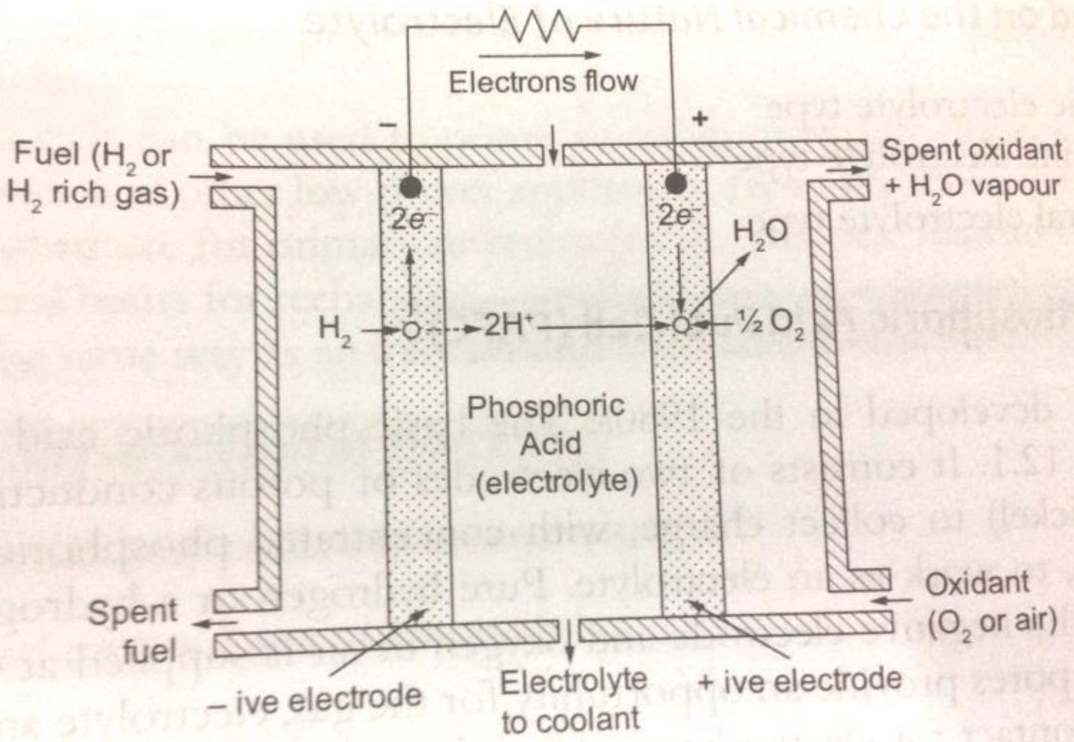


Fig. 12.1 *Phosphoric Acid Fuel Cell*

- It consists of two porous nickel electrodes immersed in the concentrated phosphoric acid working as an electrolyte. The anode has fine platinum powder as catalyst and cathode has nickel as catalyst. These catalysts accelerate the chemical reactions taking place at the electrodes.
- The hydrogen fuel is fed to the anode of the fuel cell and oxygen is fed to the cathode of the fuel cell. At the anode, the hydrogen atom is split into positively charged H+ ion and negatively charged electron.
- The electrons originating at the anode travel thought the external wire to reach cathode creating direct electric current. The positive H+ ions travel through the electrolyte to reach cathode. In the cathode, the H+ ions combine with electrons and oxygen atom to create water. This water created at the cathode is the waste product of the fuel cell

Hybrid PV systems

- Solar photo voltaic system is unreliable source energy because it can supply energy only when there is solar radiation.
- The intensity of solar radiations gets affected during cloudy conditions.
- Hence to maintain the continuity of power supply, other sources such as diesel generators, wind generators or fuel cells are operated in conjunction with solar PV system. Such systems are known as hybrid PV systems.

Types of hybrid PV systems.

Hybrid PV systems are classified depending on the type of source used in conjunction with PV system. Accordingly, the following are the different types of hybrid PV systems:

- PV-diesel hybrid system
- PV-wind hybrid system
- PV-fuel cell hybrid system

Block diagram PV-Wind hybrid system

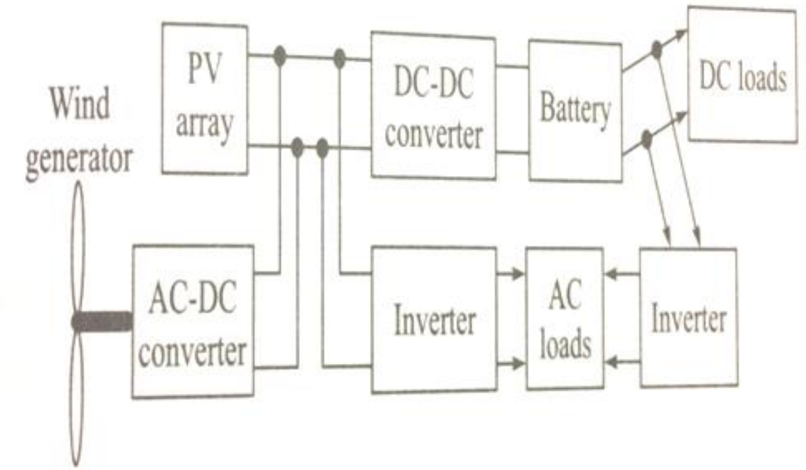
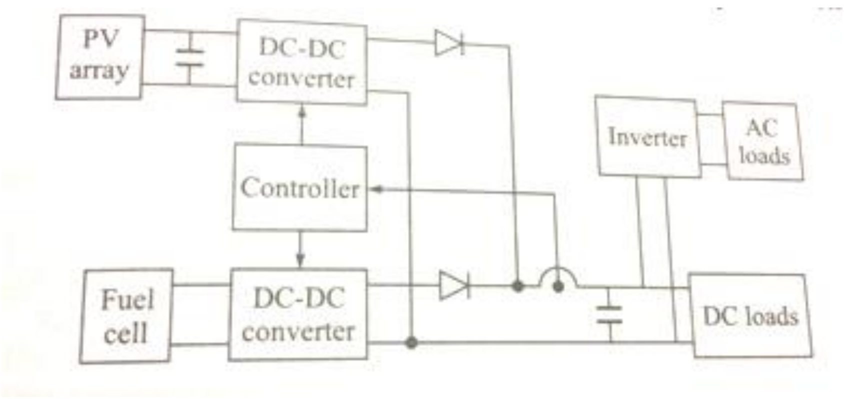


Figure shows the arrangement of PV-wind hybrid system. The variation of the wind velocity results in large changes in the frequency and output voltage of the generator. Hence the AC output of the wind generator is first converted to DC and then converted back to AC through the inverter. The DC output of the PV array and the rectified output of wind generator are connected in parallel to the DC link.

The main drawback of this system is that both PV array and wind generator are unreliable sources and hence in the absence of sun and wind, a large battery bank is needed to meet the load demand.

PV-fuel cell hybrid system.



The reliability problem of PV-wind hybrid system is eliminated by using weather independent source such as fuel cell.

This system uses two DC-DC converters, one fed from PV array and the other fed from fuel cell.

Both of these DC-DC converters are connected in parallel to the DC bus. The DC output generated from the PV array and the fuel cell is converted back to AC using inverter and fed to the AC load.

The DC-DC converter is operated such that it extracts maximum power from the PV array.

UNIT 5

ECONAMICS OF POWER GENERATION

Definition of some terms

Installed capacity or plant capacity:- It is the sum of the ratings of all generating units installed in a power house.

Installed capacity or plant capacity =Max demand + Reserve capacity

Reserve capacity:- It is the spare capacity,over and above the max load.

Cold reserve:- It is the reserve capacity which is available for service,but not in operation

Hot reserve:- It is the reserve capacity which is in operation but is not in service

Spinning reserve:- it is the reserve capacity which is connected to the bus and it ready to serve ie take load

Firm power:- It is the power available all the time

Connected load :- It is the sum of continuous ratings of all the equipments connected to supply system.

Maximum demand :- It is the greatest demand of load on the power station during a given period

Demand factor:- It is the ratio of maximum demand on the power station to its connected load

i.e., Demand factor = Maximum demand/ Connected load

The value of demand factor is usually less than 1

Average load:- The average of loads occurring on the power station in a given period (day or month or year) is known as average load or average demand.

Load factor:- The ratio of average load to the maximum demand during a given period is known as load factor

Load factor = Average load/ Max. demand

- Diversity factor. The ratio of the sum of individual maximum demands to the maximum demand on power station

Diversity factor = Sum of individual maximum demands /Maximum demand on power station

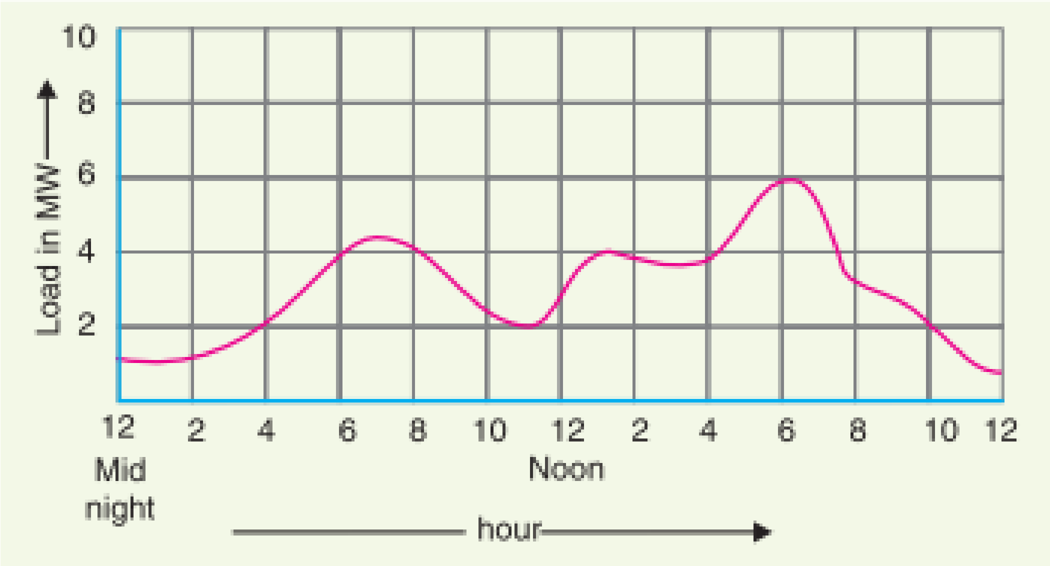
- Plant capacity factor:- It is the ratio of actual energy produced to the maximum possible energy that could have been produced during a given period

Plant capacity factor = Actual energy produced /Max. energy that could have been produced

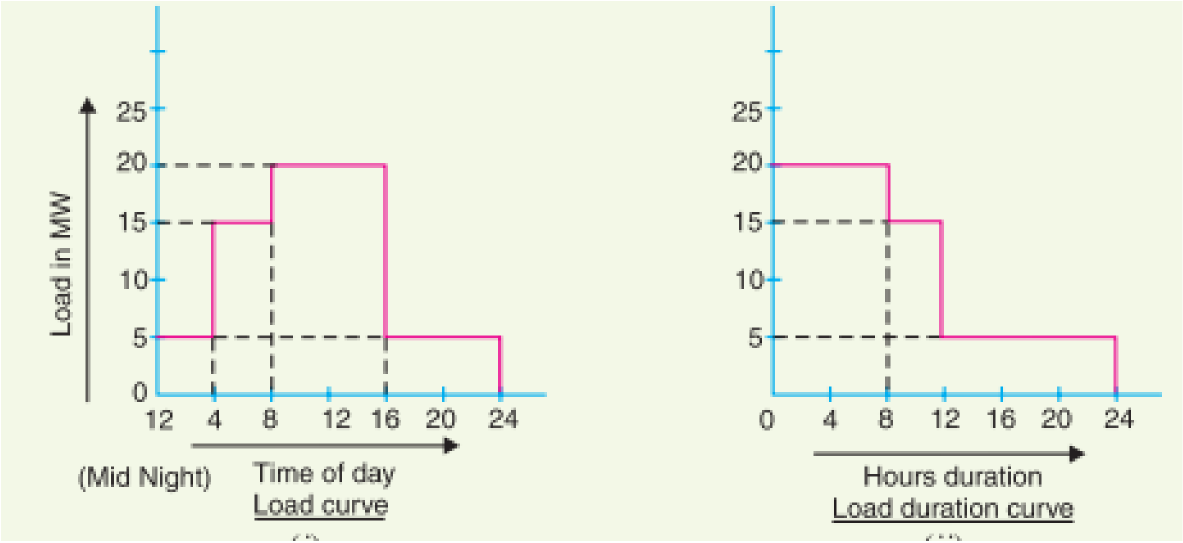
Plant use factor:- It is ratio of kWh generated to the product of plant capacity and the number of hours for which the plant was in operation Plant use factor = Station output in kWh /Plant capacityX Hours of use

Load curve

The curve showing the variation of load on the power station with respect to (w.r.t) time is known as a load curve



load duration curve:- When the load elements of a load curve are arranged in the order of descending magnitudes, the curve thus obtained is called a load duration curve.



3.11 Base Load and Peak Load on Power Station

The changing load on the power station makes its load curve of variable nature. Fig. 3.13. shows the typical load curve of a power station. It is clear that load on the power station varies from time to time. However, a close look at the load curve reveals that load on the power station can be considered in two parts, namely;

(*i*) Base load

(*ii*) Peak load

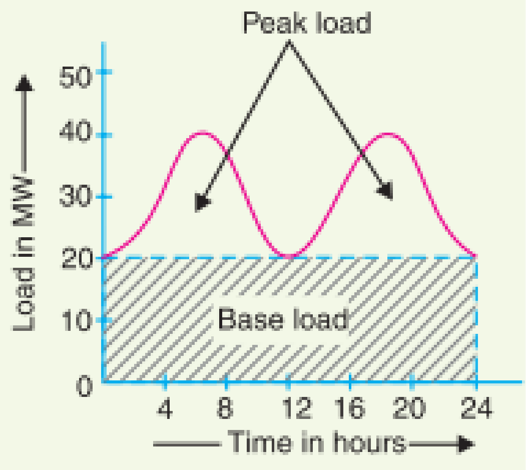


Fig. 3.13

(*i*) **Base load.** *The unvarying load which occurs almost the whole day on the station is known as* **base load.**

Referring to the load curve of Fig. 3.13, it is clear that 20 MW of load has to be supplied by the station at all times of day and night *i.e.* throughout 24 hours. Therefore, 20 MW is the base load of the station. As base load on the station is almost of constant nature, therefore, it can be suitably supplied (as discussed in the next Article) without facing the problems of variable load.

(*ii*) **Peak load.** *The various peak demands of load over and above the base load of the station is known as* **peak load.**

Referring to the load curve of Fig. 3.13, it is clear that there are peak demands of load excluding base load. These peak demands of the station generally form a small part of the total load and may occur throughout the day.

Choice of size and number of generator units, combined operation of power station

- The load on a power station is not constant
- It varies from time to time.
- A single generating unit will not be an economical to meet this varying load.
- It is because a single unit will have very poor efficiency during the periods of light loads on the power station.
- Therefore, in actual practice, a number of generating units of different sizes are installed in a power station.
- The selection of the number and sizes of the units is decided from the annual load curve of the station.
- The number and size of the units are selected in such a way that they correctly fit the station load curve.
- Then it becomes possible to operate the generating units at or near the point of maximum efficiency

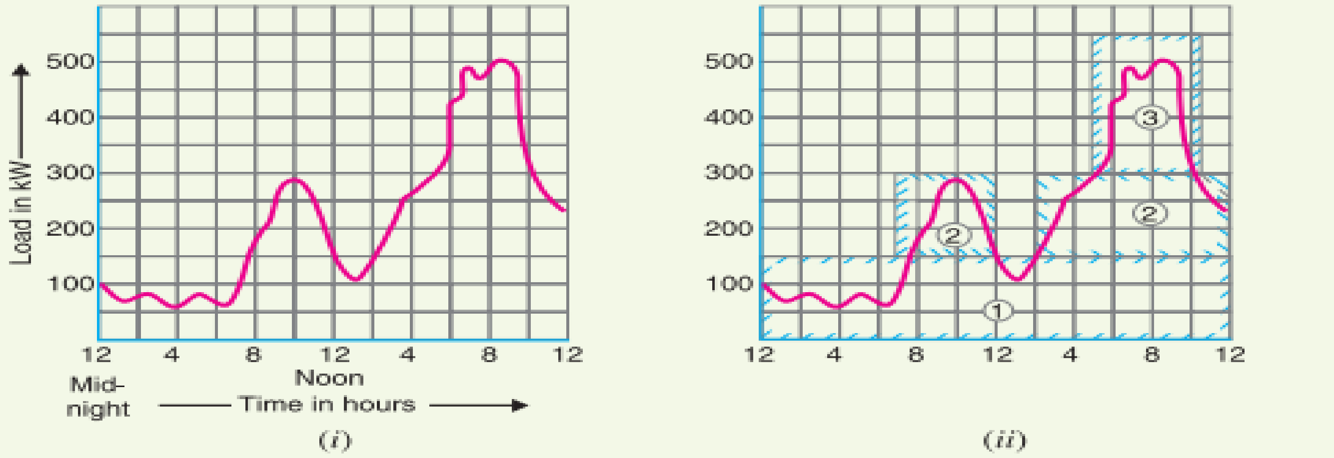


Fig. 3.11

As discussed earlier, the total plant capacity is divided into several generating units of different sizes to fit the load curve. This is illustrated in Fig. 3.11(*ii*) where the plant capacity is divided into three* units numbered as 1, 2 and 3. The cyan colour outline shows the units capacity being used. The three units employed have different capacities and are used according to the demand on the station. In this case, the operating schedule can be as under :

Time	*Units in operation*
From 12 midnight to 7 A.M.	Only unit no.1 is put in operation.
From 7 A.M. to 12.00 noon	Unit no. 2 is also started so that both units 1 and 2 are in operation.
From 12.00 noon to 2 P.M.	Unit no. 2 is stopped and only unit 1operates.
From 2 P.M. to 5 P.M.	Unit no. 2 is again started. Now units 1 and 2 are in operation.
From 5 P.M. to 10.30 P.M.	Units 1, 2 and 3 are put in operation.
From 10. 30 P.M. to 12.00 midnight	Units 1 and 2 are put in operation.

Thus by selecting the proper number and sizes of units, the generating units can be made to operate near maximum efficiency. This results in the overall reduction in the cost of production of electrical energy.

Important Points in the Selection of Units While making the selection of number and sizes of the generating units,

- The number and sizes of the units should be so selected that they approximately fit the annual load curve of the station.
- The units should be preferably of different capacities to meet the load requirements. Although use of identical units (i.e., having same capacity) ensures saving* in cost, they often do not meet the load requirement.
- The capacity of the plant should be made 15% to 20% more than the maximum demand to meet the future load requirements.
- There should be a spare generating unit so that repairs and overhauling of the working units can be carried out.
- The tendency to select a large number of units of smaller capacity in order to fit the load curve very accurately should be avoided. It is because the investment cost per kW of capacity increases as the size of the units decreases.

The connection of several generating stations in parallel is known as interconnected grid system.

Some of the advantages of interconnected system are listed below

(i) Exchange of peak loads : An important advantage of interconnected system is that the peak load of the power station can be exchanged. If the load curve of a power station shows a peak demand that is greater than the rated capacity of the plant, then the excess load can be shared by other stations interconnected with it.

(ii) Use of older plants : The interconnected system makes it possible to use the older and less efficient plants to carry peak loads of short durations. Although such plants may be inadequate when used alone, yet they have sufficient capacity to carry short peaks of loads when interconnected with other modern plants. Therefore, interconnected system gives a direct key to the use of obsolete plants.

(iii) Ensures economical operation : The interconnected system makes the operation of concerned power stations quite economical. It is because sharing of load among the stations is arranged in such a way that more efficient stations work continuously throughouts the year at a high load factor and the less efficient plants work for peak load hours only.

(iv) Increases diversity factor : The load curves of different interconnected stations are generally different. The result is that the maximum demand on the system is much reduced as compared to the sum of individual maximum demands on different stations. In other words, the diversity factor of the system is improved, thereby increasing the effective capacity of the system.

(v) Reduces plant reserve capacity : Every power station is required to have a standby unit for emergencies. However, when several power stations are connected in parallel, the reserve capacity of the system is much reduced. This increases the efficiency of the system.

UNIT 6

Basics of Transmission and Distribution

Transmission systems

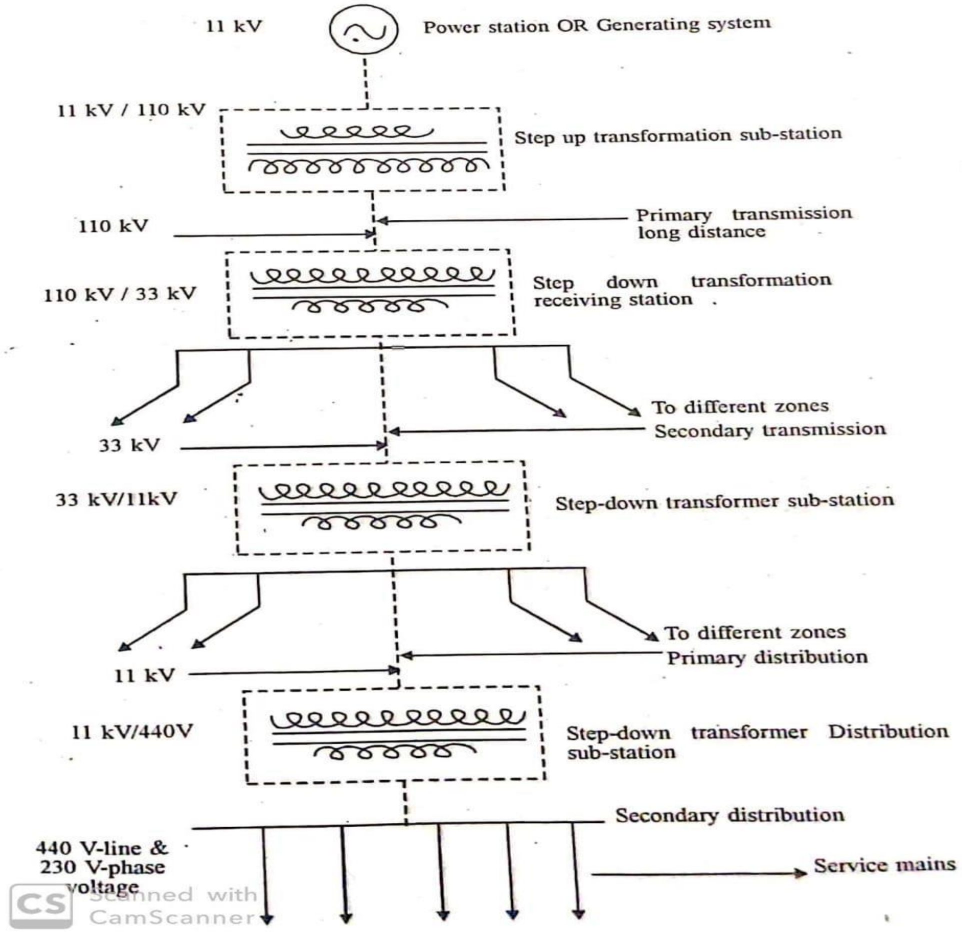
Transmission Systems: -

The large network of connectors between the power station and the consumers is broadly divided into 2 parts:

i. Transmission System

ii. Distribution System

Single line diagrams with components of the electric supply transmission and distribution systems.



Components of the electric supply transmission and distribution systems.

I. Generating station/ Power station: -

- In generating station, mechanical energy is converted into electrical energy by using 3 Φ parallel alternators. The usual generating voltage is 11kV, for economy in the transmission of electrical power, the generating voltage is stepped up to 110kV at generating station with the help of step up three phase transformers.

II. Primary transmission: -

- After generation voltage is raised to 110kV, it is sent to long distance transmission called primary transmission, it is carried out by 3 Φ wire overhead lines.

III. Secondary transmission: -

- The power at 110kV is reduced at receiving station, here the voltage is reduced to 33kV by using step down transforms, which is supplied to different substations, is called secondary transmission.

IV. Primary distribution: -

- The power at 33kV is brought to another substation and voltage is reduced to 11kV, by using step down transformers which is distributed along the major road of the city called primary distribution.

V. Secondary distribution: -

- The power from 11kV line is brought to distribution substation which is located (fixed) near the consumers and the voltage reduced from 11kV to 440volts between the lines at 230volts between any phase and Neutral.

Primary and secondary transmission standard voltage level used in India

The standard voltage rating used for transmission and distribution are given below: -

1. Generation – 11kV.22kV or 33kV
2. Primary transmission – 110kV or 220kV
3. Secondary transmission – 33kV or 66kV
4. Primary distribution – 11kV
5. Secondary distribution – 440V between lines and 230 between phase and neutral

System of electrical power transmission

Generally electrical power system is classified into two ways

I. According to the method of arrangement of conductors

a) Overhead System

b) Underground System

II. According to the nature of the current

A. Direct current system

1. DC 2 wire system
2. DC 2 wire with midpoint earth
3. DC 3 wire system

B. AC single phase system

1. **1 Φ 2 wire system**
2. **1 Φ 2 wire system with midpoint earth**
3. **1 Φ 3 wire system**

C. 3 phase system

1. **3 Φ 3 wire system**
2. **3 Φ 4 wire system**

Classification of transmission lines

III According to distance i.e., length of transmission lines, nature of current and voltage rating the transmission lines are classified as follows:

1. Short transmission lines:

- When the length of an overhead transmission line is up to 80km and its voltage rating is below 20kV, then the lines termed as short transmission lines.

2. Medium transmission lines:

- When the length of an overhead transmission line is in between 80km-250km and its voltage rating is in between 20kV-100kV, then the line is termed as medium transmission lines.

3. Long transmission lines:

- When the length of an overhead transmission line is above 250km and its voltage rating is more than 100kV then the line is termed as long transmission lines.

Characteristics of high voltage for power transmission.

(Advantages and limitations of High Voltage Transmission)

- Advantages: -

1. It reduces volume of conductor material required.
2. It reduces/decreases the line loss.
3. It increases transmission efficiency.
4. Regulation will be improved due to high voltage.

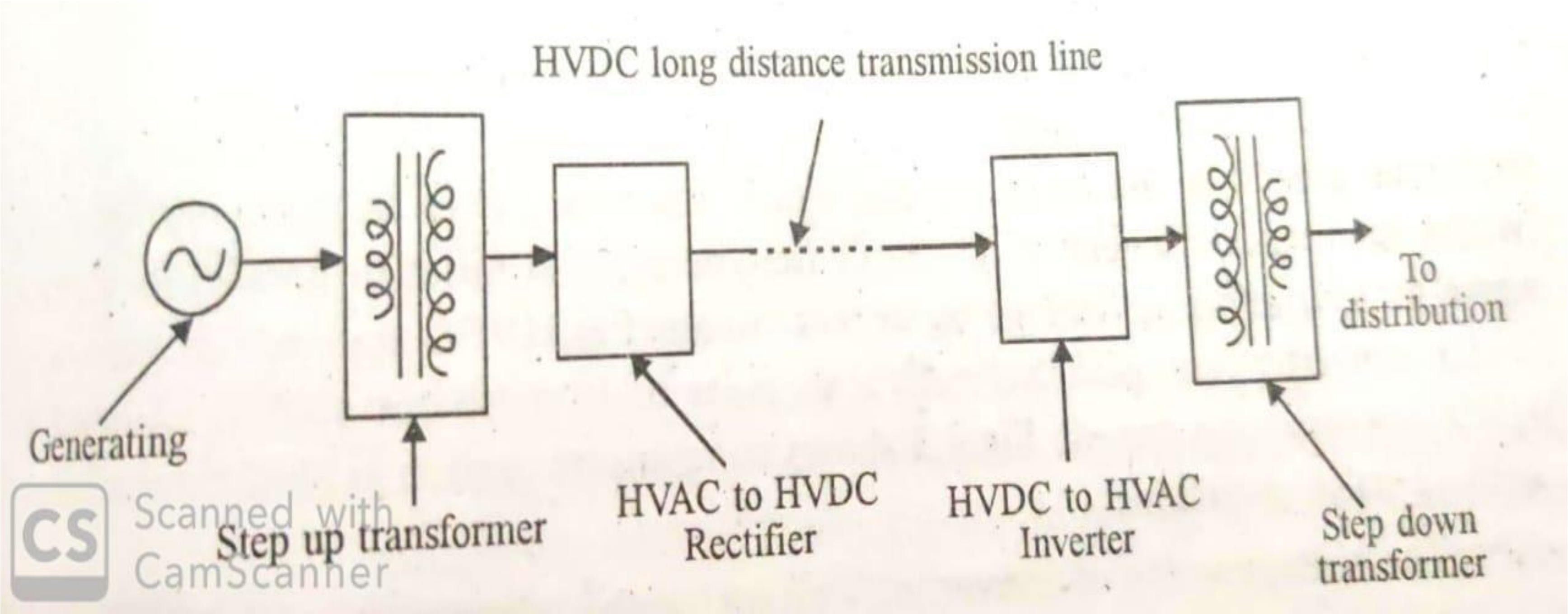
- Disadvantages: -

1. It increases cost of insulators, transformers, switch gear, etc.
2. It increases spacing between the conductors.
3. It is necessary to keep large distance between ground level and conductors.

High voltage direct current transmission

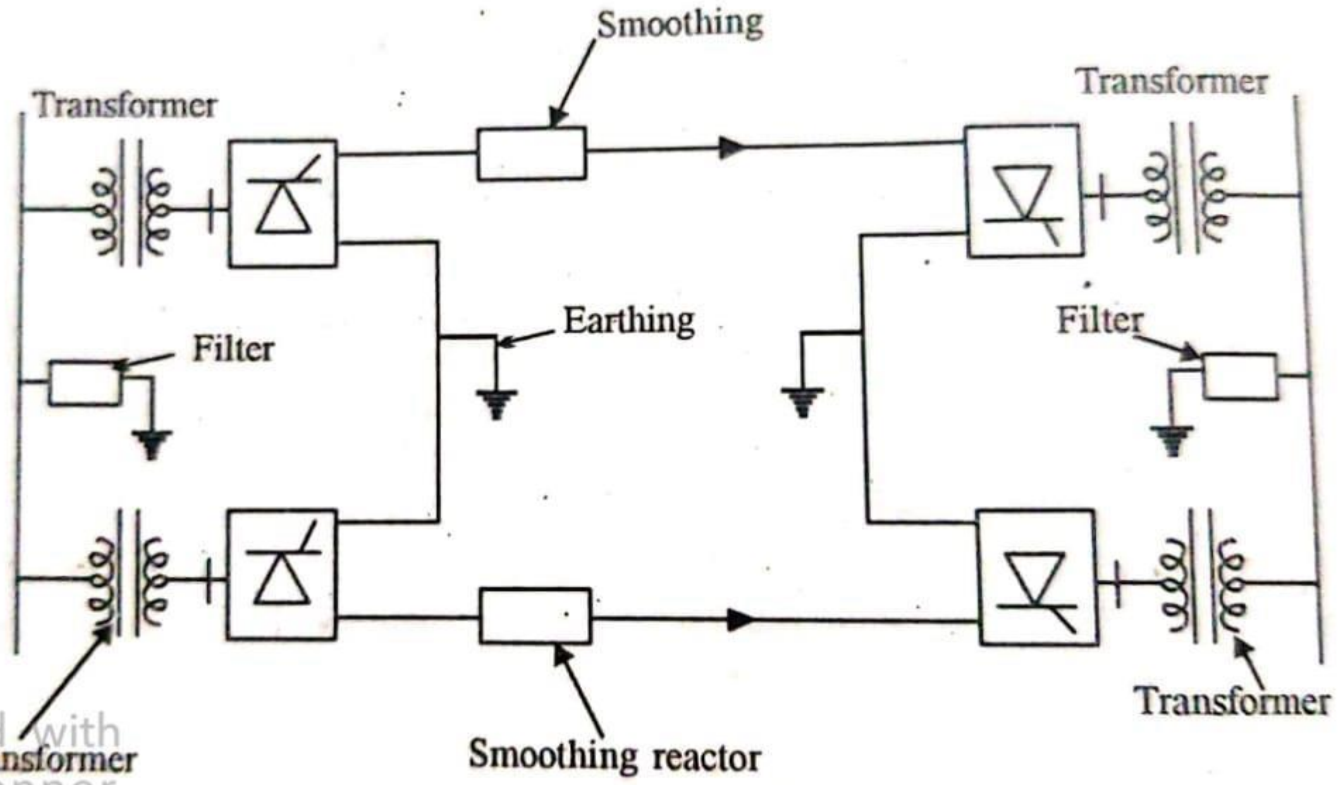
The growing trend towards the rapid increase of the load and demand for generation & transmission made it necessary to transmit large quantity of Electrical power over a large distance, HVDC transmission has many advantages over conventional AC transmission, hence now a day’s bulk quantity of power being transmitted by HVDC transmission.

Single line/ Block diagram of HVDC Transmission



- Figure shows single line diagram of HVDC Transmission. The electrical power generated is AC .
- it is increased by the voltage using step up transformer.
- This high voltage AC is converted into DC by wing Converter or Rectifier and HVDC is transmitted for long distance.
- The HVDC is once again converted into AC at the receiving end by using inverter.
- Now the available AC power is at high voltage which is reduced by using step down transformer at the Receiving end.
- Finally, Reduced AC voltage is neat for distribution.

Main Components of HVDC Transmission



1. Converter:

Converters are the main components of HVDC transmission System, each HVDC transmission should have at least two converters one at the sending end which convert power from AC into DC as a rectifier. Another converter placed at the receiving end which converts power from DC into AC works as inverters.

2. Converter transformers:

The Construction of Converter transformer is slightly different from general transformers. In this type of transformer windings are not placed closed to the yoke and windings are completely insulated. The Eddy current loss of this transformer in very high and leakage flux contains very high harmonic currents. The leakage impedance of their transformer should be higher than Conventional transformer.

3. Smoothing Reactor:

- The smoothing reaction are used in HVDC transmission for smoothing DC current o/p in the DC line.

4. Harmonic filters:

- These are used to provide low-impedance path to the Ground for the harmonic currents and are connected to the converter terminals so that harmonics should not enter the AC systems.

5. Reactive power source:

Converter used in HVDC transmission does not consume any reactive power due to phase displacement between voltage and current but the system requires reactive power source which is supplied by filters. Capacitors and synchronous condensers.

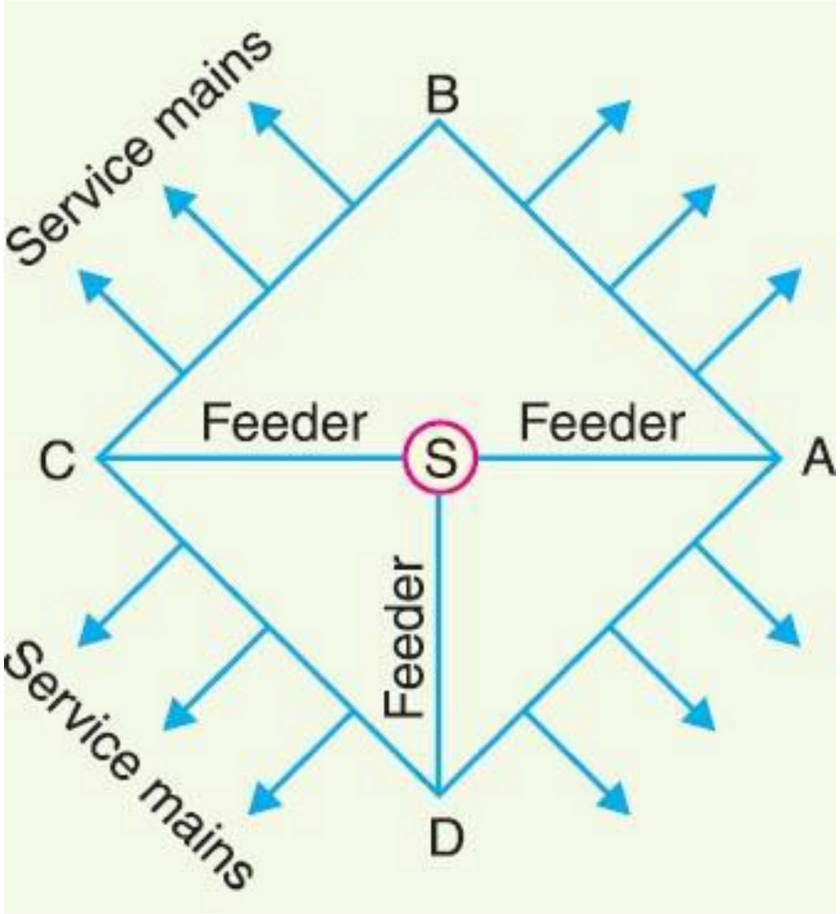
6. Earth electrode:

The Earth electrode used must have very low resistance i.e. ≤ 0.1 ohm. The Earth electrode is buried into the Earth up to 5M deep where resistivity is3 to 10ΩM.

Distribution System

- The electrical energy produced at the generating station is conveyed to the consumers through a network of transmission and distribution systems.
- That part of power system which distributes electric power for local use is known as distribution system.
- In general, the distribution system is the electrical system between the sub-station fed by the transmission system and the consumers meters. It generally consists of feeders, distributors and the service mains

Distribution System



Distribution System

(i) Feeders. A feeder is a conductor which connects the sub-station (or localized generating station) to the area where power is to be distributed. Generally, no tapings are taken from the feeder so that current in it remains the same throughout. The main consideration in the design of a feeder is the current carrying capacity.

(ii) Distributor. A distributor is a conductor from which tapings are taken for supply to the consumers. In Fig. *AB*, *BC*, *CD* and *DA* are the distributors. The current through a distributor is not constant because tapings are taken at various places along its length.

(iii) Service mains. A service main is generally a small cable which connects the distributor to the consumers' terminals

Classification of the distribution systems

1. According to nature of current-

a. AC distribution system.

b. DC distribution system.

2. According to construction-

a. Overhead distribution system.

b. Underground distribution system.

3. According to scheme of connection-

a. Radial system.

b. Ring main system.

c. Interconnected system

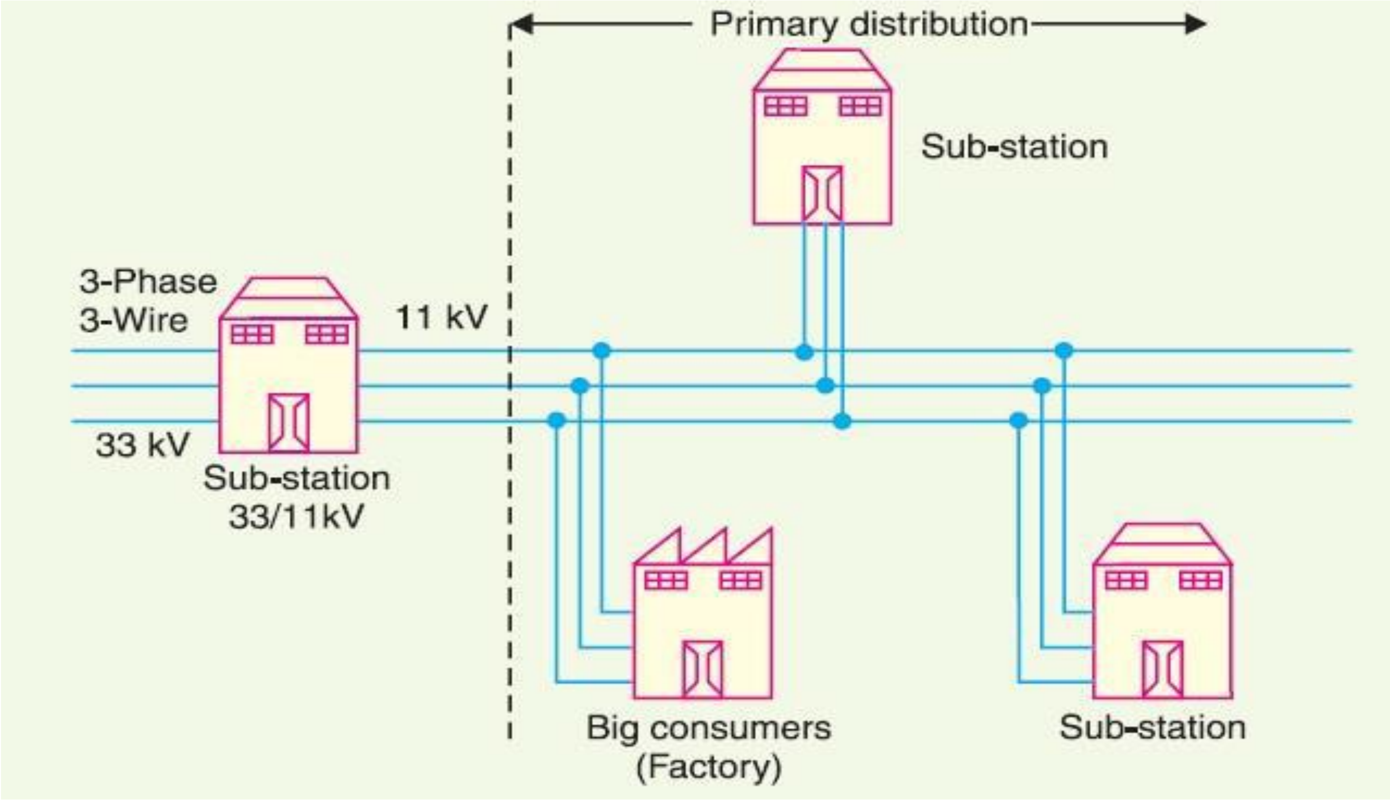
1. A.C. Distribution system:

Now-a-days electrical energy is generated, transmitted and distributed in the form of alternating current. One important reason for the widespread use of alternating current in preference to direct current is the fact that alternating voltage can be conveniently changed in magnitude by means of a transformer. Transformer has made it possible to transmit a.c. power at high voltage and utilize it at a safe potential. High transmission and distribution voltages have greatly reduced the current in the conductors and the resulting line losses.

The a.c. distribution system is classified into

(*i*) primary distribution system and **(*ii*)** secondary distribution system.

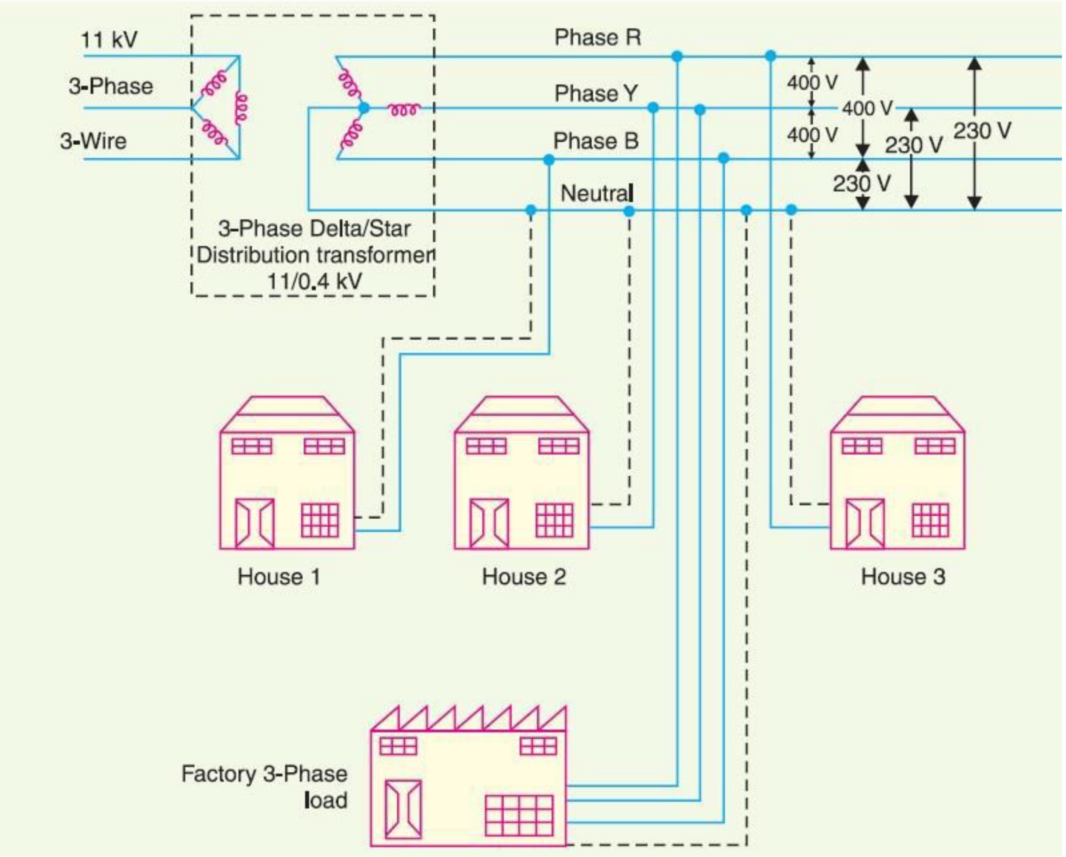
Primary distribution system.



Primary distribution system.

- It is that part of a.c. distribution system which operates at voltages somewhat higher than general utilisation and handles large blocks of electrical energy than the average low-voltage consumer uses.
- The voltage used for primary distribution depends upon the amount of power to be conveyed and the distance of the substation required to be fed.
- The most commonly used primary distribution voltages are 11 kV, 6·6kV and 3·3 kV.
- Due to economic considerations, primary distribution is carried out by 3-phase, 3-wire system.
- Fig. shows a typical primary distribution system. Electric power from the generating station is transmitted at high voltage to the substation located in or near the city. At this substation, voltage is stepped down to 11 kV with the help of step-down transformer.
- Power is supplied to various substations for distribution or to big consumers at this voltage. This forms the high voltage distribution or primary distribution.

(ii) Secondary distribution system.



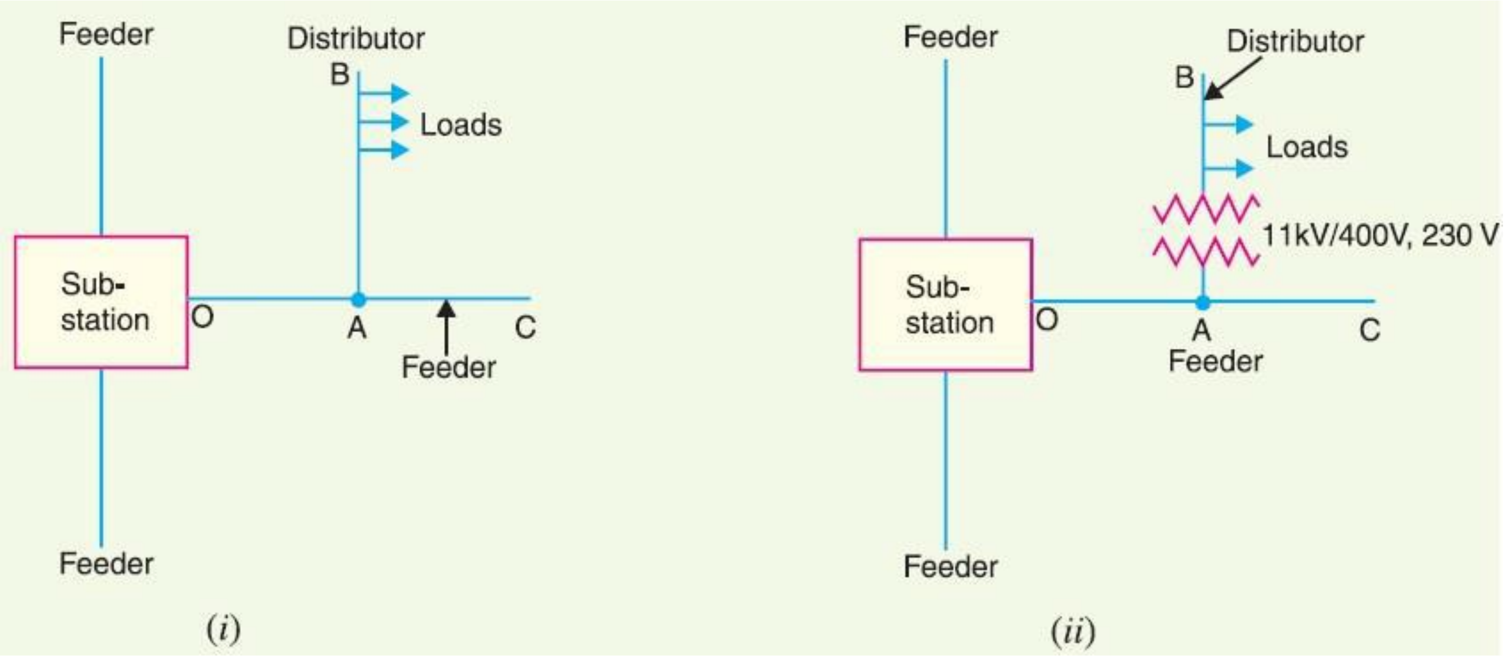
Secondary distribution system.

- It is that part of a.c. distribution system which includes the range of voltages at which the ultimate consumer utilizes the electrical energy delivered to him.
- The secondary distribution employs 400/230 V, 3-phase, 4-wire system.
- Fig. shows a typical secondary distribution system. The primary distribution circuit delivers power to various substations, called distribution substations.
- The substations are situated near the consumers localities and contain step-down transformers. At each distribution substation, the voltage is stepped down to 400V and power is delivered by 3phase,4wire a.c. system.
- The voltage between any two phases is 400 V and between any phase and neutral is 230V.
- The single-phase domestic loads are connected between any one phase and the neutral, whereas 3-phase 400 V motor loads are connected across 3-phase lines directly.

Connection Schemes of Distribution System

- All distribution of electrical energy is done by constant voltage system. In practice, the following distribution circuits are generally used

i. Radial System.



i. Radial System.

- In this system, separate feeders radiate from a single substation and feed the distributors at one end only.
- Fig.(a) shows a single line diagram of a radial system for d.c. distribution where a feeder *OC* supplies a distributor *AB* at point *A*. Obviously, the distributor is fed at one end only *i.e.*, point *A* is this case.
- Fig. (*b*) shows a single line diagram of radial system for a.c. distribution. The radial system is employed only when power is generated at low voltage and the substation is located at the center of the load. This is the simplest distribution circuit and has the lowest initial cost.
- However, it suffers from the following drawbacks:

(a) The end of the distributor nearest to the feeding point will be heavily loaded.

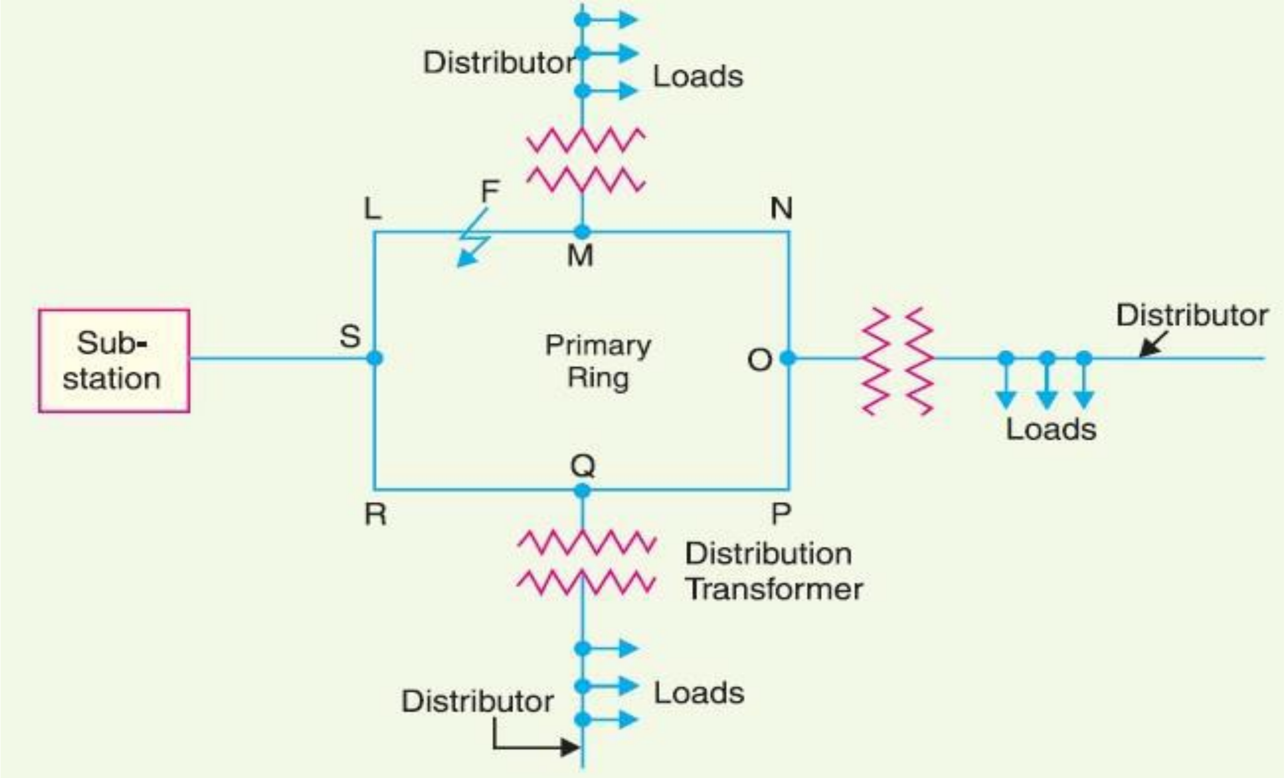
(b) The consumers are dependent on a single feeder and single distributor. Therefore, any fault

on the feeder or distributor cuts off supply to the consumers who are on the side of the fault away from the substation.

(c) The consumers at the distant end of the distributor would be subjected to serious voltage

fluctuations when the load on the distributor changes only

(ii) Ring main system.

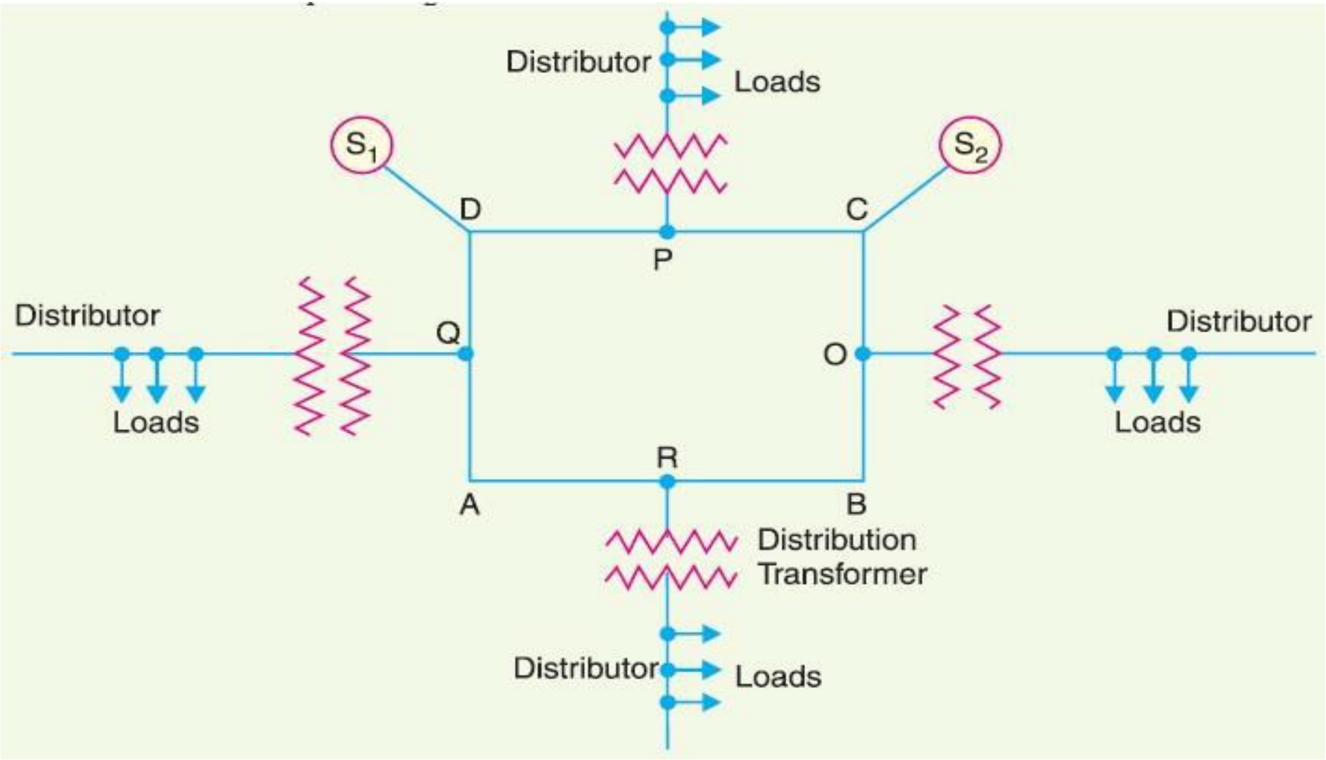


- In this system, the primaries of distribution transformers form a loop. The loop circuit starts from the substation bus-bars, makes a loop through the area to be served, and returns to the substation.
- Fig. shows the single line diagram of ring main system for a.c. distribution where substation supplies to the closed feeder LMNOPQRS.
- The distributors are tapped from different points *M*, *O* and *Q* of the feeder through distribution transformers. The ring main system has the following advantages

(a) There are less voltage fluctuations at consumer's terminals.

(*b*) The system is very reliable as each distributor is fed *via* *two feeders. In the event of fault on any section of the feeder, the continuity of supply is maintained.

(*iii*) Interconnected system.



(*iii*) Interconnected system

- When the feeder ring is energized by two or more than two generating stations or substations, it is called interconnected system.
- Fig. shows the single line diagram of interconnected system where the closed feeder ring *ABCD* is supplied by two substations *S*1 and *S*2 at points *D* and *C* respectively.

Advantage of interconnected distribution system

1. In this system of distribution reliability is more.

2. Load factor and efficiency is increased by interconnection.

3. A particular area fed from one station during peak load hours can be fed from other generating station.

Characteristics of feeder, distributor and service mains.

Feeders	Distribution	Service mains
High current carrying capacity.	Medium current carrying capacity.	Low current carrying capacity.
Large diameter ACSR conductors are used.	Small diameter ACSR conductor is used.	Small cables are used.
There is no tapping.	They have number of tapping.	Directly given to consumers.

Substation:

- The assembly of operators used to change some characteristics (Voltage level, AC to DC, Frequency, Power factor etc.) of electric supply is called substation. The substations are important part of power system. The connectivity of supply depends up on the operation of substation.

Functions of Substation

1. To switch ON and OFF the power lines.
2. To change voltage level, of the system.
3. To convert AC to DC or DC to AC.
4. To improve the power factor.
5. Changing of supply frequency.

Classifications of substation

The substation is classified

1. According to service requirement

a. Transformer Substation.

b. Switching Substation.

c. Power factor correction Substation.

d. Frequency changing Substation.

e. Converting Substation.

f. Industrial Substation.

2. According to construction

a. Outdoor Substation.

b. Indoor Substation.

c. Underground Substation.

d. Pole mounted Substation.

3 According to service requirement-

I. Transformer Substation:

- These substations with change the voltage level of electric supply are called transformer substation. These are main components in substation.

II. Switching Substation:

- These substations do not change the voltage level i.e. incoming and outgoing lines have the same voltage; however, they simply perform the switching operations (ON and OFF) of power lines.

III. Power factor correction Substation:

- These substations which improve the power factor of the system are called power factor correction Substation. Which are generally located at the receiving end of the transmission lines. These Substation generally use synchronous condensers for improving the power factor.

IV. Frequency changing Substation:

- These substations which change the supply frequency are known as frequency changes Substation, these substations may be required for industrial utilization like high frequency induction heating.

V. Converting Substation:

- Those substations which change AC power into DC power are called converting substations. These substations suitable for fraction, electro plating, battery charging etc.

VI. Industrial Substation:

- Those substations which supply power to individual industries are known as industrial substation.

According to construction

I. Outdoor Substation:

- For voltage beyond 66kv equipment is invariably install outdoor because for such voltage the clearance between the conductors and space required for switches, circuit breakers and other equipment becomes so great hence it is not economical to install the equipment in indoor substation.

II. Indoor Substation:

- For voltage up to 11kv the equipment of substation is installed indoor because of economic considerations.

III. Underground Substation:

- In thickly populated area the space available for equipment and building is limited and the cost of land is very high. Under such conditions the substation is created underground.

IV. Pole Mounted Substation:

- This is an outdoor substation which equipment installed overhead on H-pole (2 pole) or pole structure it is cheapest form of substation for voltages not exceeding 11kv