UNIT I : Hydroelectric and Thermal Power Plants

Session1

Overview:-Power Sector scenario including Generation, Transmission and Distribution scenario of India.

Power is a major factor in deciding the socio-economic growth of any country and therefore it is important to know the power scenario of our country.

- India is the world's third largest producer and third largest consumer of electricity.
- The total power generated in India as on 2020 is 374.2 GW.

Power Sector is made of four divisions.

1. Generation
2. Transmission
3. Distribution
4. Load or Demand.

The power generated in India by various sources as shown below:

Fuel	Power Generation in GW	% of Total Power Generated
Thermal (Coal, Gas, Diesel)	**231.3**	**61.8%**
Hydro	**45.7**	**12.2%**
Nuclear	**6.8**	**1.8%**
Renewable Energy Sources (Small Hydro, Biogas, Biomass Power, Urban & Industrial Waste Power, Solar and Wind Energy)	**90.4**	**24.2%**

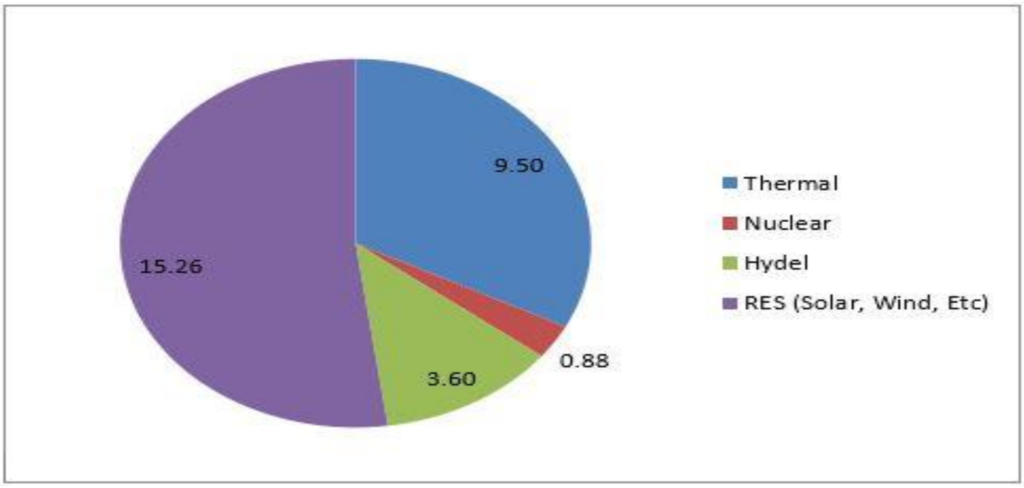
- It is seen that major portion of the power is generated by fossil fuels (Coal, Gas, Diesel).
- The government is making efforts to increase power generation using renewable energy sources.
- It is planned to generate 44.7% of the total electricity using renewable energy sources by the year 2029-30

- The per capita electricity consumption in India is 1,181 kWh. It is low compared to most of other countries. India has a surplus power generation capacity but lacks infrastructure for distribution.
- To address this, the Government of India has launched a program called "Power for All". The program aims to provide uninterrupted electricity supply to all households, industries and commercial establishments.

Power Scenario in Karnataka

- Karnataka generates 29.3 GW of power. It is 7.84% of the country's total power generation.
- Karnataka is the highest renewable energy producer of the country. Karnataka generates 15.23 GW from renewable energy sources.

This chart shows the power generation in GW by various sources in Karnataka.



- In Karnataka, Power generation is looked after by Karnataka Power Corporation Ltd (KPCL)
- Power transmission is taken care by Karnataka Power Transmission Corporation Ltd (KPTCL)
- Power Distribution is monitored by Bangalore Electricity Supply Company (BESCOM), Mangaluru Electricity Supply Company (MESCOM), Hubblli Electricity Supply Company (HESCOM) ,Gulbarga Electricity Supply Company (GESCOM).

UNIT I: Hydroelectric and Thermal Power Plants

Session 2

Overview: Introduction, Importance of Electrical Power Generation, Sources of energy, conventional and non-conventional sources of electrical energy.

INTRODUCTION

Energy is the basic necessity for the economic development of a country. There is a close relationship between the energy used person and his standard of living. The greater the per capita consumption of energy in a country, the higher is the standard of living of its people.

Energy exists in different forms in nature but the most important form is the electrical energy. The modern society is so much dependent upon the use of electrical energy that it has become a part and parcel of our life.

Importance of electrical power generation

The electrical power generation is important due to following reasons:

- **i.** **Convenient form:** Electrical energy is a very convenient form of energy. It can be easily converted into other forms of energy like heat, light, mechanical energy, chemical energy, etc.
- **ii.** **Easy control:** The electrically operated machines have simple and convenient starting, control and operation.
- **iii.** **Greater flexibility:** Electrical energy offers greater flexibility and it can be easily transported from one place to another with the help of conductors.
- **iv.** **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.
- **v.** **Cleanliness:** Electrical energy is not associated with smoke, fumes or poisonous gases. Hence it is non-polluting.
- **vi.** **High transmission efficiency:** Electrical energy can be transmitted conveniently and efficiently from the centers of generation to the consumers with the help of transmission lines.

Various sources of energy available in nature

The different sources of energy available in nature are:

i. Water power
ii. Solid fuel (coal)
ii. Liquid fuel (diesel, petrol)
iv. Gaseous fuel (natural gas)
v. Nuclear power
vi. Solar power
vii. Wind power
viii. Tidal power
ix. Geo thermal power
x. Biomass/Biogas
xi. Ocean thermal
xii. Piezo electric
xiii. Thermo electric
xiv. Magneto hydro dynamic (MHD)

Classification of power Sources

A. <u>Based on Usage</u>

i. Conventional sources of energy
ii. Non-conventional sources of energy

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:

a) Solar power
b) Wind power
c) Geo thermal power
d) Tidal power
e) Ocean thermal power
f) Biogas/Biomass
g) Piezo electric, thermo electric
h) MHD etc

B. <u>Based on availability of resources</u>

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

i. Renewable sources of energy: They are inexhaustible 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 again.

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

UNIT I - Hydroelectric and Thermal Power Plants

Session 3

Overview of session 3:

- **Factors to be considered for selection of site for hydroelectric Power Plant**
- **General layout of hydro power plant and its components**

Hydroelectric Power Plant:

A generating station which uses potential energy of water at a high level for the generation of electrical energy is known as Hydro Electric Power Plant.

Factors to be considered for site selection of Hydroelectric Power Plant:

1. Availability of water: Water is the primary requirement of hydroelectric power plant. So, the plant should be built at a place where adequate quantity of water at good head is available.

2. Storage of water: As rainfall is not uniform throughout the year, the site selected for hydro power plant should have facilities for constructing dam and storing water.

3. Head of water: The potential energy of water is more if water head is high. So, the site selected should provide sufficient water head.

4. Accessibility of site: For easy transportation of equipment and machines, the site selected should be accessible by rail or road.

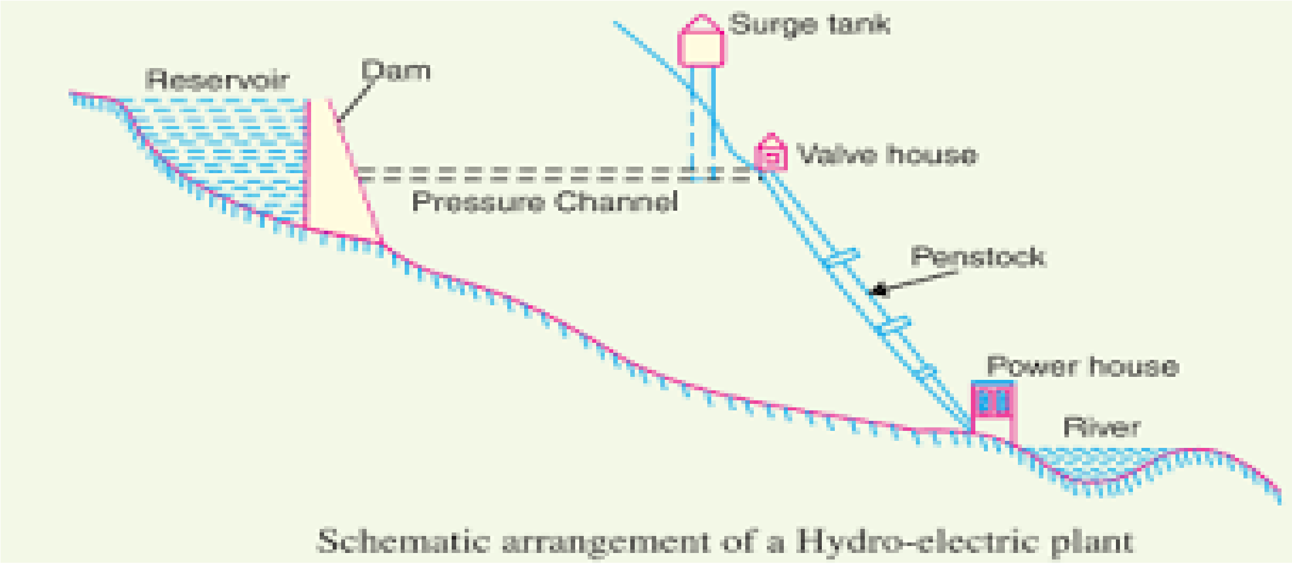
5. Large catchment area: The site should have large catchment area for collecting rain water.

6. High mountains for dam construction: The site should preferably have high mountains on the two sides of the dam to be constructed.

7. Cost of land: The cost of the land should be low.

8. Less impact on the ecology: The site selected should have less impact on the ecology by the construction of dam.

General layout of Hydroelectric Power Plant:



The important components of hydroelectric power plant are dam, reservoir, forebay, penstock, anchor blocks, surge tank, trash rack, tail race, prime mover, power station, draft tube and alternator.

1. **Dam:** The dam is a barrier constructed across a river or a lake to trap water and to provide water head.

2. **Reservoir:** The main function of reservoir is to store water behind dam.

3. **Pressure Tunnel:** It is the passage which carries water from reservoir to surge tank.

4 **Surge tank:** It is a small reservoir or tank placed at the beginning of the penstock. Water level in the surge tank rises or falls due to sudden changes of pressure in penstock. Thus, it prevents water hammer effect on the penstock.

5. **Penstock:** Penstocks are concrete or steel 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.**Power station:** The power station contains turbines, alternators, circuit breakers and other control devices. It is located near the foot of the dam.

8. **Prime mover or Turbine**: The prime mover also called as turbine, converts the kinetic energy of the water into mechanical energy. There are two types of turbines namely:

- **Reaction Turbine:** Francis Turbine and Kaplan Turbine.
- **Impulse Turbine:** Pelton Wheel Turbine

9. **Generator:** The generator is coupled to the turbine. It converts mechanical energy of the turbine into electrical energy.

10. **Draft tube:** Draft tube is a metal pipe or a concrete tunnel which connects the turbine outlet to the tail race.

11.. **Tail race:** Tail race is an open channel or a tunnel which discharges water into the original river or some other river.

12.Trash rack: Trash rack is provided at the inlet to stop the entry of debris to the turbine.

UNIT I: Hydroelectric and Thermal Power Plants

Session 4

Overview :

- **• Meaning of water hammer and its effect**
- **• Classification of hydroelectric power plants**

Water hammer and its effect:

- • Whenever there is sudden reduction in the load on the turbine, the governor closes the gates of the turbine to reduce the water flow.
- • It causes pressure to increase abnormally in the penstock.
- • This results in hammering action in the penstock known as water hammer.
- • If the water hammer is not prevented it may result in bursting of penstock.

Water Hammer – Its Prevention:

- • Surge tank is used to prevent water hammering effect.
- • A surge tank is a small reservoir or tank which is open at the top.
- • It is fitted at the beginning of the penstock.
- • The water level in the surge tank rises or falls to reduce the pressure variations in the penstock and prevents water hammer.

Classification of Hydroelectric Power Plants:

The hydroelectric power plants are classified as given below.

1. Based on the head of water:
2. Based on the plant capacity:
3. Based on the construction:
4. Based on load:

1. Based on the head of water:

i. Low head power plant:

- ✦ Water head is less than 30m.
- ✦ A small dam is built to provide water head.
- ✦ Surge tank is not needed as power house is located near the dam.
- ✦ Kaplan turbine is used.

ii. Medium head plant:

▪ Water head is between 30m to 300m.
▪ A pond or a small canal constructed behind the dam called forebay is used.

▪ Open channel brings the water from the main reservoir to the forebay
▪ Penstock carries water to the turbines
▪ Surge tank is not needed as forebay itself stores rejected water when the load on the turbine decreases.
▪ Francis turbine is used.

iii. High head plant:

▪ Water head is above 300m.
▪ Large quantity of water is stored in the reservoir behind the dam
▪ Stored water is brought to the surge tank by pressure channel and then to the power house using penstock.
▪ Surge tank reduces the water hammer effect on the penstock.
▪ Pelton wheel turbine is used.

2. Based on the plant capacity:

i Micro hydro plant Less than 100kW
ii Mini hydro plant 100kW – 1MW
iii Small hydro plant 1MW – 15MW
iv Medium hydro plant 15MW – 100MW
v Large hydro plant Above 100MW

3. Based on the construction:

i. Run off river plants without pondage:

▪ This plant does not store water. It uses water as it comes.
▪ Generating capacity of the plant depends on rate of water flow.
▪ During low flow periods, the generating capacity of the plant will be low.
▪ Some quantity of water goes as waste during rainy season.
▪ During high flow periods, it can supply base load.

ii. Run off river plants with pondage:

▪ This plant uses pondage to store water during off peak periods and use this water during peak periods.
▪ It can take care of hour-to-hour fluctuations in load on the station.
▪ Pondage increases the generating capacity of the station.

iii. Reservoir plants:

▪ Reservoir plant stores water in big reservoir behind the dam.
▪ Water storage in the reservoir increases the generating capacity of the plant. Most of the plants are of this type.
▪ It can be used either as base load plant or as peak load plant.

4. Based on load:

i. Base load plants:

▪ Base load plants generate power continuously and supply base load of the system.
▪ Run off river plants without pondage is used as base load plant.

ii. Peak load plants:

▪ Peak load plants are used to supply peak load of the system.
▪ Run off river plants with pondage or reservoir plants are used as peak load plants.

iii. Pumped storage plants:

▪ The pumped storage hydroelectric power plant is a special type of power plant.
▪ During peak load period it generates electricity. This is called generating phase.

▪ During off peak period water is pumped back from the tail race to the head race. This is called pumping phase.
▪ It uses a reversible turbine pump unit. It operates as a turbine during generating phase and as pump during pumping phase.
▪ The generator works as motor during reverse operation.

UNIT I: Hydroelectric and Thermal Power Plants

Session 5

Overview:

Advantages and Disadvantages of Hydroelectric power plant
Environmental impact of hydroelectric power plant

Advantages and Disadvantages of Hydro Power Plant:

Advantages:

- It requires no fuel as water is used for the generation of electrical energy.
- It is neat and clean since no smoke and ash is produced.
- It requires low running cost because water is freely available in nature.
- It is simple in construction and requires less maintenance.
- It does not require long starting time like thermal power stations. It can be put into service instantly.
- It is robust and has a long life.
- It does not need highly skilled persons for operation.

Disadvantages:

- It requires high capital cost due to construction of dam.
- It requires large land area.
- The duration required for construction is very long (about 10years)
- Skilled and experienced personal are required to build the plant.
- Power generation depends on weather conditions.
- Transmission cost and losses are very high because hydro electric plants are located in hilly areas which are away from load centers.
- Due to construction of dams and reservoirs, a large portion of area is submerged in water which leads to environmental and social problems.

Environmental impacts of hydroelectric power plants:

i. The construction of reservoir results in flooding of large area of upstream land.
ii. The flooding destroys forest land, wildlife habitat, agricultural land and scenic lands.
iii. Dam stops the flow of nutrients to the downstream which will harm the plant and animal life in the downstream.
iv. The construction of dam may obstruct fish migration and affect their population.
v. Changes in water quality due to lack of dissolved oxygen near the bottom of reservoirs can be toxic to fish and other aquatic life.
vi. The reservoir will have higher than normal amounts of sediments and nutrients, which can cultivate an excess of algae and other aquatic weeds. These weeds will have negative impact on the growth of other plant and animal life in the river.
vii. The flooding of area due to construction of dam results in anaerobic decomposition of vegetation. This releases greenhouse gases like carbon dioxide and methane leading to global warming.

UNIT I: Hydroelectric and Thermal Power plants

Session-06

Overview:

Thermal Power Plant: Factors to be considered for selection of site.
General layout of Thermal (steam) Power Plant.

Thermal Power Plant:

A generating station which converts heat energy of coal on combustion into electrical energy is known as steam power plant or thermal power station.

Factors to be considered for selection of site for thermal power plant:

1. Supply of fuel:
The steam power station should be located near the coal mines so that the transportation cost of fuel is minimum.

2. Availability of water:
Huge amount of water is required to produce steam and to condense exhaust steam from the turbine.

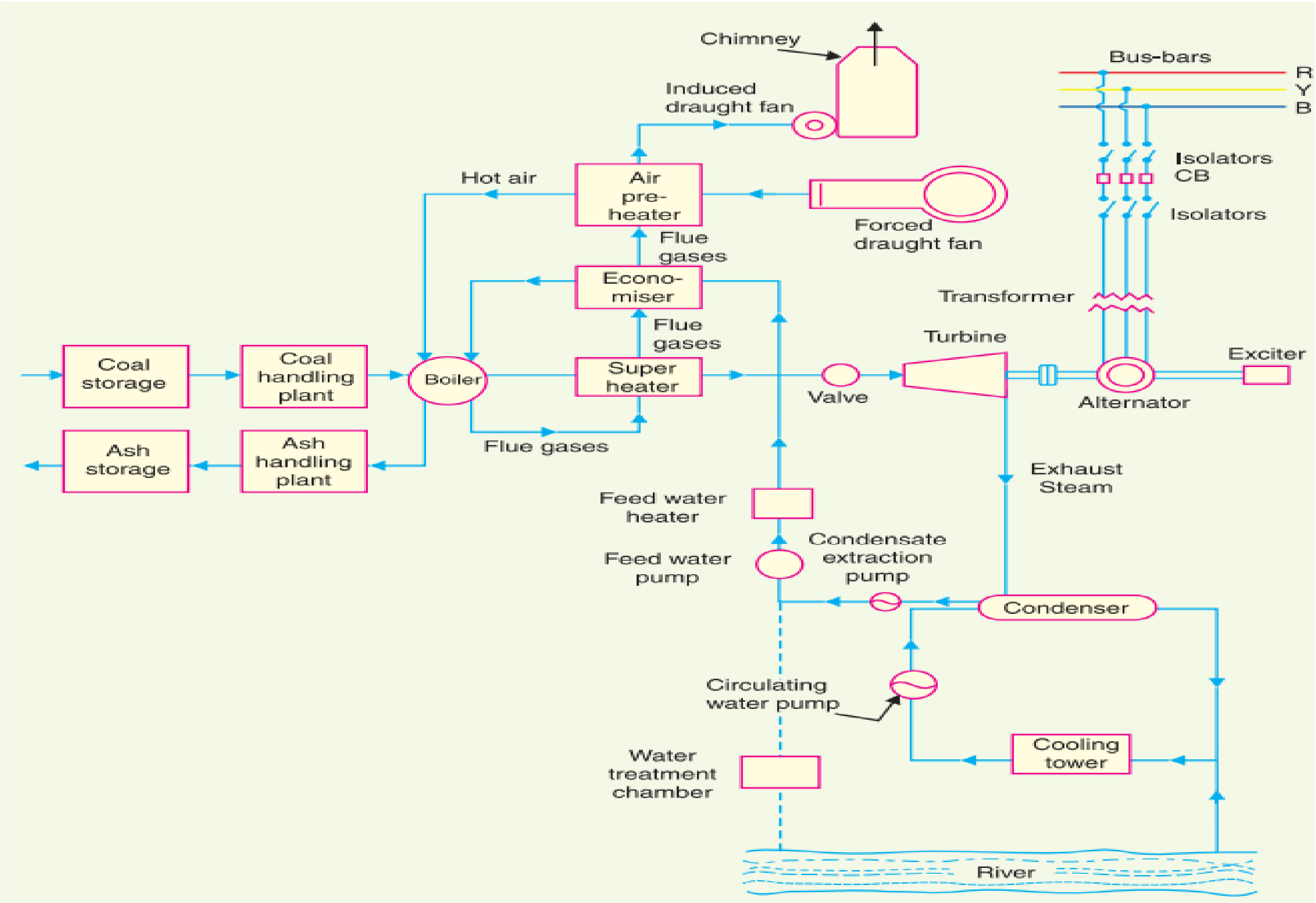
3. Transportation facilities:
The power station should be well connected by road or rail for the transportation of men, material and machinery.

4. Cost and type of land:
The cost of land should be less and also it should be capable of bearing the load of heavy equipments.

5. Nearness to load centre:
The plant should be located near the load centre to reduce the transmission cost and transmission losses.

6. Distance from populated area:
The plant should be located at a considerable distance from the populated area because large amount of smoke and fumes are produced as huge amount of coal is burnt in thermal power station, which pollute the surrounding area.

General layout of Thermal Power plant:



Main components of a Thermal Power plant are:

Figure shows the general layout of thermal power plant. The main components of thermal power plant are:

Fuel system	Boiler
Super heater	Economizer
Air pre heater	Draught system
Steam turbine	Alternator
Feed water system	Cooling arrangement.

1. Fuel system:

The fuel system consists of: coal storage, coal handling, ash handling and ash storage.

- Coal storage plant stores the coal transported by road or rail.
- Coal handling plant receives the coal from the coal storage and pulverizes the coal which is fed to the boiler through belt conveyor.
- The ash handling plant stores the ash produced due to combustion of coal in the boiler.
- The ash storage plant disposes the ash delivered to it from the ash handling plant.

2. Boiler:

- Is a closed vessel in which water is converted into steam at high pressure and temperature by utilizing the heat of combustion of coal.
- The flue gases from the boiler pass through superheater, economizer, air preheater and are finally exhausted into atmosphere through the chimney.

3. Super heater:

- The super heater consists of group of special alloy steel tubes which are heated by the heat of flue gases while passing from boiler to the chimney.
- The heated tubes convert the wet steam produced by the boiler into dry steam which increases the overall efficiency of the plant.

4. Economizer:
- Is a feed water heater which derives the heat from the flue gases to heat the feed water.
- The feed water from the economizer is then fed to the boiler.

5. Air pre heater:
- increases the temperature of the air supplied for coal burning by deriving the heat from the flue gases.

6. Draught system:
- Uses forced draught fan for supplying air to the furnace.
- Uses induced draught fan for exhausting the flue gases from the boiler through the chimney.

7. Steam turbine:
- The steam turbine converts heat energy of steam into mechanical energy.

8. Alternator:
- The alternator coupled to the steam turbine converts the mechanical energy of turbine into electrical energy.

9. Feed water system:
- The feed water which is the condensate from the condenser on the way to the boiler is heated by feed water heater and economizer.

10. Cooling arrangement:
- The cooling arrangement consists of condenser and cooling tower.
- The condenser condenses the exhaust steam from the turbine by circulating water from the river, canal and lake.
- The cooling towers will cool the hot water coming from the condenser which has absorbed the heat of the exhaust steam.
- The cold water from the cooling tower is reused in the condenser to condense the steam.

UNIT I: Hydroelectric and Thermal Power plants

Session-07

Overview:

Thermal power plant: **Advantages , Disadvantages**

Environmental Impacts of Thermal Power Plant:

Advantages

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

(ii) Less initial cost as compared to other generating stations.

(iii) It can be installed at any place irrespective of the existence of coal. The coal can be transported to the site of the plant by rail or road.

(iv) It requires less space as compared to the hydroelectric power station.

(v) The cost of generation is lesser than that of the diesel power station.

Disadvantages

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

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

iii. Efficiency of the plant is very less Requirement of source is very large in scale

iv. Difficult in transportation of coal High Maintance and operating charge Handling of coal and disposal of ash is quite difficult

Environmental Impacts of Thermal Power Plant:

The following are the environmental impacts of thermal power plant:

1. Large amount of land is used to dispose fly ash from the coal based Plants. Due to this there is a change in soil properties. It becomes more alkaline due to the alkaline nature of fly ash.
2. Soft bodied soil workers like earth worms will die out.
3. Increased transportation activities due the operation of the power plant lead to increase in noise levels in the adjacent localities. Also the employees are exposed to high noise levels.
4. Air quality degenerates due to:
   - Production of carbon dioxide, the main green house gas.
   - Production of oxides of sulphur and nitrogen:
     - SO_2 is a product of Combustion and depends on the amount of sulphur in Coal. SO_2 contributes to the formation of small acidic particulates that can penetrate into human lungs and be absorbed by the bloodstream. Sulphur dioxide also causes acid rain, which can damage crops, forests, and soils, and acidifies lakes and streams.
     - Nitrogen in fuel reacts with Oxygen at high temperatures to form NO_2. Fossil fuel power plants are the second largest emitter of NO_2.This is a hazardous pollutant creating visual and respiratory problems. Also NO_2 combines with water to form acid rain, smog, and ground ozone.
   - Production of gases of mercury, which is a poisonous gas.

5. Ash is the residue after combustion. Ash contains toxic elements that can percolate into the drinking water system. The wind carries away the ash particles to surrounding areas causing harm to humans and vegetation.

6. Power plants have elaborate arrangements to collect the ash. A small quantity still goes out through the stack and is categorized as Particulate Matter emission. The particles of size less than 2.5 microns are of great concern since these are responsible for respiratory illness in humans.

UNIT II: Nuclear, Diesel and Gas Turbine Power Plants

Session 9

Overview:

1) Factors to be considered for selection of site

2) Schematic diagram of nuclear power plant.

Nuclear Power Plant:

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

Factors to be considered for selection of site

Availability of water:

Sufficient water is required for steam generation and cooling purpose in nuclear power plant. Therefore the plant site should be located where large quantity of water is available.

Disposal of waste:
The waste produced by fission in the nuclear power station is radioactive and it must be disposed off properly to avoid health hazards. Therefore the site selected should have proper arrangement for disposal of radioactive waste.

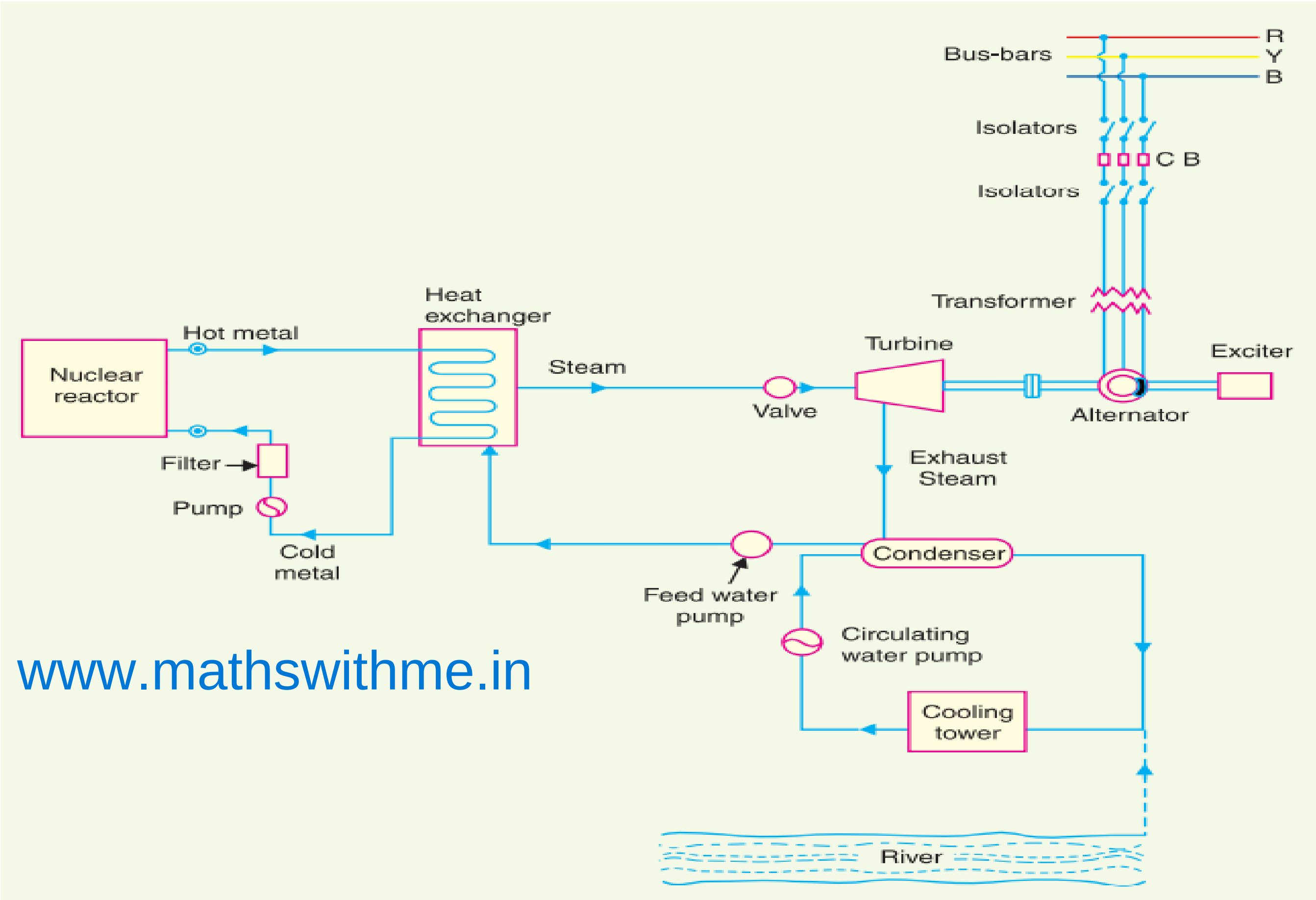
Distance from populated area:
The site selected for nuclear plant should be away from populated area as there is a danger of presence of radio activity in the atmosphere near the plant.

Transportation facilities:
The site selected should have adequate facilities to transport the heavy equipments during erection.

Nearness to load centre:
The power station should be nearer to the load centre to reduce the cost of transmission lines and line losses.

Cost:
The site should be available at reasonable cost.

Schematic diagram of Nuclear Power Plant



Schematic arrangement of Nuclear Power Station

The main parts of a Nuclear Power Plant are
1. Nuclear Reactor
2. Heat Exchanger
3. Steam Turbine
4. Alternator
5. Condenser

UNIT II: Nuclear, Diesel and Gas Turbine Power Plants

Session 10

Overview:

- **Construction of Nuclear Power Plant**
- **Working of Nuclear Power Plant**

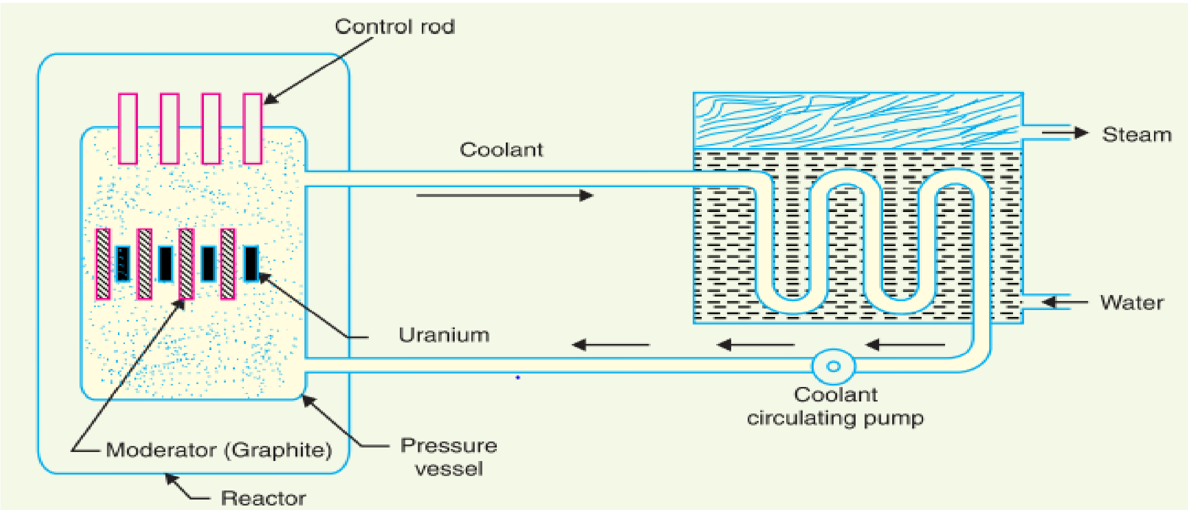
Construction of Nuclear Power Plant

1. Nuclear reactor:

• This is the main component of nuclear power station.

• This is an apparatus in which the nuclear fuel U^{235} is subjected to controlled nuclear fission to release heat energy.

• The nuclear reactor consists of a cylindrical pressure vessel which houses the fuel rods of uranium, moderator and control rods.



Nuclear Reactor

The main parts of a nuclear reactor are

• **Fuel rods:** They are the fission material which release huge amount of energy when bombarded with slow moving neutrons.

• **Moderator:** The moderator consists of the graphite rods which enclose the fuel rods. The moderator slows down the neutrons before they bombard the fuel rods.

• **Control rods:** The control rods are made of cadmium and are inserted into the reactor. Cadmium is a strong neutron absorber and thus regulates the supply of neutron for fission. When the control rods are pushed inside, they absorb the neutrons and stop the fission chain reaction. But when the control rods are withdrawn, more and more fission neutrons cause fission reaction and increase the heat produced. Thus lowering and raising of control rods regulate the power output of nuclear reactor.

• **Coolant:** The heat produced in the reactor is removed by the coolant which is generally sodium or potassium metal. The coolant carries the heat to the heat exchanger.

2.Heat exchanger: The coolant gives up the heat to the heat exchanger which is utilized in raising the steam. After giving up the heat, the coolant is fed back to the reactor.

3.Steam turbine: Steam produced in the heat exchanger is fed to the steam turbine through a valve. The steam turbine converts the heat energy of steam into mechanical energy. Steam turbine is also known as prime mover.

4.Alternator: The steam turbine drives the alternator which converts mechanical energy into electrical energy. The output from the alternator is fed to the bus bars through transformer, circuit breakers and isolators.

5.Cooling system: The exhaust steam from the turbine is condensed in the condenser. The condensed steam is fed back to the heat exchanger through feed water pump. The hot water in the condenser is cooled by using cooling tower.

Working of Nuclear power plant

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

• In nuclear power station, enriched Uranium (U_{235}) is subjected to controlled nuclear fission in a special apparatus known as nuclear reactor.

• The heat energy released during nuclear fission is carried by the coolant to the heat exchanger which produces steam at high pressure and temperature.

• This steam runs the steam turbine which converts heat energy of steam into mechanical energy.

• The turbine in turn drives the alternator which converts mechanical energy into electrical energy.

• The exhaust steam from the turbine is condensed in the cooling system.

UNIT II: Nuclear, Diesel and Gas Turbine Power Plants

Session 11

Overview:

- **Nuclear Waste**
- **Nuclear Waste Disposal**
- **Impact on Health**
- **Comparison between Thermal and Nuclear power plants**

Nuclear Waste

Nuclear Waste are wastes that contain radioactive materials. Nuclear Waste are by-products of nuclear power generation and other applications of nuclear fission or nuclear technology.

There are three types of nuclear waste, classified according to their radioactivity: low-, intermediate-, and high-level.

The vast majority of the waste (90% of total volume) is composed of only lightly contaminated items, such as tools and work clothing, and contains only 1% of the total radioactivity.

By contrast, high-level waste – mostly comprising used nuclear (sometimes referred to as spent) fuel that has been designated as waste from the nuclear reactions – accounts for just 3% of the total volume of waste, but contains 95% of the total radioactivity

Nuclear Waste Disposal:

• The solid wastes like rejected control rods, pieces of fuel etc., are stored in shielded concrete containers and dumped into ocean or buried deep underground. The radioactive waste then undergoes natural decaying over a period of time and settles into a safe level of radio-activity

• The liquid waste is filtered, diluted and adjusted for proper pH level before discharging. Sometimes the radioactivity from liquid waste is removed by ion exchange process. The liquid wastes are then discharged through special drains into concrete storage tanks.

• Gaseous wastes are filtered before discharging into atmosphere. Also the filtered gaseous waste is discharged at high levels so that it is dispersed properly.

Impact on health:

Nuclear wastes produce highly penetrating α, β and gamma radiations are dangerous to human health.

Exposure to large amounts of radioactivity can cause nausea, vomiting, hair loss, diarrhoea, haemorrhage, destruction of the intestinal lining, central nervous system damage, and death.

It also causes DNA damage and raises the risk of cancer, particularly in young children and foetuses.

Comparison between thermal power plant and nuclear power plant

Sl No.	**Nuclear power station**	**Thermal power station**
1	Heat released due to nuclear fission of U_{235} is used for steam generation.	Heat released due to combustion of coal is used for steam generation
2	Amount of fuel required is very less.	Large amount of fuel is required.
3	Transportation cost of fuel is less.	High transportation cost of fuel.
4	Space required for the nuclear power plant is less.	Space required is more when compared to nuclear power plant
5	Low running cost and high capital cost.	High running cost and relatively low capital cost.
6	A large deposit of nuclear fuel is available. Hence these plants ensure continuous supply of electrical energy for 1000 of years.	Due to depletion of fossil fuel, this method of power generation cannot sustain for many years.
7	It produces radioactive waste and hence disposal of waste is very difficult.	Does not produce radioactive waste and hence waste disposal is not very difficult.
8	It uses wet steam of relatively low temperature and pressure.	It uses dry steam and its temperature and pressure is high when compared to nuclear power plant.

UNIT II: Nuclear, Diesel and Gas Turbine Power Plants

Session 12

Overview:

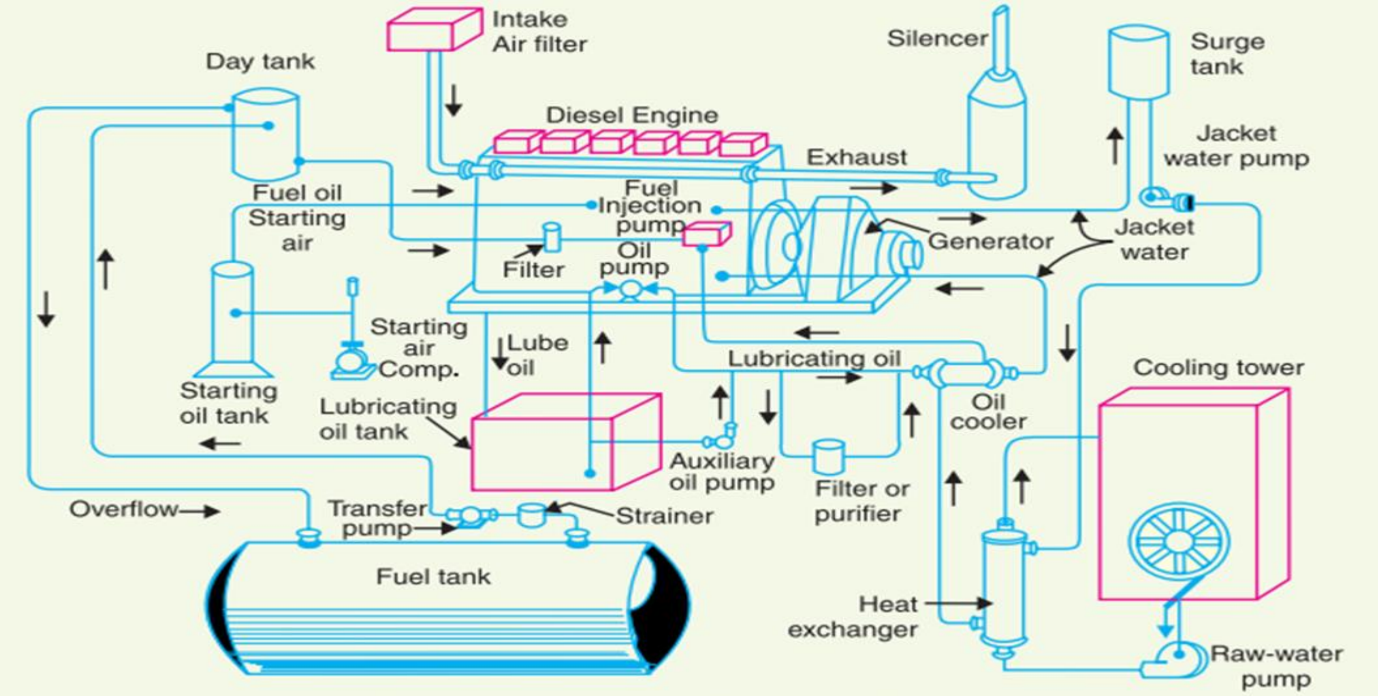
• Schematic diagram of a Diesel generator unit and its main components.

• Advantages and disadvantages of Diesel Power Plant

Diesel Power Plant

A generating station in which diesel engine is used as the prime mover for generation of electrical energy is known as Diesel Power Station or Diesel Power Plant.

Schematic diagram of Diesel Power Plant



Schematic arrangement of Diesel Power Plant

Fuel supply system:

It consists of fuel tank, strainers, fuel transfer pump and day tank.

• Fuel supplied to the plant is stored in fuel tank.

• Every day, the fuel from the fuel tank is pumped to the day tank.

• Strainer removes the impurities in the fuel.

• Clean fuel from the day tank is injected into the engine by fuel injection pump.

• In case of overflow, the fuel returns from day tank to fuel tank.

Air intake system:

• It supplies air to the engine for fuel combustion.

• Air filter removes the dust particles from the air.

Engine starting system:

• In small sets, engines are manually started.

• In larger sets, compressed air is used for starting.

• Once the engine starts, it runs on its own power.

Exhaust system:

• It carries exhaust gas from the engine and discharges it into atmosphere.

• A silencer is used to reduce the noise level.

Cooling system:
It keeps the engine temperature within safe limits. It consists of surge tank, water pump, heat exchanger and cooling tower.
• The cold water takes heat from the engine and becomes hot.

• This hot water is stored in surge tank and is then pumped to the heat exchanger.

• The hot water transfers heat to cooling water in the heat exchanger and is recirculated back to the engine.

• The cooling water which becomes hot in the heat exchanger is then cooled in the cooling tower.

Lubrication system:
It lubricates and reduces wear and tear of the engine parts. It consists of lubrication oil tank, oil pump, filter and oil cooler.
• Lubrication oil from the lubrication oil tank is pumped to the engine for lubrication.

• The filter removes impurities in the oil.

• Oil cooler keeps the temperature of the lubricating oil low.

Diesel engine:
• In diesel engine, the diesel is burnt in presence of air. The products of combustion produce mechanical energy.

Alternator:
• Alternator coupled to the diesel engine converts mechanical energy into electrical energy

Advantages of Diesel Power Plant
• Simple in design and layout

• It occupies Less Space

• It can be located at any place

• It can be started quickly

• It can pick up load in short time

• It requires less water for cooling

• Overall cost is much less than steam power station of the same capacity.

• Thermal efficiency is higher than that of steam power plant

• Requires fewer operating staff.

Disadvantages of Diesel Power Plant
• It has high running cost as the fuel used is costly.

• The plant does not work satisfactorily under continuous overload conditions.

• It causes pollution of the environment

• It can generate small power. Hence it can be used only as standby power plant.

• Cost of lubrication is high.

• Maintenance charges are high.

UNIT II: Nuclear, Diesel and Gas Turbine Power Plants

Session 13

Overview:

• Schematic diagram of Gas Turbine Power Plant

• Advantages and disadvantages of Gas Turbine Power Plant

Gas Turbine Power Plant

A generation station in which energy produced by the combustion of natural gas is used for the generation of electricity is known as gas turbine power plant.

Advantages of Gas Turbine Power Plant

• It is smaller in size.

• It is simple in design since no boilers are needed.

• It requires less water as no condenser is used.

• No stand-by losses.

• It can be started quickly from cold condition.

• It is simple in construction and operation.

• Maintenance charges are small.

• Initial and operating costs are lower.

Disadvantages of Gas Turbine Power Plant

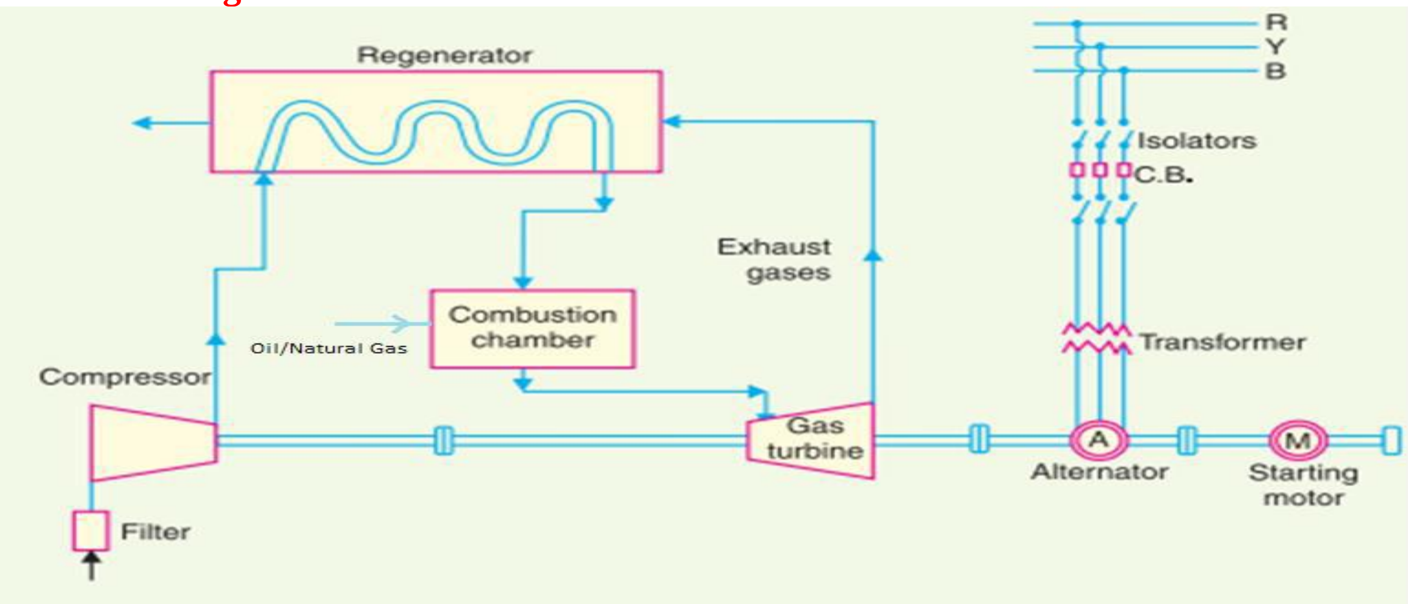
• Starting unit is needed. Therefore, it needs External Power

• Part of the power developed by the turbine is used for driving the compressor. Therefore, net output is low.

• As the exhaust gas of the turbine contain sufficient heat, Overall efficiency is low

• Temperature of the combustion chamber is extremely high (3000ºF). This reduces the life of the power plant

Schematic diagram of Gas Turbine Power Plant



Schematic arrangement of gas turbine power plant.

Compressor:

• Air at atmospheric pressure is drawn and compressed in a compressor.

• Filter removes the dust from the air.

• The high-pressure air from the compressor is then fed to the regenerator.

Regenerator:

• Regenerator is used for preheating the compressed air.

• It consists of a network of tubes. The compressed air from the compressor is passed through these tubes.

• The hot exhaust gas from the gas turbine is passed over these tubes to pre-heat the compressed air.

• This pre-heated compressed air is fed to the combustion chamber.

Combustion chamber:

• Preheated compressed air from the regenerator is fed into the combustion chamber.

• Oil or natural gas is also injected into the combustion chamber at high pressure.

• The oil mixes with compressed air and undergoes combustion.

• The hot high-pressure gases produced in the combustion chamber is then fed to the gas turbine.

Gas turbine:

• Gases at high pressure and temperature from the combustion chamber are passed into the gas turbine.

• Gases while passing over the turbine blades expand and cause the turbine blades to rotate.

Alternator:

• Alternator coupled to the gas turbine converts the mechanical energy of turbine into electrical energy.

• Output from the alternator is then given to the busbars through transformer, circuit breakers and isolators.

Starting motor:

• Compressor, turbine and alternator are all mounted on the same shaft.

• Before starting the turbine, the compressor has to be started. For this purpose, a starting motor is used.

• The starting motor is mounted on the same shaft and is energized by the batteries to start the compressor.

• Once the unit starts, a part of the mechanical energy of the turbine drives the compressor and there is no need for the starting motor now.

UNIT III: Solar photovoltaic system and wind power plant

Session 15

<u>Overview</u>:

- **Photovoltaic effect**
- **Solar Power**
- **Construction of Solar cell**
- **Solar photovoltaic module with block diagram.**

Introduction

- All matters are made up of atoms.
- Atoms are made of protons, neutrons and electrons. Protons are positively charged, Neutrons carry no charge and electrons carry negative charge.
- Electrons revolve round the nucleus in fixed orbits. The number of electrons in any orbit is given by the formula $2n^{2,}$ where n is the number of the orbit starting from the nucleus side.
- Electrons in the outermost orbit of an atom are also called valence electrons.
- Atom tries to become stable by having 8 valence electrons.
- Conductors have 1, 2 or 3 valence electrons, insulators have 5 ,6 7 or 8 valence electrons, while semiconductors have 4 Valence electrons. Examples of semiconductor material are Germanium and Silicon.
- Each orbit has certain amount of energy. Outer orbits have more energy than inner orbits.
- The range of energy possessed by valence electrons is valence bond.
- In conductor materials, the electrons are freely bound to the nucleus. Given a potential difference they move towards the positive terminal of the battery. Such electrons are called as free electrons. The range of energy possessed by free electrons are called as conduction band.
- To increase electrical conductivity, pure semiconductors are doped with trivalent impurity (atoms having 3 valence electrons) to form P type semiconductor and pentavalent impurity (atoms having 5 valence electrons) to form N type semiconductor.
- In P type semiconductor vacancies or holes are majority carriers and in N type semiconductors free electrons are majority carriers.

Photovoltaic Effect: -

The photovoltaic effect is the creation of voltage or electric current in a semiconductor material upon exposure to light.

Solar Power:

- Solar energy is an inexhaustible source of energy capable of meeting significant portion of world's energy needs with minimum environmental impacts.
- It is an unconventional energy source capable of supplying all energy needs.
- The earth receives about 1.7 X 10^{17} W of radiations from the sun.
- The solar energy incident on the earth in one year is more than total fossil energy on the earth.
- India happens to be a tropical region which receives a good quantity of solar flux.
- At some places in Rajasthan, the average solar radiation is found to be 7.4KWh/m^2.
- If it is possible to utilize even a part of this solar heat, the energy problems would be solved forever.
- But the solar energy is not constant and varies from day to night and season to season. Also, huge scale conversion of solar energy into electricity is not economical yet. Hence we are not able to convert all the solar energy reaching the earth into usable form.
- Ministry of non conventional energy sources, Governement of India, is trying to promote solar energy in a big way. The ministry provides subsidies to manufacturers and users to promote the use of solar energy.
- It is expected that total solar power utilization in India would be around 10000 MW by the year 2020.

Construction of 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.

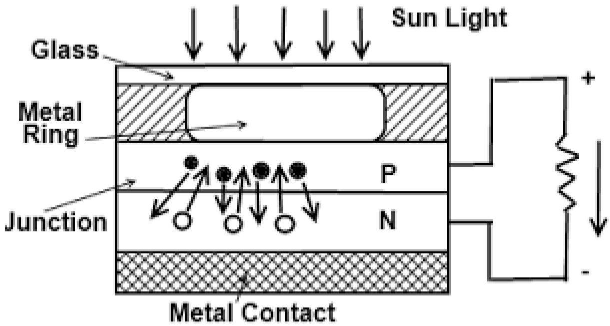
A solar cell consists of a pn semiconductor junction.

Figure shows the construction of solar cell.

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.



When a bright sunlight strikes the photovoltaic cell, the photons of the sunlight penetrate the junction and create electron-hole pairs.

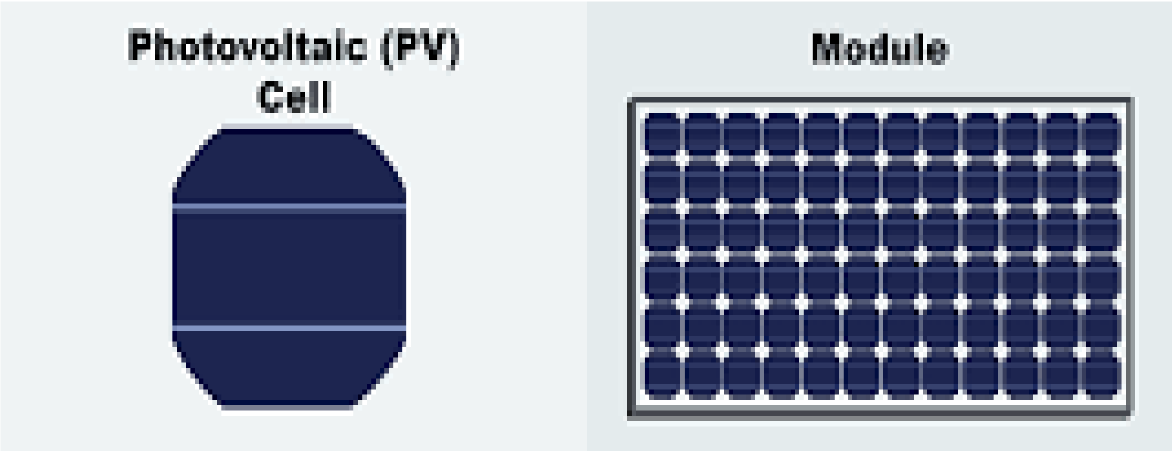
The barrier field existing across the **pn** junction causes the electron hole pair to separate.

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:



The output voltage of a single cell is very small and is about 0.3 to 0.5V.

Photovoltaic cells are connected electrically in series and/or parallel circuits to produce higher voltages, currents and power levels. Photovoltaic modules consist of PV cell circuits sealed in an environmentally protective laminate, and are the fundamental building blocks of PV systems.

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.

UNIT III: Solar photovoltaic system and wind power plant

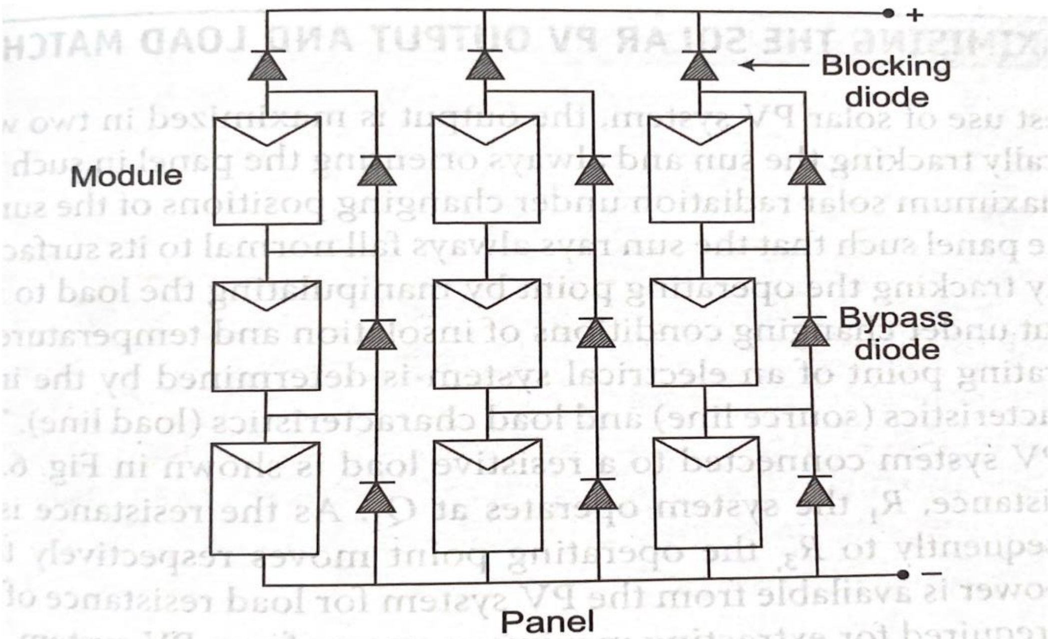
Session 16

Overview:

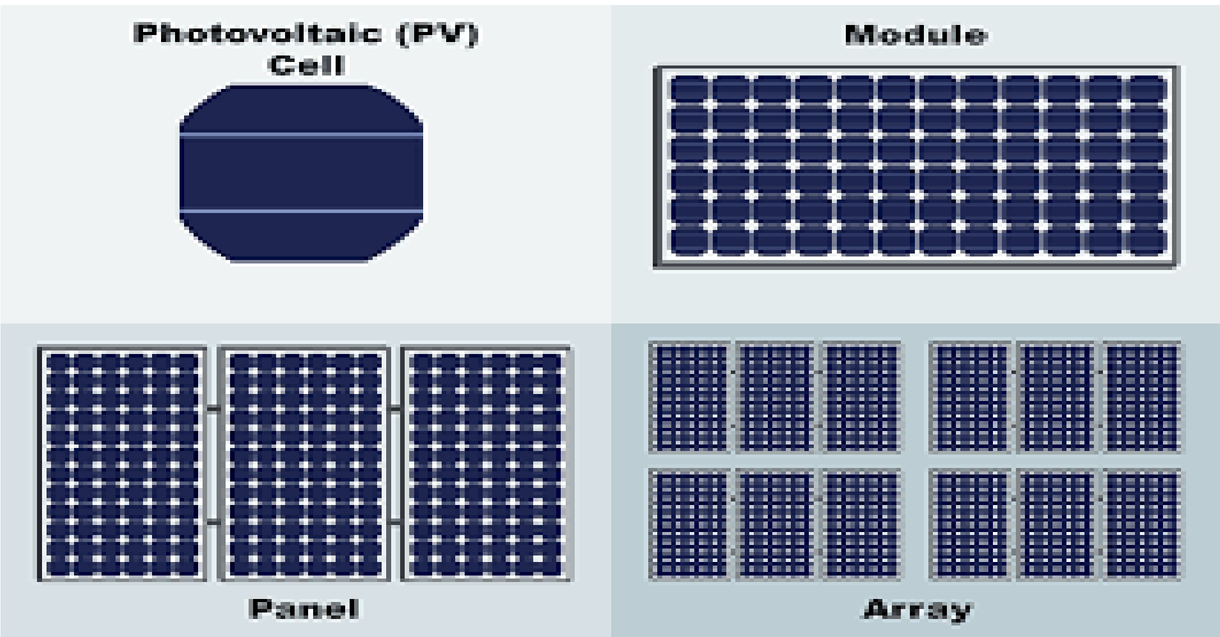
- **Construction of photovoltaic panel and PV array with block diagrams**
- **Materials used in solar cells**
- **Solar cell applications**

Construction of photovoltaic panel

- A single solar module can produce only limited power
- So most installations contain multiple modules connected in series -parallel combination to increase the voltages or current in the working system
- Photovoltaic panels include one or more PV modules assembled as a pre-wired, field-installable unit.
- In parallel connection,
  - if any string fail, blocking diodes will prevent absorption of power output of the remaining strings from the failed string.
  - Bypass diodes are used to bypass the failed module.



Construction of Photovoltaic array



- A large number of interconnected solar panels constitute PV array.
- A photovoltaic array is the complete power-generating unit.
- There are two types of solar arrays namely:
  - Tracking arrays
  - Fixed arrays

Tracking arrays are movable type and they are always aligned perpendicular to the direction of sun rays to receive maximum solar radiation.

A fixed array is placed east-west and tilted at an angle equal to the latitude of that place.

Materials Used in Solar Cell:

The materials used for the solar cells must have the following properties:

- They must have an energy band gap of 1ev to 1.8ev.
- They must have high optical absorption.
- They must have high electrical conductivity.
- The raw material for solar cell must be available in abundance and the cost of the material must be low

Based on these criteria, the following are the commonly used materials for solar cells.

- 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.

UNIT III: Solar photovoltaic system and wind power plant

Session 17

Overview:

Classification of solar photovoltaic systems

There are three types of photovoltaic power systems namely:

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

UNIT 3: Solar photovoltaic system and wind power plant

Session 18

Overview:

- Stand-alone Solar PV System
- Grid interactive Solar PV System

Stand alone solar photovoltaic system:

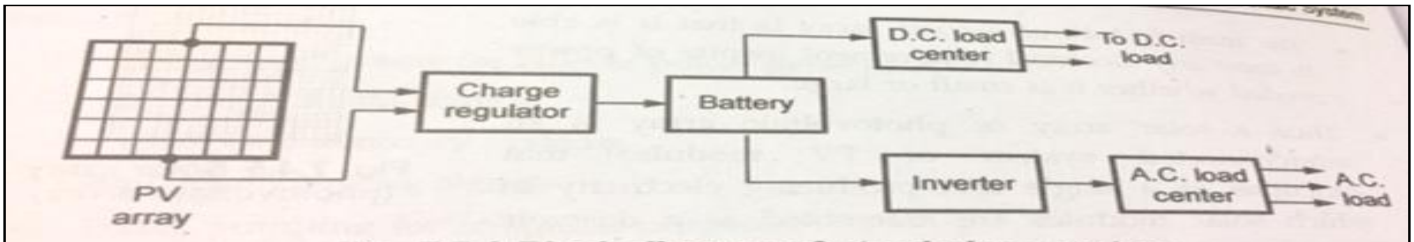
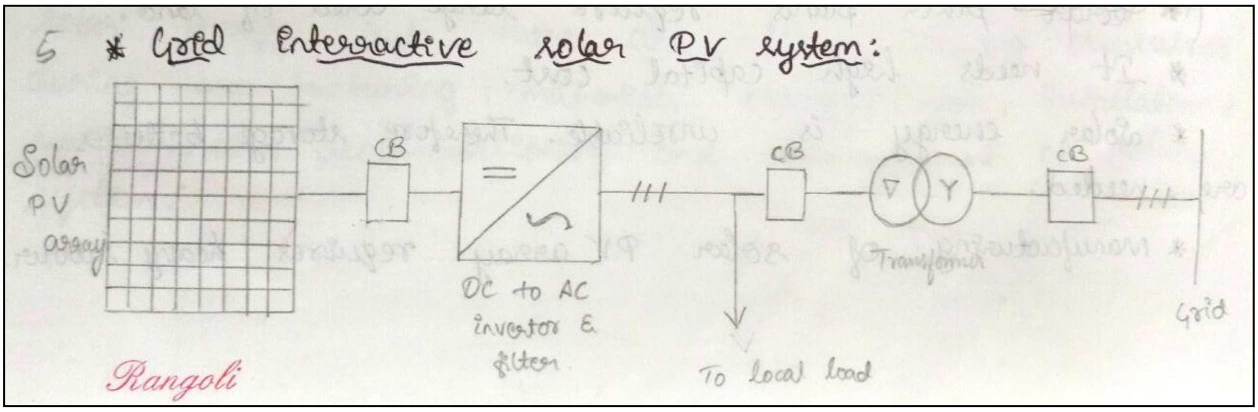


Fig. 7.5.1 Block diagram of stand alone system

- Fig shows the block diagram of standalone 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:



In grid interactive solar photovoltaic system, all the excess power is fed to the central power grid.

Fig shows the block diagram of grid interactive solar photovoltaic system.

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 and then the harmonics are filtered.

The filtered 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.

UNIT III: Solar photovoltaic system and wind power plant

Session 19

Overview:

- Advantages and disadvantages of PV Systems
- Environmental impacts of solar PV system on environment

Advantages of solar photovoltaic system:

- 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 of solar photovoltaic system:

- 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.

UNIT III: Solar photovoltaic system and wind power plant

Session 20

Overview:

Importance of Wind Energy. Explain the origin of Global and local winds

Importance of wind energy

- Wind energy is the kinetic energy associated with the movement of large masses of air. The movements of air result from uneven heating of the atmosphere by the sun creating temperature, density and pressure difference. Thus it is an indirect form of solar 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.

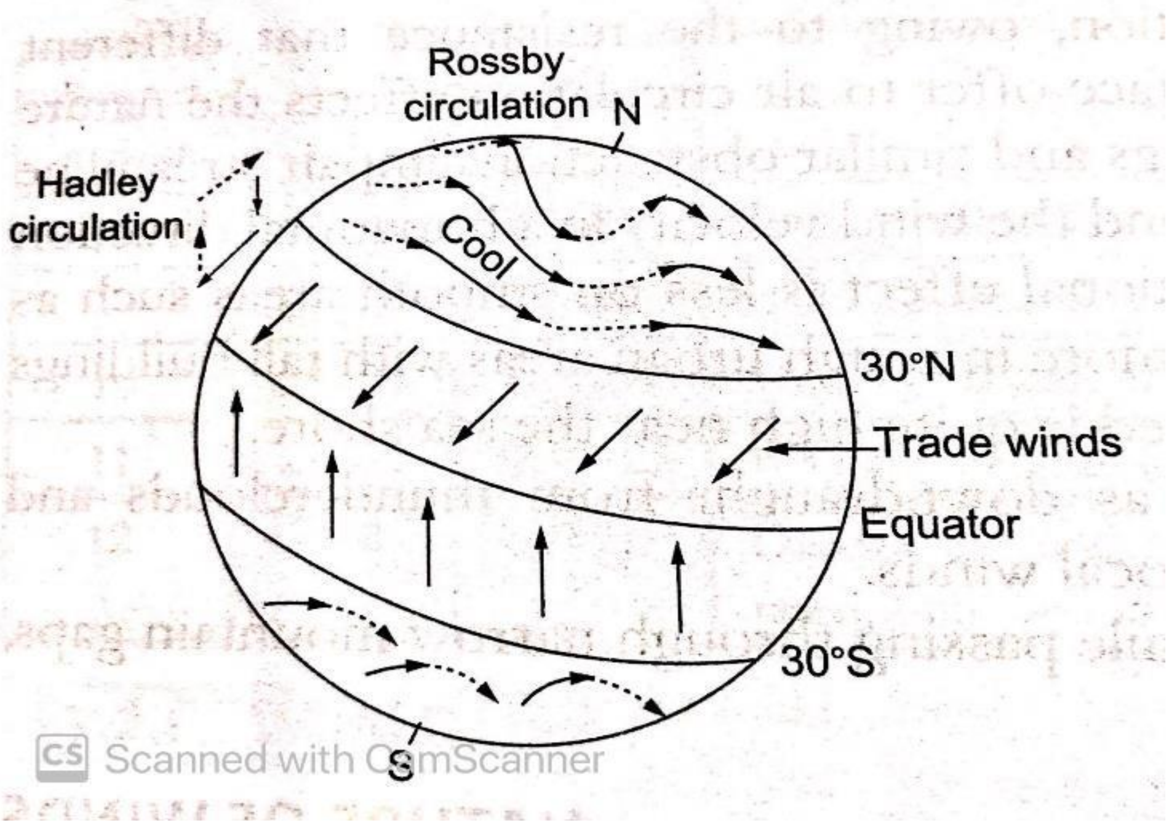
- Wind energy is converted into mechanical energy with the help of wind turbine. The mechanical energy thus obtained can be used to operate farm appliances and water pumps. It can also be converted into electrical energy by coupling a generator to the wind turbine. A generator coupled to the wind turbine is known as aero-generator.

- Wind speeds ranging from 20km/h to 25km/h are required for power generation using wind turbines.
- With modern blade materials, the life of wind turbine has exceeded 20 years. The installation cost is also comparable with conventional thermal power plant. Due to these reasons, the wind energy is gaining importance and is competing with conventional power sources.
- Global installed capacity by the end of year 2007 has reached 94,123 MW. India has an installed capacity of 8000MW at the end of year 2007.

Origin of winds

There are two sources of winds namely, global winds and local winds.

Global winds:



Global winds are produced due to difference in heating of the earth at equatorial and polar regions. The solar radiation causes temperature at equator to be more than that of polar region. Therefore the warmer air over the equator starts moving towards the poles and the cold air from the poles move towards the equator. This exchange of warm and cold air between the equator and the poles produces global wind belts. Earth's rotation about its axis creates a force called 'coriolis' force. This force causes the direction of the winds to bend toward west and causes circulation of global wind.

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 the direction of wind to reverse. This results in local winds.

Similarly there is a differential heating between low land and hill slopes. The hill slopes heat up during the day and cool down at night more rapidly than that of low land. This causes cool air to blow from land to the hill slope during day and from the hill slope to land during night. This also results in local winds.

UNIT III: Solar photovoltaic system and wind power plant

Session 21

Overview:

Factors affecting distribution of wind energy on surface of the earth.
Factors to be considered for site selection.

Factors affecting the distribution of wind energy on the surface of the earth:

Many factors are responsible for distribution of wind energy on the surface of the earth. Some are global factors and others are local factors. The factors affecting are:

- On the global level, high mountains affect the circulation of wind.
- The friction caused by hills, trees, buildings, etc obstruct the circulation of wind.
- Frictional effect is less on smooth surface of seas and therefore wind speed is high on seashore.
- Climatic disturbances such as rainfall also affect the circulation of wind.
- Turbulence results in wind velocity to get reduced.
- Wind speed increases while passing through narrow mountain gaps where it gets channelized.

Factors to be considered for site selection of wind power plants:

- The site selected for wind power plant should have an average wind speed of 20-30km/h.
- 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.
- 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.
- The land should be accessible by road or rail.
- The site should be near the load center to reduce transmission cost and losses.

Merits of wind power plant:

- Wind power stations are non-polluting.
- It uses renewable source of energy which is free of cost.
- The energy generated by wind power station is cheaper.
- It avoids fuel transport.
- It is simple in construction and requires less maintenance.

Demerits of wind power plant:

- Wind energy is fluctuating in nature.
- Wind power plant needs storage devices because of irregularity in wind speed.
- It is suitable for only small power generation.
- Its operation is noisy.

UNIT III: Solar photovoltaic system and wind power plant
Session 22

Overview:

- Nature of winds with neat sketches,

Nature of wind:

To predict the performance of wind turbines and for proper designing the supporting structure for wind turbines, it is necessary to study the nature of winds. The beaufort scale gives the description of the nature of the wind. The description of wind based on beaufort numbers is given in table below:

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

UNIT III: Solar photovoltaic system and wind power plant
Session 23

Overview:

Classification of wind turbine generator,

Comparison between horizontal axis and vertical axis wind turbine generator

Environmental Impact of wind plants.

Classification of wind turbine generator

- Horizontal axis wind turbine generator.
- Vertical axis wind turbine generator.

Horizontal axis wind turbine generator:

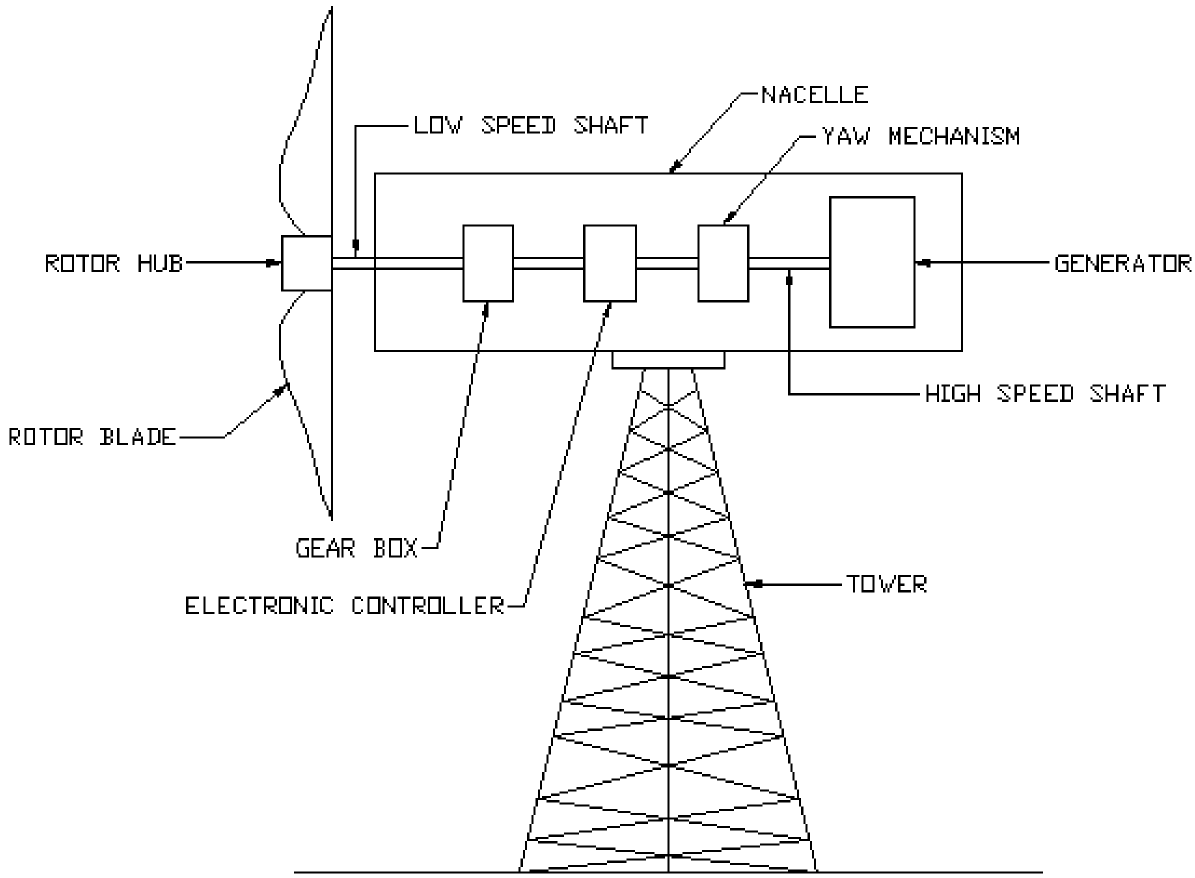
Horizontal axis wind turbine is the commonly used type of wind turbine. In this turbine shaft is mounted horizontally parallel to the ground. All the components are mounted on a tower of about 80m height. The following are the components of the horizontal axis wind turbine generator,

Rotor blades: About 2 or 3 blades are mounted on the rotor hub. These blades capture wind energy and convert it into rotational energy of shaft.

Shaft: Transfers rotational energy from the wind turbine to the electric generator.

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

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



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

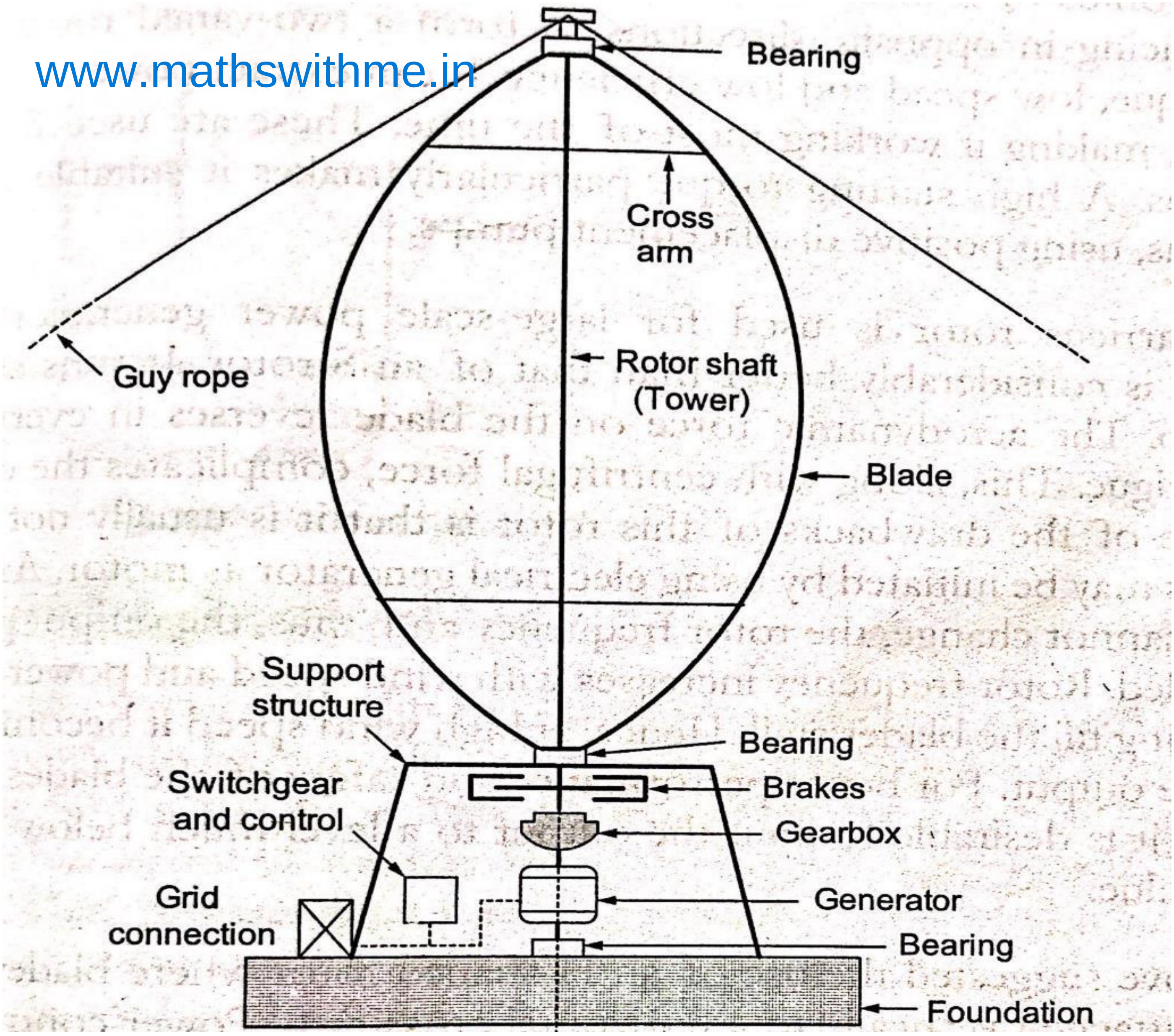
Yaw mechanism: Moves the rotor to align with the direction of wind to capture maximum wind energy.

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

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

Vertical axis wind turbine generator:

Fig shows the constructional details of vertical axis wind turbine generator. In this turbine, the rotor turbine is perpendicular to the ground. The following are the important components of 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 control.

Support structure: The support structure is provided at the ground and it has gear box, brakes, generator and switch gear controls. The gear box increases the speed of the turbine shaft from 30-60 rpm to match with generator speed of 1500-1800 rpm. The brakes stop the rotation of shaft in case of overload or system failure. The generator converts rotational energy of the shaft into electrical energy. The electrical energy is fed to the grid through switch gear control.

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	They use tower for support.	They use 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.
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	They take little ground space.	They take large ground space.
8	Energy output is more.	Energy output is less.

Environmental Impacts of Wind Power Plant:

The environmental impact of wind turbine power plant is very less when compared to the fossil fuel power plants. But there are certain negative impacts of wind power plants on the environment. They are as follows:

- **Land use impact:** Wind turbine installations use a large area. But the vegetation clearing and ground disturbance is very less when compared with thermal power stations. Less than one acre per megawatt of land is disturbed permanently by wind power plant. The remaining land can be used for other purposes like livestock grazing, agriculture, highways, etc.
- **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.
- Noise from the wind turbine may result in stress and stress related diseases in human beings. By making design changes, using insulating materials and by using proper sites the noise impacts can be minimized.
- **Visual Impacts:** Due to their height, wind turbines are highly visible structures in any landscape. They may result in aesthetic impacts to the landscape.
- **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.
- **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. Another impact of wind turbines is that they interfere with radar and telecommunication facilities.

UNIT IV: URBAN WASTE ENERGY CONVERSION

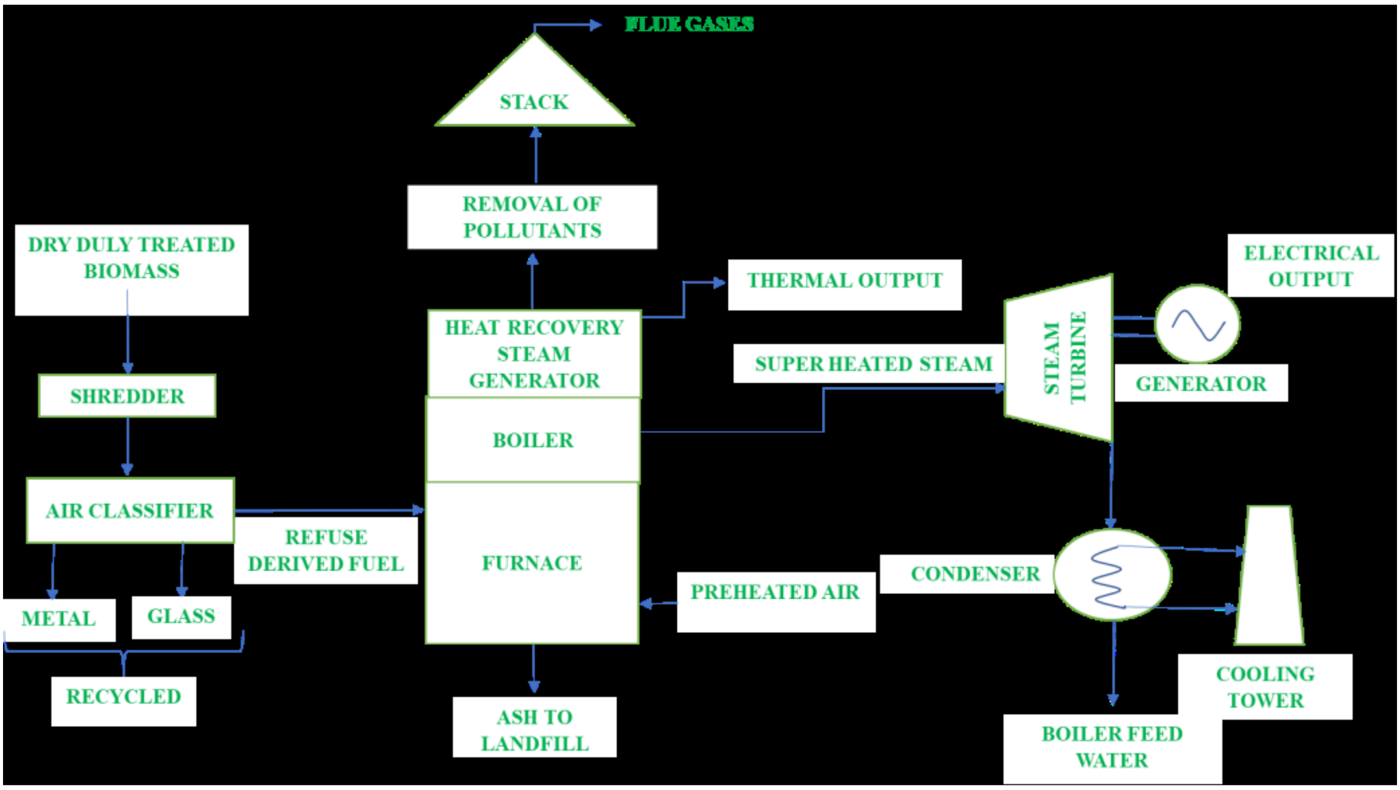
Session 25

Overview:

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 centers.
- The solution for this problem is to use MSW incineration plant.
- In this plant, the waste biomass is used as an energy source for electricity generation for the city itself.
- The small residue of used biomass (ash) from MSW incineration plant can be disposed in the landfills.

MSW incineration plant



- Figure shows the block diagram of MSW to energy incineration plant.
- The dry biomass is cut (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 undergoes combustion in presence of preheated air in a furnace at about 1000^0C.
- The combustion process may be assisted by using auxiliary fuel if needed.
- The hot flue gases from the furnace is used to produce steam in the boiler.
- The superheated steam thus obtained from the boiler is used to run steam turbine coupled with an alternator to generate electricity.

• The exhaust steam from the steam turbine is condensed using condenser and cooling tower and is fed back to the boiler as feed water.
• The heat recovery steam generator (HRSG) extracts maximum possible heat from the flue gases to form thermal output. This may be utilized for preheating air and feed water to the boiler.
• The flue gases are then discharged in to 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.

UNIT- IV: Biomass Power, Fuel Cell and Hybrid PV Systems
Session - 26

Overview:

Bio Energy: Describe biomass and its sources,
Importance of biomass energy and its scope,
Conversion process,
Biomass briquetting,
Benefits of Biomass.

Biomass:
• Biomass is renewable organic material that comes from plants, animals, fungi and bacteria.

• Energy obtained from biomass is known as bio energy.

Sources of Biomass:
1. **Forests:**

Forest is a source for fuel wood, charcoal and producer gas.

2. **Agricultural Residues:**

Crop residues such as rice husk, coconut shell, groundnut shell, sugarcane bagasse can be gasified to get producer gas. They can also be converted into pellets and used as solid fuel.

3. Energy Crops:

Crops like sugar cane, sugar beet, starch plants, oil producing plants form the raw material for biofuel.

4. Aquatic Plants:

Water plants like hyacinth, seaweed and algae provide raw material for biogas.

5.Urban Waste:

There are two types of urban waste a) Municipal solid waste b) Sewage. Energy from MSW is obtained from combustion. Sewage can be used to produce biogas.

Importance of biomass energy and its scope:
• Biomass is renewable organic material that comes from plants, animals, fungi and bacteria.

• 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.

• It can be used for generation of heat for domestic and industrial purposes. It can also be used to generate electricity with the same equipment or power plants that are used for 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 Conversion Process:

The following are the different methods used for extracting energy from biomass.

1. Physical Method: In this type, the volume of the biomass is reduced by compression through the processes called briquetting and palletisation. This method reduces the moisture in the biomass and increases its heat value.

2. Incineration: In this method, the biomass undergoes direct combustion. The heat produced by combustion is used for industrial processes, cooking and for generating electricity.

3. Thermochemical: In this method, the biomass is heated in the absence of oxygen to produce either gaseous fuel, oil like liquid or charcoal. This method is known as pyrolysis.

4. Biochemical: In this method, the wet biomass and animal waste undergoes anaerobic fermentation by the action microorganisms to produce biogas.

Biomass briquetting:

• Biomass briquettes are wooden pellets made from wooden matters like saw dust and agricultural waste.

• Briquetting of wood is done by compressing and squeezing to remove moisture and breaking its elasticity to form pellets.

• There are no binders involved in this process. The natural lignin in the wood binds the wood particles to form the solid piece.

• As the moisture content of briquettes is low, they are highly efficient than burning firewood.

• They are used in place of fossil fuels like coal and oil for heating in boilers.

Benefits of Biomass:

- It is a renewable energy source.
- The pollutant emissions by combustion of biomass are lower than that of fossil fuels.
- Use of biomass energy reduces the problems of disposal of industrial waste and municipal urban waste.
- Use of biogas plants leads to improved sanitisation and better hygienic conditions in rural areas.
- Nitrogen rich biogas sledge forms good manure for plants.
- Biomass plants of any capacity can be installed and operated.

UNIT- IV: Biomass Power, Fuel Cell and Hybrid PV Systems

Session - 27

Overview:

• Electricity generation using biomass
• Factors to be considered for site selection
• Line diagram of biomass power plant.

Electricity generation using biomass:

Renewable biomass fuels can be used for generating electricity similar to fossil fuels. There are three ways to use the energy stored in biomass to produce electricity:

1. Burning: Burning is the commonly used method. In this, electricity is generated from biomass by direct combustion. Biomass is burned in a boiler to produce high-pressure steam. This steam is used to rotate steam turbine which in turn drives a generator, producing electricity.

2. Bacterial Decomposition (Anaerobic Digestion): In this method, the wet biomass such as animal dung or human sewage undergoes anaerobic decomposition to produce biogas. This biogas can be used to generate electricity.

3. Conversion to a Gas or Liquid Fuel: Biomass can be converted to a gaseous or liquid fuel through pyrolysis. The gaseous fuel called syngas can then be burned in a conventional boiler to produce electricity. Similarly, the liquid fuel called bio-oil can be used in place of diesel for electricity production.

Factors to be considered for site selection of biomass plants:

i. **Availability of Biomass:** Huge quantity of biomass should be available at the site selected.

ii. **Availability of water:** Large quantity of water is required for steam generation. Hence abundant water should be available at the site selected.

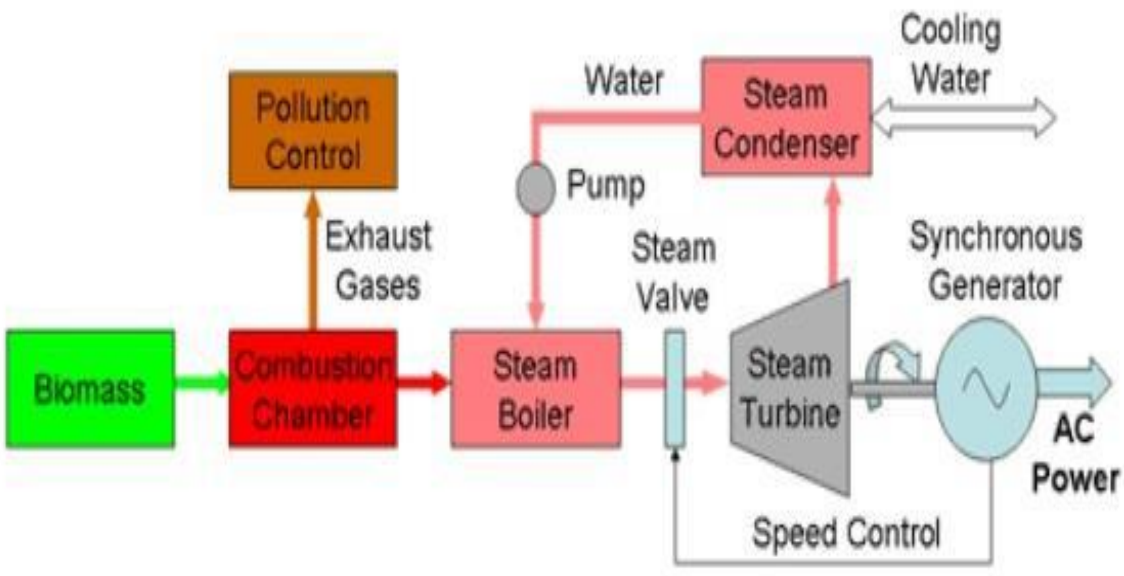
iii. **Transportation facilities:** The plant area should be well connected by road or rail for transportation of biomass.

iv. **Cost and type of land:** The cost of the land should be low. The land should be suitable for installing huge equipment of biomass plant.

v. **Distance from populated areas:** As large quantity of particulate matters is released by the combustion of biomass; the site should be away from populated areas.

vi. **Nearness to load centres:** The site should be close to the load centres to minimise transportation cost and losses.

Line diagram of biomass power plant:



Electricity Generation Powered by Biomass

Figure shows the line diagram of biomass power plant. The different components of biomass power plant are:

i. **Combustion Chamber:** In combustion chamber, the biomass consisting of wood chips and other organic waste matter undergoes combustion in presence of oxygen to produce large quantity of heat.

ii. **Steam Boiler:** The heat produced in the combustion chamber is used for raising steam in the steam boiler.

iii. **Steam turbine:** The high-pressure steam generated in the boiler is then passed on the steam turbine. Here thermal energy of steam is converted into mechanical energy.

iv. **Generator**: The steam turbine in turn rotates the electrical generator to generate electricity.

v. **Steam Condenser:** The low-pressure exhaust steam from the steam turbine is condensed in steam condenser and fed back to the boiler as feed water.

vi. **Pollution Control:** Hot flue gas from the combustion chamber is cleaned in an electrostatic precipitator to remove ash and other particulate matter before releasing into atmosphere.

UNIT- IV: Biomass Power, Fuel Cell and Hybrid PV Systems

Session - 28

Overview:

Bio fuels, Biogas plant, Types of biogas plant

Biofuels:

• Biofuels are the renewable energy source made from biomass such as corn or sugar, vegetable oils or waste feedstocks.

• Biofuels emit less carbon dioxide (CO2) than conventional fuels. Hence, they are blended with existing fuels to reduce CO2 emissions in the transport sector.

There are two types of bio fuels namely:

1. Ethanol: Ethanol is produced by fermenting sugar or starch products such as sugarcane or corn. It is blended with petrol at levels up to 10% or higher and is used in vehicles called "flex-fuel" vehicles.

2. Biodiesel: Biodiesel is produced from vegetable oils and animal fats. It is blended with diesel at low levels up to 7%.

Biogas plant:

• Biomass can be converted into a more convenient form of gaseous fuel called biogas.

• Biogas is produced in a digester by anaerobic decomposition of wet biomass such as animal dung or human sewage by the action bacteria.

• Biogas mainly contains methane (CH_4) and carbon dioxide (CO_2) and small amounts of hydrogen sulphide (H_2S).

• Biogas plants use biogas as fuel to produce electricity.

Types of biogas plants:

Biogas plants are mainly classified as:

1. Batch type biogas plant

2. Continuous type biogas plant

2a) Floating drum type biogas plant

2b) Fixed dome type biogas plant

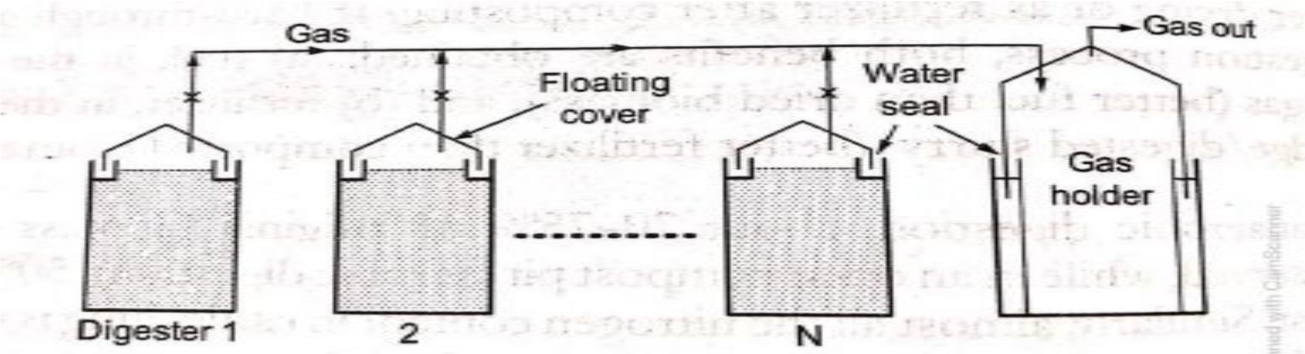
1. Batch type biogas plant:

• In batch type plant, the digester is filled with biomass. 8-10 days after filling, it starts producing biogas.

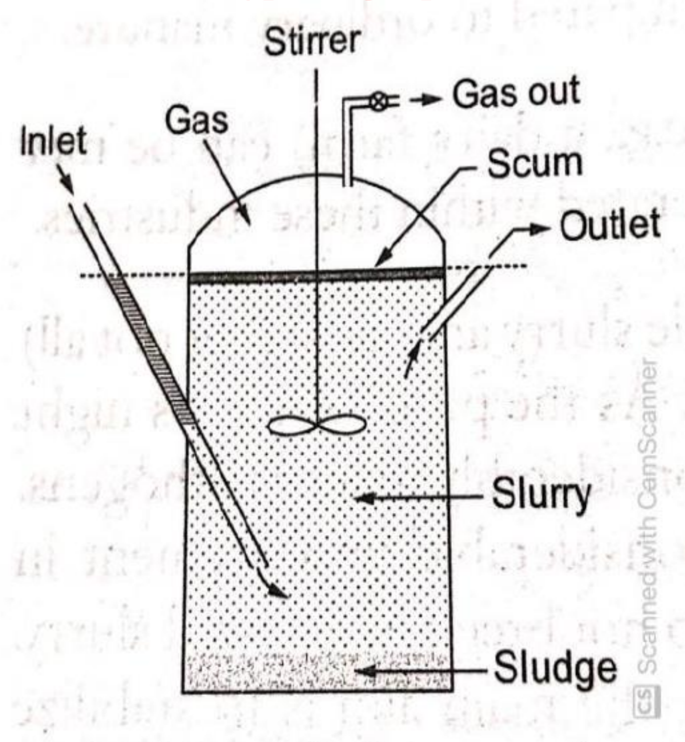
• The biogas is produced continuously for about 40-50 days.

• After the digestion is complete and biogas production stops, the residue is emptied and digester is filled again.

• A battery of digesters is used and the digesters are filled and emptied one by one so that continuous supply of gas is maintained in a common gas holder



2. Continuous type biogas plant:



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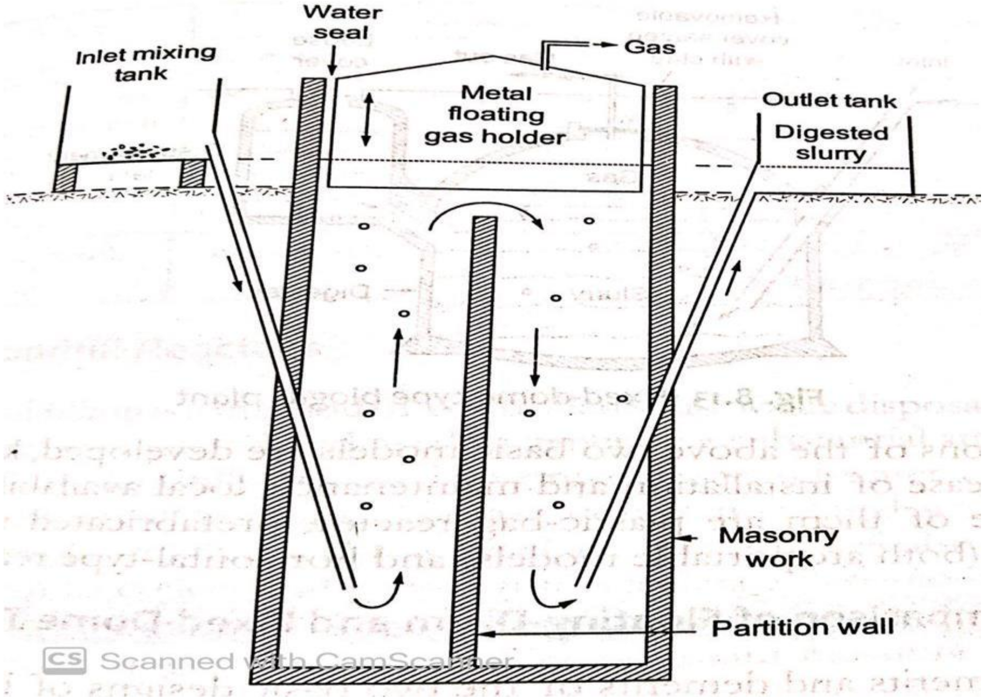
- In continuous type biogas plant, the supply of the gas is continuous and the digester is fed with biomass regularly.

• The gas produced is stored in a gas holder which can be drawn out when required. The digested slurry is removed out through an outlet.

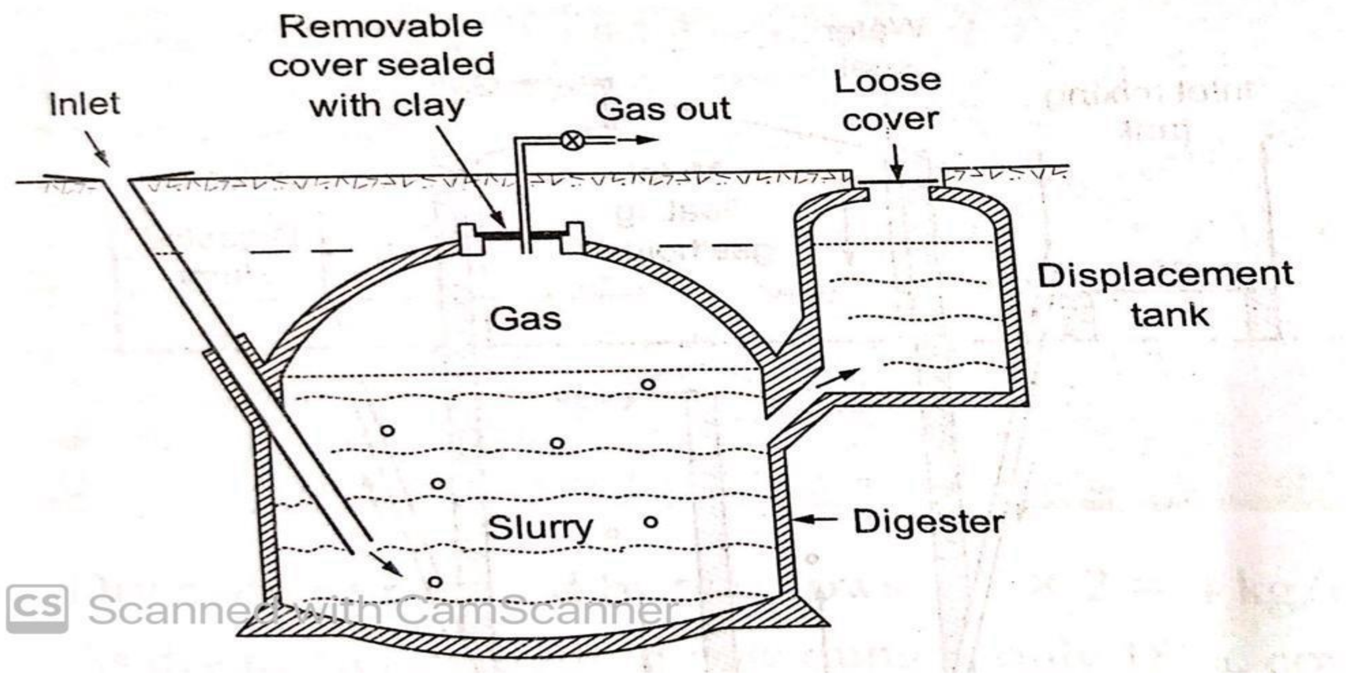
Types of Continuous type biogas plant:

2a. Floating Drum Type (Movable Drum Type) Biogas Plant:



- The floating drum type consists of a digester with an inlet on one side for feeding slurry and an outlet on the other side for removing digested slurry.
- Fig shows the line diagram of floating drum type biogas plant.
- Slurry (mixture of equal quantities of biomass and water) is prepared in a mixing tank and is fed into the digester through the inlet pipe.
- The plant is left unused for about two months. During this period, anaerobic decomposition of slurry takes place and produces biogas in the digester.
- The gas collects in a steel drum which is inverted over the slurry.
- The drum floats as the gas gets collected and it sinks when the gas is taken out from the top.

2b. Fixed dome type biogas plant:



- A fixed-dome plant consists of a fixed, non-movable gas holder, which forms the dome of the digester. Fig shows the line diagram of fixed dome type biogas plant.
- Slurry is prepared in a mixing tank and is fed into the digester through the inlet pipe.

- The plant is left unused for about two months. During this period, anaerobic decomposition of slurry takes place and produces biogas in the digester.
- The biogas starts collecting in the dome of the digester.
- When more and more gas is produced, the pressure inside the digester increases and the spent slurry is displaced into the displacement tank.
- This spent slurry can be used as manure for plants.
- The gas valve is opened whenever a supply of biogas is required.

UNIT- 4: Biomass Power, Fuel Cell and Hybrid PV Systems

Session - 29

Overview:

Chemical to energy source:
Fuel cells, Working of fuel cells,
Classification of fuel cells,
Applications of fuel cells

Fuel Cell:

Fuel cell is an electrochemical energy conversion device that converts chemical energy of the fuel directly into DC electrical energy.

Working of a Fuel Cell:

• Fuel cell mainly uses hydrogen as fuel. Fig shows the diagram of a fuel cell.

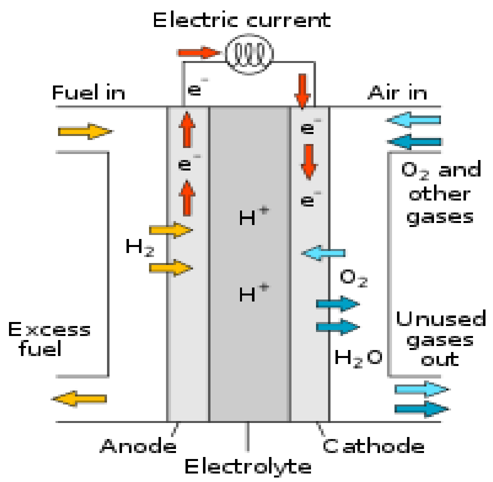
• It consists of two electrodes namely anode and cathode with an electrolyte between them.

• The hydrogen fuel is supplied to the anode and the oxygen is supplied to the cathode.

• At the anode, the hydrogen atom is split into positively charged H^+ ion and negatively charged electrons.

$$2H_2 \rightarrow 4H^+ + 4e^-$$

• The electrons from the anode flow to the cathode through an external circuit producing direct current electricity.



- The positive H^+ ions travel through the electrolyte to reach cathode.
- In the cathode, the H^+ ions combine with electrons and oxygen atom to form water. The water formed at the cathode is the by-product of the fuel cell.
  $$4H^+ + 4e^- + O_2 \rightarrow 2H_2O$$
- Each fuel cell generates an average DC voltage of about 0.7V.
- Several cells are connected in series- parallel combination to increase the current and voltage.

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

a) Phosphoric Acid Fuel Cell (PAFC)

b) Alkaline Fuel Cell (AFC)

c) Polymer Electrolytic Membrane Fuel Cell (PEMFC)

d) Molten Carbonate Fuel Cell (MCFC)

e) Solid Oxide Fuel Cell (SOFC)

Applications of fuel cells:
a) Used in central power generation

b) Used as residential power source of 5 to 10 KW

c) Used as power source for isolated sites such as construction sites and military camps

d) Used as emergency power supplies in hospitals

e) Used as power source in submarines and spacecrafts

f) Used to power electric vehicles for road and rail transport.

g) Used as power source in communication systems.

UNIT- 4: Biomass Power, Fuel Cell and Hybrid PV Systems
Session - 30

Overview:
- **Hybrid PV System,**
- **Types of Hybrid PV System,**
- **Block diagram of PV-Wind Hybrid System and**
- **PV-Fuel Cell Hybrid System.**

Hybrid PV System:
• 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 combination with solar PV system. Such systems are known as hybrid PV systems.

Types of Hybrid PV System:

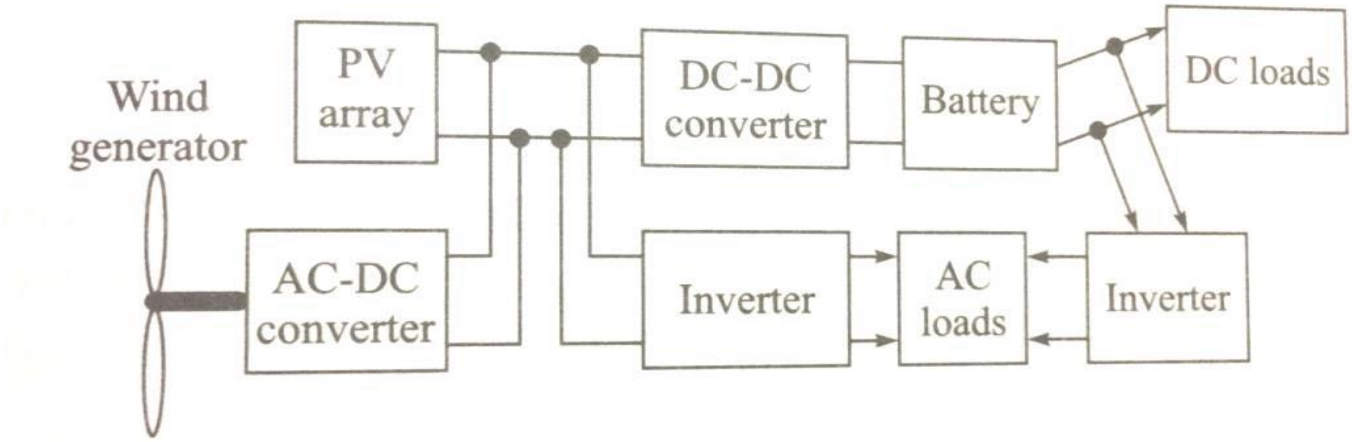
Hybrid PV systems are classified depending on the type of source used in combination with PV system. Accordingly, the following are the different types of hybrid PV systems:

• PV-diesel hybrid system

• PV-wind hybrid system

• PV-fuel cell hybrid system

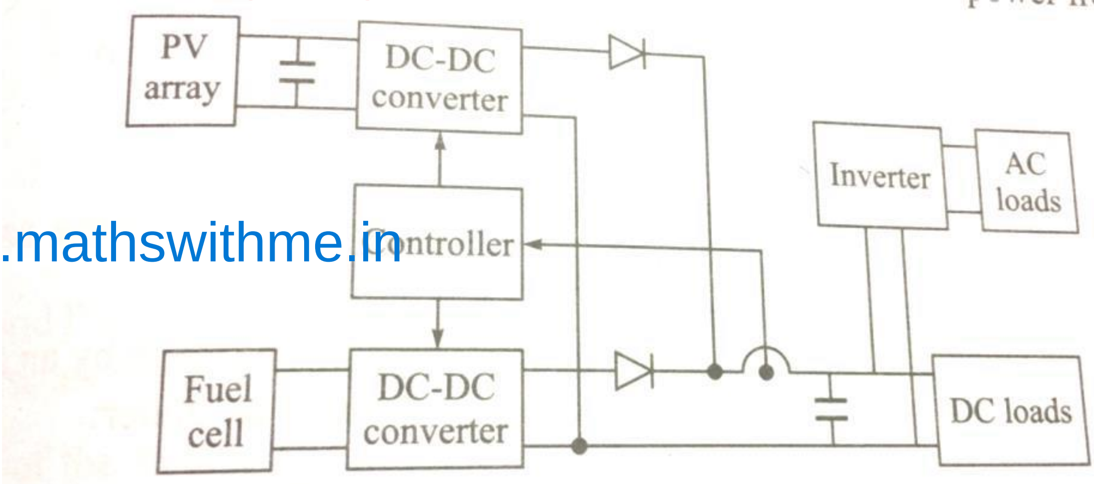
PV-Wind Hybrid System:



- Figure shows the arrangement of PV-wind hybrid system. The wind generator converts wind energy into AC electrical output.

- The variation of the wind velocity results in large changes in the frequency and output voltage of the wind generator.
- Hence the AC output of the wind generator is first converted to DC and then converted back to AC through the inverter. The inverter output is used to feed the AC loads.
- The DC output of the PV array and the rectified output of wind generator are connected in parallel to the DC link.
- The DC-DC converter is used for converting the DC link voltage to a suitable value for charging the battery and for feeding the DC loads.
- 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.
- Figure shows the arrangement of PV-fuel cell hybrid system. 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: Economics of Power Generation

Session-32

Overview: Connected Load,

- **Firm Power,**
- **Cold Reserve,**
- **Hot Reserve,**
- **Spinning Reserve.**

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Economics of Power Generation:

The art of determining cost of production of per unit of electrical energy is known as economics of power generation.

Note: 1 unit = 1 kWh =1000W X 1 hour

Connected Load:

The sum of continuous rating of all the equipment connected to electrical supply system is known as connected load.

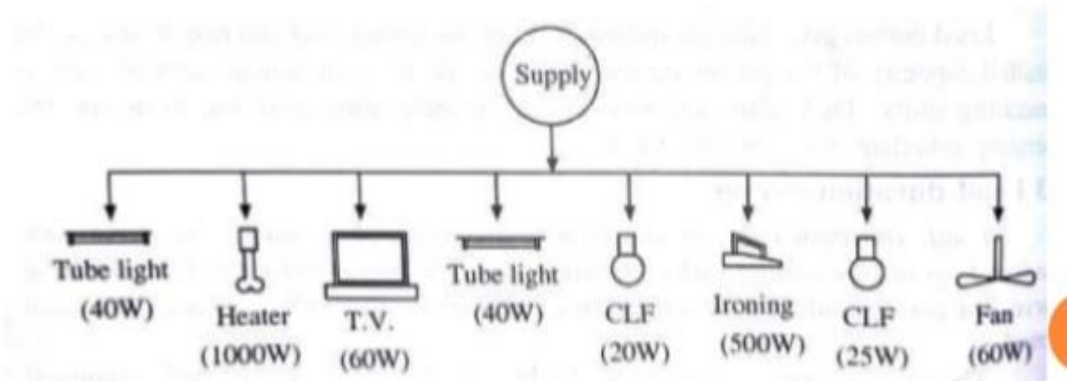


Figure shows the various load connected to the supply system. Therefore, the connected load of the above system is: 40+1000+60+40+20+500+25+60 = 1745W

Firm power: Firm power is the value of power which a power plant is supposed to produce throughout the year. It is the power which should always be available even under emergency conditions.

Cold Reserve: Cold Reserve is that reserve generating capacity of a plant which is available for service but is not currently in operation. For example, an idle generator is a cold reserve that can be put into service if demand arises.

Hot Reserve: Hot Reserve in a power system is that reserve capacity of a generating unit which is already in operation but not put into service. For example, a generator rated 200 MVA is currently supplying only 150 MVA. In this case, 50 MVA is the hot reserve that can be put into service when required.

Spinning Reserve: The spinning reserve is the extra generating capacity that is available by increasing the power output of generators that are already connected to the power system.

The power output of the generators is increased by increasing the torque applied to the turbine.

UNIT 5 Economics of Power Generation

Session-33

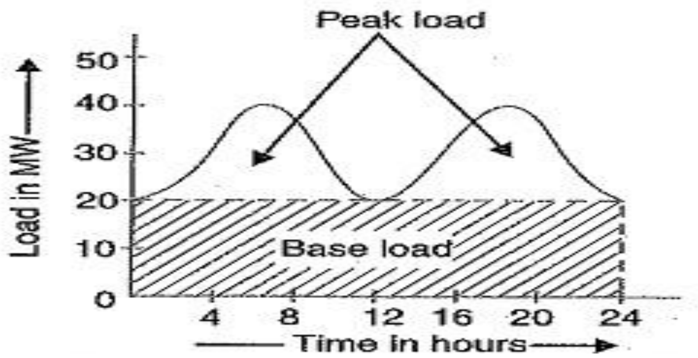
Overview: **Base load and Peak load**

Load Curve,

Load Duration Curve,

Integrated Duration Curve

Base-Load: The unvarying load which occurs on the station for the whole day is known as base load.

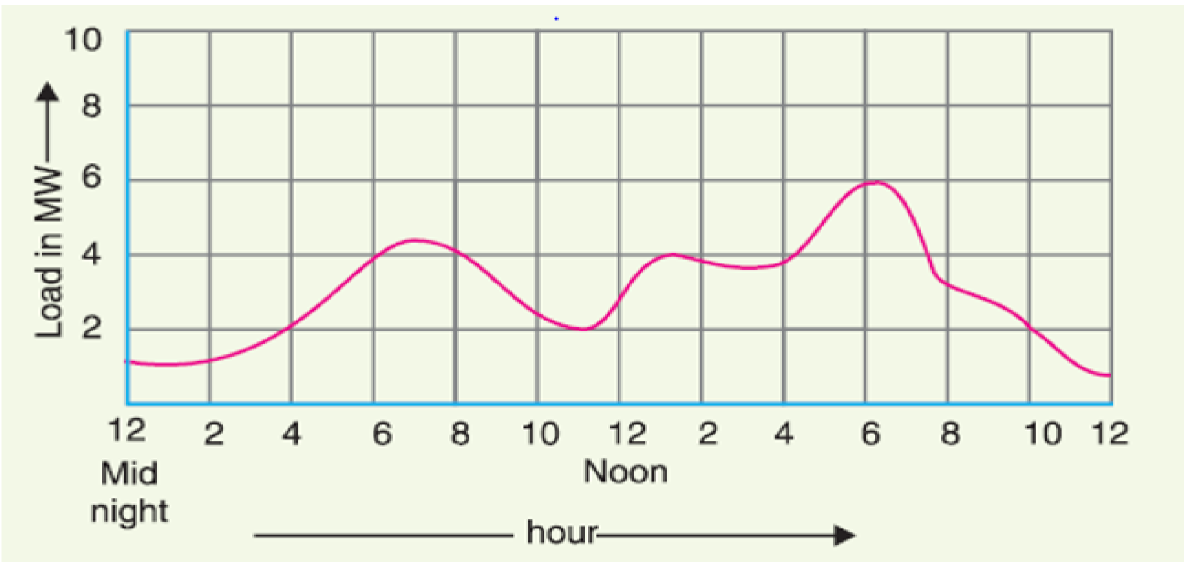


As seen from the load curve, it is clear that 20 MW of load has to be supplied by the station throughout the day. Therefore, 20 MW is the base load of the station. The base load on the station is almost constant in nature.

Peak-Load: The various peak demands of load over and above the base load of the station is known as peak load. As seen from the load curve, the peak demands of the station form a small part of the total load and may occur throughout the day.

Load curve:

The curve showing the variation of load on the power station with respect to time is known as load curve.



The Load curve gives the following information:

a) The daily load curve shows the variation of load on the power station during different hours of the day.

b) The area under the daily load curve gives the number of **units generated in the day.**

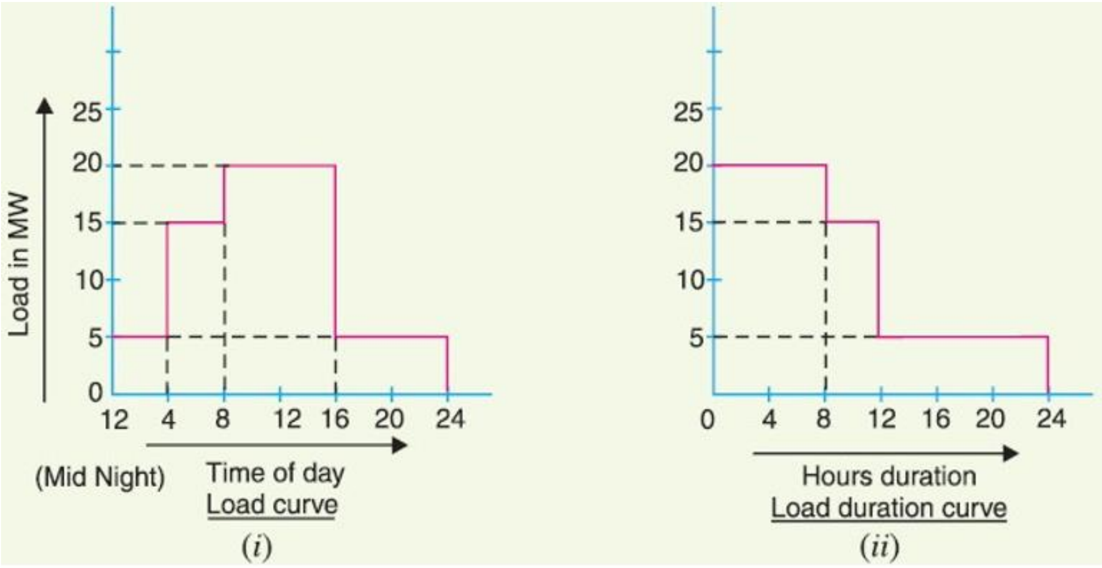
Unit generated/day= Area (in kWh) under daily load curve.

c) The highest point on the daily load curve represents the **maximum demand** on the station on that day.

d) The area under the daily load curve divided by the total number of hours gives the **average load** on the station in that day.

e) The ratio of area under daily load curve to the total area of the rectangle in which it is contained gives the **load factor**.

Load duration curve

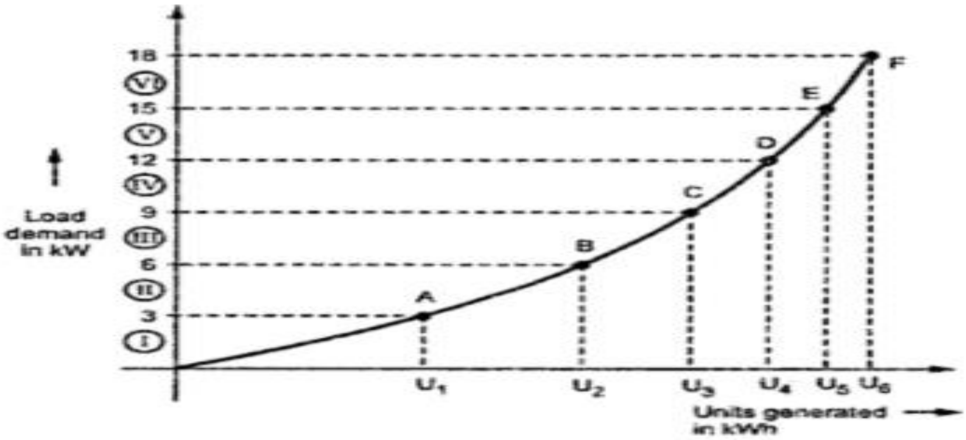


The load elements of a load curve arranged in the descending order of magnitudes gives load duration curve. Figure (i) shows the daily load curve. Figure (ii) indicates the load duration curve in which the magnitudes of load elements are in descending order.

The load duration curve gives the following information:

- The load duration curve readily shows the number of hours during which the given load has prevailed.
- Similar to load curve, the area under daily load duration curve (in kWh) also gives the number of units generated on that day.

Integrated duration curve: **A plot of number of units generated (kWh) for a given demand (kW) is called as integrated duration curve.** This curve can be drawn from load duration curve.



The above figure shows the integrated duration curve, its X-axis represents units generated in kWh and Y-axis represents demand of load in kW.

UNIT- 5: Economics of Power Generation

Session - 34

Overview: Cost of Generation: Average Demand, Maximum Demand, Demand Factor, Plant Capacity Factor, Plant Use Factor, Diversity Factor, Load Factor and Plant Load Factor.

Average Demand or Average Load: The average of loads occurring on the power station in a given period is known as average load or average demand.

- Daily Average Load = $\frac{\text{Number of Units (KWh) generated in day}}{\text{24 Hours}}$

- Monthly Average Load =$\frac{\text{Number of Units (KWh) generated in Month}}{\text{Number of Hours in a Month}}$

- Yearly or Annual Average Load = $\frac{\text{Number of Units (KWh) generated in Year}}{\text{24 Hours} * \text{365 Days in a Year}}$

Maximum Demand: It is the greatest demand of load on the Power Station during a giving period is known as Maximum Demand.

OR

The maximum demand of the power station is equal to maximum load on the station considered in a given period of time.

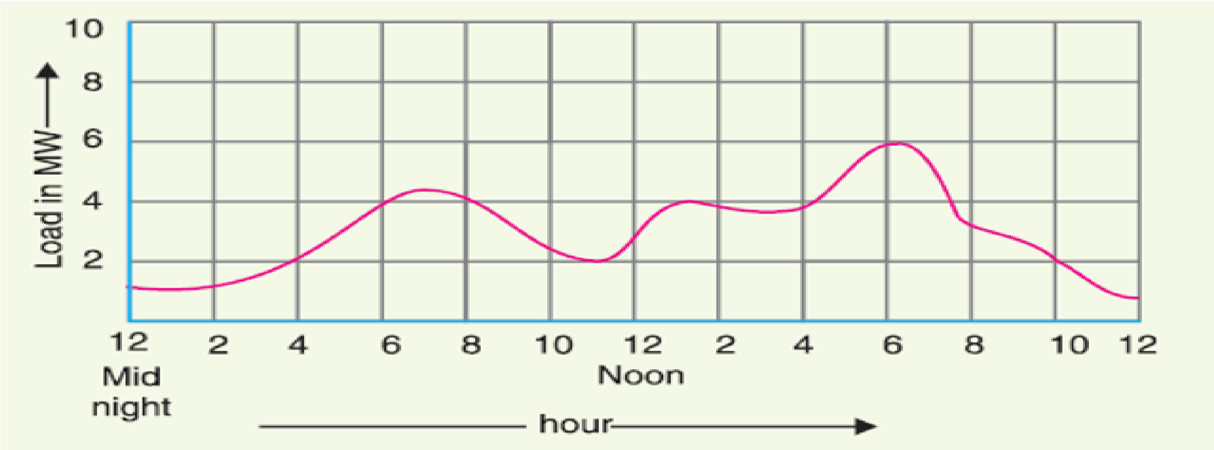


Fig: Load Curve

We know that, the load on every power station in not constant. The load varies from time to time. The variation of load on the power station is depends upon the demand of load with respect to time. Consider, the above figure, the figure X-axis Represents Time in Hours & Y-axis represents Load in MW. In this figure, at every two hours give information about how much load generated. Out of the 6MW load generated during evening period. So that maximum Demand is 6MW. The Knowledge of Maximum Demand is very important as it helps in determining the installed capacity of the power station

Demand Factor: It is the Ratio of Maximum Demand on the Power Station to its Connected Load.

$$\text{Demand Factor} = \frac{\text{Maximum Demand}}{\text{Connected Load}}$$

The value of Demand factor is usually less than 1. It is excepted because maximum demand on the power station generally less than the connected load.

The knowledge of Demand Factor is vital in determining the capacity of the plant equipments.

Plant Capacity Factor: The Plant Capacity Factor is the ratio of average demand on the Power Station divided by the maximum installed capacity of the power station.

$$\text{Plant Capacity Factor} = \frac{\text{Average Demand on the Power Station}}{\text{Maximum Installed Capacity of the Power Station}}$$

OR It is the ratio of actual energy produced to the maximum possible energy that could have been produced during a given period.

$$\text{Plant Capacity Factor} = \frac{\text{Actual Energy Produced}}{\text{Maximum possible Energy that could have been produced}}$$

The plant capacity factor is an indication of the reserve capacity of the plant.

Reserve Capacity = Plant Capacity Factor – Maximum Demand

Plant Use Factor: It is the ratio of kWh generated to the product of plant capacity and the number of hours for which the plant was in operation.

$$\text{Plant Use Factor} = \frac{\text{Output of Power Station in KWh}}{\text{Plant Capacity} * \text{Number of Hours Plant use}}$$

$$\text{Plant Use Factor} = \frac{\text{Actual Energy Produced}}{\text{Plant Capacity} * \text{Time in Hours}}$$

Plant use factor indicated how much is the plant capacity utilized, but it does not indicate the time for which the plant remained idle

Diversity Factor: The ratio of the sum of individual Maximum Demands to the Maximum Demand on power station

$$\text{Diversity Factor} = \frac{\text{Sum of Individual Maximum Demands}}{\text{Maximum Demand on Power Station}}$$

For the above mentioned formula the value of diversity factor is more than 1

OR

$$\text{Diversity Factor} = \frac{\text{Maximum Demand of Power Station}}{\text{Sum of Individual Maximum Demand}}$$

For the above mentioned formula the value of diversity factor is less than 1

Load Factor: The ratio of number of units actually generated in a given period to number of units which could have been generated with the same maximum demands is called as load factor for the station.

The Ratio of Average Load to the Maximum Demand during a given period is known as load factor.

$$\text{Load Factor} = \frac{\text{Average Load}}{\text{Maximum Demand}}$$

Assume that the plant is operation for ‘T’ Hours

$$\text{Load Factor} = \frac{\text{Energy Generated in a Given Period}}{\text{Maximum Demand} * \text{Hours of Operations in the Given Period}}$$

The load factor may be daily, monthly or yearly load factor, if the time period considered is a day or month or year. The value of load factor is always less than 1.

Plant Load Factor: The Plant Load Factor is defined as the ratio of output of power station in kWh to the rated capacity of the plant.

$$\text{Plant Load Factor} = \frac{\text{Output of Power Station in KWh}}{\text{Rated Capcity of the Power Station}}$$

The plant load factor indicated how best the plant capacity has been utilized but it does not indicate the time for which the plant remained idle.

Unit Generated per Annum: It is often required to find the kWh generated per annum form maximum demand & load factor.

Load Factor = $\frac{\text{Average Load}}{\text{Maximum Demand}}$

Average Load = Maximum Demand * Load Factor

Units Generated/Annum = Average Load in kW * No. of Hours in a Year

Units Generated/Annum = Maximum Demand in kW * Load Factor * 8760 (No. of Hours in a Year)

UNIT 5 Economics of Power Generation

Session-35

Overview: Simple problems on Cost of Generation:

1.The maximum demand on power station is 100 MW. If the annual load factor is 40%, calculate the total energy generated in a year.

Given Data:

Maximum Demand = 100MW = 100 * 10^3 kW

Annual Load Factor = 40% = 40/100 = 0.4

Total no. of days in year = 365

Total no. of hours in year = 365 * 24 hours of the day = 8760

To Find:

Total energy generated in a year.

Formula used:

Energy generated in a year = Units generated per annum = Maximum demand (in kW) * Load factor * Number of hours in a year

Solution:

Energy generated in a year **=** Maximum demand (in kW) * Load factor * Number of hours in a year

Energy generated in a year = (100 * 10^3) * 0.4 * 8760 = **3504 * 10^5 kWh**

2.A generating station has a connected load 120MW & it supplies maximum demand of 60 MW. The numbers of units generated in a year is 48 * 10^7 kWh. Calculate: i. demand factor ii. load factor.

Given Data:

Connected load = 120 MW = 120 * 10^3 kW

Maximum demand = 60 MW = 60 * 10^3 kW

Number of units generated in a year = $48 * 10^7$ kWh

To Find: i. Demand factor ii. Load factor

Formula Used:

i. Demand Factor = $\frac{\text{Maximum Demand}}{\text{Connected Load}}$

ii. Load Factor = $\frac{\text{Energy generated in a given period}}{\text{Maximum Demand} * \text{Hours of operations in the given period}}$

Solution:

i. Demand Factor = $\frac{\text{Maximum Demand}}{\text{Connected Load}} = \frac{60 * 10^3}{120 * 10^3}$ = **0.5**

ii. Load Factor = $\frac{\text{Energy generated in a given period}}{\text{Maximum Demand} * \text{Hours of operations in the given period}}$

Load Factor = $\frac{48 * 10^7}{60 * 10^3 * 24 * 365}$ = **0.9132**

3.A generating plant works on a maximum demand of 600MW. The annual load factor being 60% and capacity factor is 30%. Find the reserve capacity of the plant.

Given Data:

Maximum Demand = 600MW Annual load factor = 0.6

Capacity factor = 0.3

To Find: Reserve Capacity of the Plant

Formula Used:

Reserve capacity = Plant capacity – Maximum demand

Plant capacity = $\frac{Energy\ generated\ per\ annum}{Capacity\ factor * Number\ of\ hours\ in\ a\ year}$

Energy generated per annum = Maximum demand * Load factor * Number of hours in a year

Solution:

Energy generated per annum = Maximum demand * Load factor * Number of hours in a year

Energy generated per annum = $(600*10^3) * 0.6 * 8760 = 3153600 * 10^3$ kWh

Plant capacity = $\frac{Energy\ generated\ per\ annum}{Capacity\ factor * Number\ of\ hours\ in\ a\ year}$

Plant capacity = $\frac{3153600 * 10^3}{0.3 * 24 * 365}$ = 1200 * 10^3 kW = 1200MW

Reserve capacity = Plant capacity – Maximum demand

Reserve capacity = 1200 – 600 = **600MW**

4.A generating station has a connected load of 43MW and a maximum demand of 20 MW; the units generated being 61·5 * 10^6 kWh per annum. Calculate: (i) the demand factor and (ii) load factor.

Given Data: Maximum Demand = 20MW   Units generated per annum= 61.5*10^6 kWh

Connected load = 43MW

To Find: (i) the demand factor (ii) the load factor.

Formula Used:

Demand factor = $\frac{Maximum\ demand}{Connected\ load}$

Average demand = $\frac{Units\ generated\ per\ annum}{Hours\ in\ a\ year}$

Load Factor = $\frac{Average\ Demand}{Maximum\ Demand}$

Solution:

(i) Demand factor = $\frac{Maximum\ demand}{Connected\ load}$ = $\frac{20}{43}$ = **0·465**

Average demand = $\frac{Units\ generated\ per\ annum}{Hours\ in\ a\ year}$ = $\frac{61.5 * 10^6}{24 * 365}$ = **7020 kW**

(ii) Load Factor = $\frac{Average\ demand}{Maximum\ demand}$ = $\frac{7020}{20 * 10^6}$ = **0.351** = **35.1%**

5.A diesel station supplies the following loads to various consumers: Industrial consumer = 1500 kW; Commercial establishment = 750 kW Domestic power = 100 kW; Domestic light = 450 kW If the maximum demand on the station is 2500 kW and the number of kWh generated per year is 45 * 10^5 , determine (i) the diversity factor and (ii) annual load factor.

Given Data:

Maximum demand = 2500 kW   Number of kWh generated per year = 45 * 10^5 kWh

Individual maximum demands: Industrial consumer = 1500 kW

Commercial establishment = 750 kW

Domestic power = 100 kW

Domestic light = 450 kW

<u>To Find</u>: (i) the diversity factor (ii) the annual load factor

<u>Formula Used</u>:

(i) $\text{Diversity Factor} = \dfrac{\text{Sum of individual maximum demands}}{\text{Maximum demand on power station}}$

$$\text{Average Demand} = \frac{kWh\ generated\ per\ annum}{Hours\ in\ year}$$

(ii) $\text{Annual Load Factor} = \dfrac{Average\ demand}{Maximum\ demand}$

<u>Solution</u>:

$$\text{Diversity Factor} = \frac{\text{Sum of Individual Maximum Demands}}{\text{Maximum Demand on Power Station}}$$

$$= \frac{1500+750+100+450}{2500} = \mathbf{1.12}$$

$$\text{Average Demand} = \frac{kWh\ generated\ per\ annum}{Hours\ in\ Year} = \frac{45*10^5}{8760} = \mathbf{513.7\ kW}.$$

$$\text{Annual Load Factor} = \frac{Average\ Demand}{Maximum\ Demand} = \frac{513.7}{2500} = \mathbf{0.205} = \mathbf{20.5\%}.$$

6.A 100 MW power station delivers 100 MW for 2 hours, 50 MW for 6 hours and is shut down for the rest of each day. It is also shut down for maintenance for 45 days each year. Calculate its annual load factor.

Solution.

Energy supplied for each working day = (100 * 2) + (50 * 6)

= 500 MWh

Station operates for = 365 – 45 = 320 days in a year

∴ Energy supplied/year = 500 * 320

= 160,000 MWh

Annual load factor = $\frac{MWh\ supplied\ per\ Annum}{Max.Demand\ in\ MW * Working\ Hours}$ * 100

Annual load factor = $\frac{1,60,000}{100 * 320 * 24}$ * 100

= 20.8 %

References:

Principles of Power System by : V. K. Mehta & Rohit Mehta publisher S. Chand & company LTD, Ram Nagar, New Delhi.

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UNIT VI

Basics of Transmission and Distribution 15 Hrs

38. Electric Supply System

The conveyance of electric power from a power station to consumers' premises is known as **electric supply system**.

An electric supply system consists of three principal components viz., the power station, the transmission lines and the distribution system. Electric power is produced at the power stations which are located at favourable places, generally quite away from the consumers. It is then transmitted over large distances to load centres with the help of conductors known as transmission lines. Finally, it is distributed to a large number of small and big consumers through a distribution network. The electric supply system can be broadly classified into

(i) D.C. or A.C. system

(ii) Overhead or Underground system.

Now-adays,3-phase, 3-wire A.C. system is universally adopted for generation and transmission of electric power as an economical proposition. However, distribution of electric power is done by 3-phase, 4-wire A.C. system. The underground system is more expensive than the overhead system. Therefore, in our country, overhead system is *mostly adopted for transmission and distribution of electric power.

38.1 Typical A.C. Power Supply Scheme

The large network of conductors between the power station and the consumers can be broadly divided into two parts viz.

Transmission system and Distribution system.

Each part can be further sub-divided into two-

Primary Transmission and Secondary Transmission and

Primary Distribution and Secondary Distribution.

Fig 38.1 shows the layout of a typical A.C. power supply scheme by a single line diagram. It may be noted that it is not necessary that all power schemes include all the stages shown in the figure. For example, in a certain power scheme, there may be no secondary transmission and in another case, the scheme may be so small that there is only distribution and no transmission.

(i) Generating station:

In Fig G.S. represents the generating station where electric power is produced by 3-phase alternators operating in parallel. The usual generation voltage is †11 kV. For economy in the transmission of electric power, the generation voltage (i.e., 11 kV) is stepped upto 132 kV (or**more) at the generating station with the help of 3-phase transformers. The transmission of electric power at high voltages has several advantages including the saving of conductor material and high transmission efficiency. It may appear advisable to use the highest possible voltage for transmission of electric power to save conductor material and have other advantages. But there is a limit to which this voltage can be increased. It is because increase in transmission voltage introduces insulation problems as well as the cost of switchgear and transformer equipment is increased. Therefore, the choice of proper transmission voltage is essentially a question of economics. Generally the primary transmission is carried at 66 kV, 132 kV, 220 kV or 400 kV.

(ii) Primary Transmission:

The electric power at 132 kV is transmitted by 3-phase, 3-wire overhead system to the outskirts of the city. This forms the primary transmission.

(iii) Secondary Transmission:

The primary transmission line terminates at the receiving station (*RS*) which usually lies at the outskirts of the city. At the receiving station, the voltage is reduced to 33kV by step-down transformers. From this station, electric power is transmitted at 33kV by 3-phase, 3-wire overhead system to various sub-stations (*SS*) located at the strategic points in the city. This forms the secondary transmission.

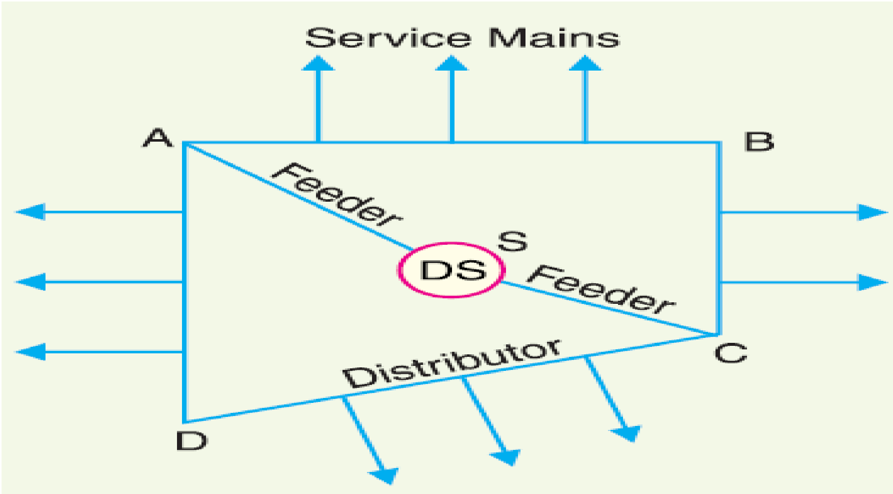
(iv) Primary Distribution:

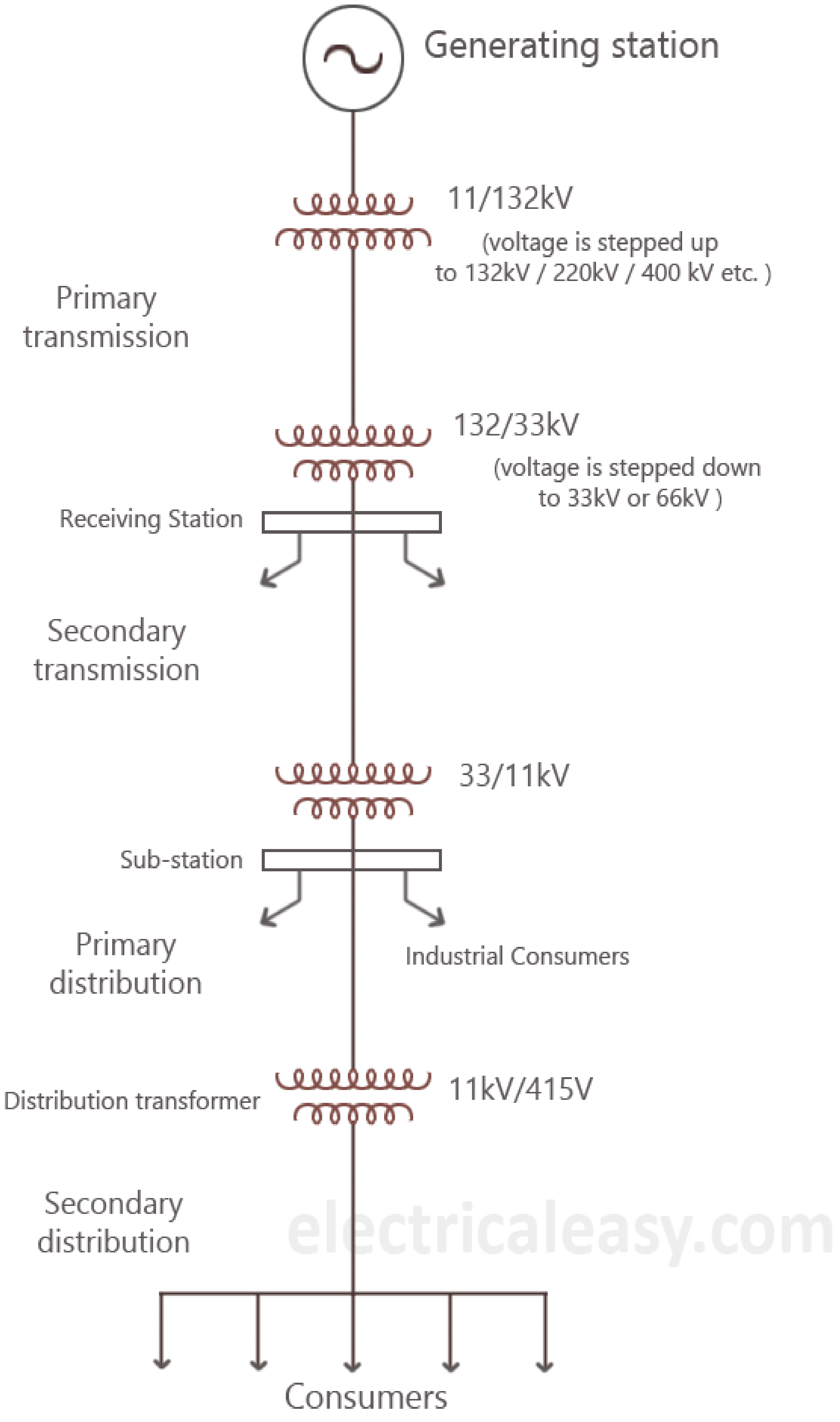
The secondary transmission line terminates at the sub-station (*SS*) where voltage is reduced from 33 kV to 11kV, 3-phase, 3-wire. The 11 kV lines run along the important road sides of the city. This forms the primary distribution. It may be noted that big consumers (having demand more than 50 kW) are generally supplied power at 11 kV for further handling with their own sub-stations.

(v) Secondary Distribution:

The electric power from primary distribution line (11 kV) is delivered to distribution sub-stations (*DS*). These sub-stations are located near the consumers' localities and step down the voltage to 400 V, 3-phase, 4-wire for secondary distribution. The voltage between any two phases is 400 V and between any phase and neutral is 230 V. The single-phase residential lighting load is connected between any one phase and neutral, whereas 3-phase, 400 V motor load is connected across 3-phase lines directly. It may be worthwhile to mention here that secondary distribution system consists of **feeders, distributors and service mains.** Fig. 38.2 shows the elements of low voltage distribution system. Feeders (*SC* or *SA*) radiating from the distribution sub-station (*DS*) supply power to the distributors (*AB*, *BC*, *CD* and *AD*). No consumer is given direct connection from the feeders. Instead, the consumers are connected to the distributors through their service mains.

Secondary distribution (Fig 38. 2)





Single Line Diagram of Power System (Fig 38.1)

40. Various Systems of Power Transmission

It has already been pointed out that for transmission of electric power, 3-phase, 3-wire A.C. system is universally adopted. However, other systems can also be used for transmission under special circumstances. The different possible systems of transmission are:

1. D.C. system

(i) D.C. two-wire.

(ii) D.C. two-wire with mid-point earthed.

(iii) D.C. three-wire.

2. Single-phase A.C. system

(i) Single-phase two-wire.

(ii) Single-phase two-wire with mid-point earthed.

(iii) Single-phase three-wire.

3. Two-phase A.C. system

(i) Two-phase four-wire.

(ii) Two-phase three wire.

4. Three-phase A.C. system

(i) Three-phase three-wire.

(ii) Three-phase four-wire.

Comparison of D.C. and A.C. Transmission

The electric power can be transmitted either by means of D.C. or A.C. Each system has its own merits and demerits. It is, therefore, desirable to discuss the technical advantages and disadvantages of the two systems for transmission of electric power.

1. D.C. transmission. For some years past, the transmission of electric power by D.C. has been receiving the active consideration of engineers due to its numerous advantages.

Advantages.

The high voltage D.C. transmission has the following advantages over high voltage A.C. transmission:

(i) It requires only two conductors as compared to three for A.C. transmission.

(ii) There is no inductance, capacitance, phase displacement and surge problems in D.C. transmission.

(iii) Due to the absence of inductance, the voltage drop in a D.C. transmission line is less than the A.C. line for the same load and sending end voltage. For this reason, a D.C. transmission line has better voltage regulation.

(iv) There is no skin effect in a D.C. system. Therefore, entire cross-section of the line conductor is utilised.

(v) For the same working voltage, the potential stress on the insulation is less in case of D.C.

system than that in A.C. system. Therefore, a D.C. line requires less insulation.

(*vi*) A D.C. line has less corona loss and reduced interference with communication circuits.

(*vii*) The high voltage D.C. transmission is free from the dielectric losses, particularly in the case of cables.

(*viii*) In D.C. transmission, there are no stability problems and synchronising difficulties.

Disadvantages

(*i*) Electric power cannot be generated at high D.C. voltage due to commutation problems.

(*ii*) The D.C. voltage cannot be stepped up for transmission of power at high voltages.

(*iii*) The D.C. switches and circuit breakers have their own limitations.

2. A.C. transmission. Now-a-days, electrical energy is almost exclusively Generated, Transmitted and Distributed in the form of A.C.

Advantages

(*i*) The power can be generated at high voltages.

(*ii*) The maintenance of A.C. sub-stations is easy and cheaper.

(*iii*) The A.C. voltage can be stepped up or stepped down by transformers with easy and efficiency. This permits to transmit power at high voltages and distribute it at safe potentials.

Disadvantages

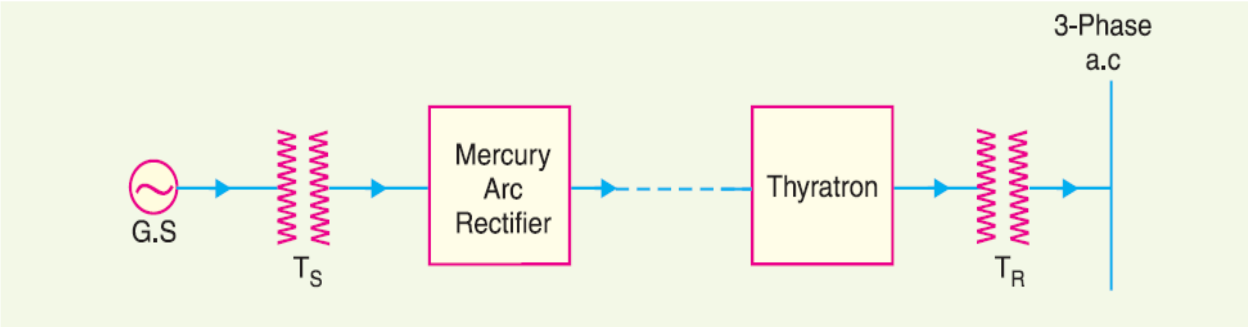
(*i*) An A.C. line requires more copper than a D.C. line.

(*ii*) The construction of A.C. transmission line is more complicated than a D.C. transmission line.

(*iii*) Due to skin effect in the A.C. system, the effective resistance of the line is increased.

(*iv*) An A.C. line has capacitance. Therefore, there is a continuous loss of power due to charging current even when the line is open

Conclusion. From the above comparison, it is clear that high voltage D.C. transmission is superior to high voltage A.C. transmission. Although at present, transmission of electric power is carried by A.C., there is an increasing interest in D.C. transmission. The introduction of mercury arc rectifiers and thyratrons have made it possible to convert A.C. into D.C. and *vice-versa* easily and efficiently. Such devices can operate upto 30 MW at 400 kV in single units. The present day trend is towards A.C. for generation and distribution and high voltage D.C. for transmission. Fig. shows the single line diagram of high voltage D.C. transmission. The electric power is generated as A.C. and is stepped up to high voltage by the sending end transformer T_S. The A.C. power at high voltage is fed to the mercury arc rectifiers which convert A.C. into D.C. The transmission of electric power is carried at high D.C. voltage. At the receiving end, D.C. is converted into A.C. with the help of thyratrons. The A.C. supply is stepped down to low voltage by receiving end transformer T_R for distribution.



Advantages of High Transmission Voltage

The transmission of electric power is carried at high voltages due to the following reasons:

(*i*) Reduces volume of conductor material.

(*ii*) Increases transmission efficiency

(*iii*) Decreases percentage line drop

Limitations of high transmission voltage. From the above discussion, it might appear advisable to use the highest possible voltage for transmission of power in a bid to save conductor material. However, it must be realised that high transmission voltage results in

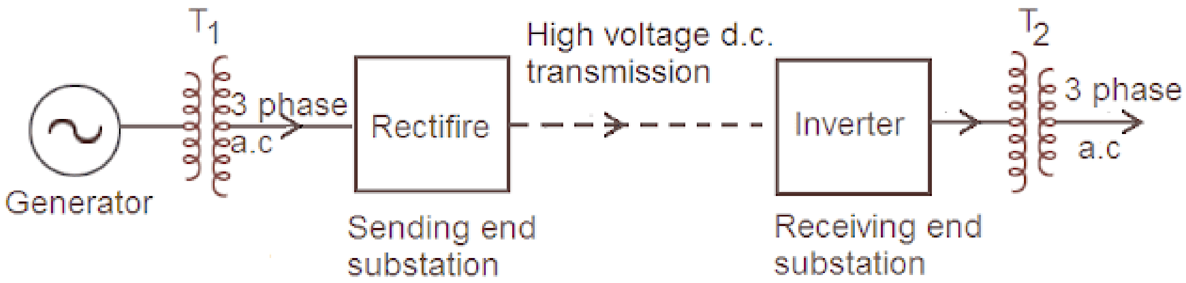
(*i*) the increased cost of insulating the conductors

(*ii*) the increased cost of transformers, switchgear and other terminal apparatus.

Therefore, there is a limit to the higher transmission voltage which can be economically employed in a particular case. This limit is reached when the saving in cost of conductor material due to higher voltage is offset by the increased cost of insulation, transformer, switchgear etc. Hence, the choice of proper transmission voltage is essentially a question of economics.

41. Components of HVDC Transmission System & Working

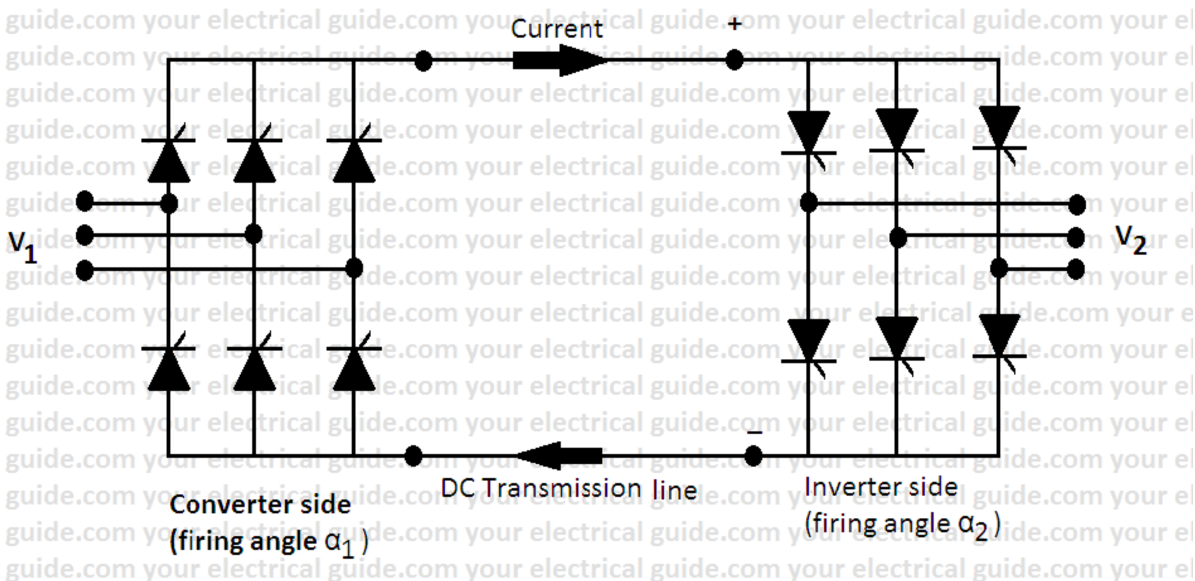
A typical HVDC transmission system is shown in Figure. In this system, the AC produced by generating stations is stepped up and converted to DC with the help of a rectifier unit. Then this DC is transmitted by the HVDC transmission line. At the receiving end, an inverter unit converts the received DC back to AC. Now, this DC is stepped down and distributed.



The converter at sending end converts AC power into DC power while the converter at the receiving end converts DC power back to AC power. Thus, the first converter acts as a rectifier unit, whereas the other one acts as an inverter unit.

The rectifier and inverter units make use of thyristor for controlled operation. By varying the firing angle of the thyristor, the magnitude DC output voltage is controlled in these units.

By changing the firing angles α_1 and α_2 so that the converter, which was previously working as a rectifier, can now work as an inverter and vice versa. Hence, power flow can be reversed in this system very easily. By changing the firing angles α_1 and α_2, the polarity of the voltages change, but the direction of current remains the same as the thyristors can conduct only in one direction.

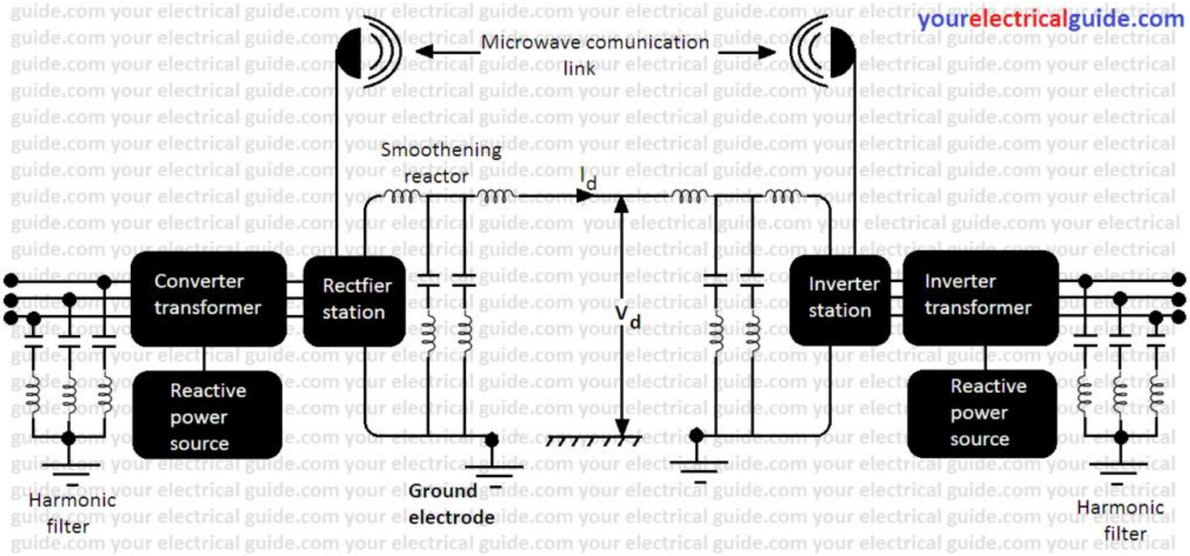


As in this transmission system voltage levels are high, each thyristor is shown in Figure **actually consists of many thyristors connected in series. Such a combination of thyristors is known as a valve. All the thyristors in each bridge arm of the rectifier are triggered at the same instant.**

Hoping you have understood the working of the HVDV transmission system. Let us head over to the “components of HVDC transmission system.”

Block Diagram of HVDC Transmission System

The **block diagram of hvdc transmission system** is shown in Figure.



Main *components of HVDC system* are as under:

- DC line inductors,
- harmonic filters,
- converter transformers,
- a reactive power source,
- ground electrodes,
- a microwave communication link between the converter stations.

Harmonic Filters

On the DC and AC side of the HVDC transmission system, harmonics are produced. It may produce undesirable noise in the neighboring communication system. Thus to remove these harmonic currents, harmonic filters are used. This filter bypasses the harmonic currents to the ground by providing a low impedance path. The filters for each phase are connected in star, and the neutral point is grounded.

The inductors connected in series with the line are used to smooth the DC output of the converter. With the use of these inductors, the DC line current is prevented from increasing rapidly under faulty conditions. An air-cored magnetically shielded reactor is used for this purpose.

Converter Transformer

It is used to provide the AC voltage required by the converter. A delta type three-phase transformer may be used for this purpose. A third winding known as tertiary winding may be added sometimes for a direct connection to the source of the reactive power.

The converter transformer on the rectifier side is provided with tappings to maintain the input AC voltage nearly constant. A motorized tap changer automatically switches the taps. The taps are also provided on the converter transformer on the inverter side.

Reactive Power Source

The variable static capacitors or synchronous capacitors are used for absorbing the reactive power of the converters. The requirement of the reactive power increases with the firing angle of the rectifier and extinction angle of the inverter. This power requirement is about 50 % to 60 % of real power transfer. As the transmitted active power varies, the reactive power must also be varied.

Ground Electrode

The DC currents in the ground have a corrosive effect on cables, metallic structures, and cables, and it causes interference in the converter transformer. The actual ground electrode is placed far from the converter station to avoid these problems. At the grounding site, special methods are adopted to minimize electrode resistance.

Communication Link

A communication link is necessary between the converters at both ends of the line for controlling purposes. A high-speed communication link between the two converters continuously transmits the controlling information.

It was a detailed description of the "components of hvdc transmission system." Now let us talk about its types.

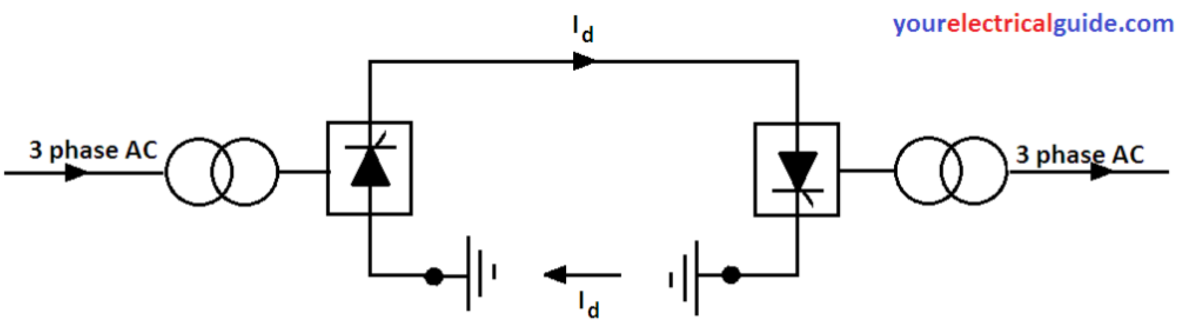
Types of HVDC Transmission System

The path of DC current, which has the same polarity with respect to earth, is known as the pole. Based on the arrangement of pole and earth return, HVDC systems are classified into different types. The following are different **types of HVDC transmission systems**.

Monopolar HVDC System

In this arrangement, a single conductor is used, and the earth is used as the return conductor. This arrangement is used for low power cable circuits.

A bipolar system is operated as a monopolar system when a pole is out of service. The earth electrodes are designed for the continuous full current operation.



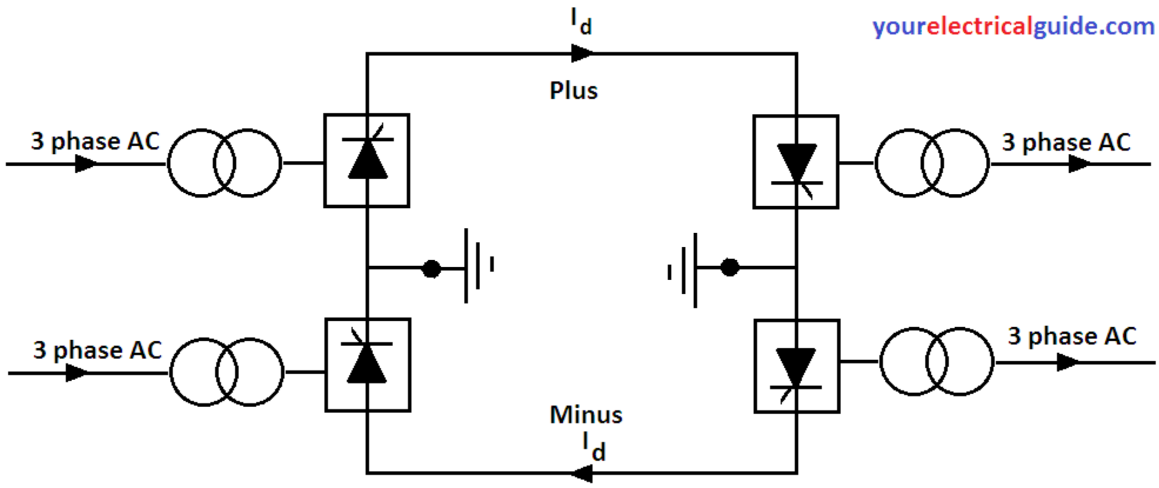
Monopolar HVDC transmission system

This system is obsolete now as it has a very high return current. However, for some schemes, the monopolar operation is the normal operation. For example, in the case of submarine cables, this arrangement is used as the cost of laying two cables is saved, and the ground return current is of less concern because of sea electrodes.

Bipolar HVDC Transmission System

This system has two poles, one positive and one negative pole with respect to earth. The midpoints of converters at each terminal are earthed.

Normally, this system consists of two separate monopolar systems with common earth. Normally, both are operated with equal currents. The earth carries only small out of balance current.



Bipola HVDC transmission system

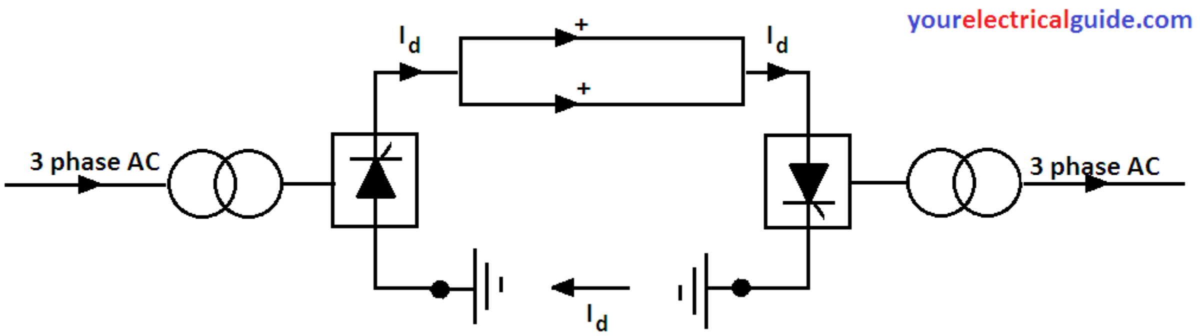
The bipolar HVDC line has two conductors, one of positive polarity and other of negative polarity with respect to earth. The voltage between the conductors is twice that of the conductor to earth. Hence, in this system, **the system voltage is expressed as ± 700 kV**.

This system is generally used for transmission of power over a long distance. The power rating of one pole is about half of the system power rating.

During fault on one pole, this system can be changed to monopolar mode. In this mode, ground current exceeds and may produce excessive heat on earth electrodes if the electrode resistance is high.

Homopolar HVDC Transmission System

In this system, there are two conductors on the tower, but both of them are of the same polarity. And the earth return is used. Such an arrangement reduces corona loss.

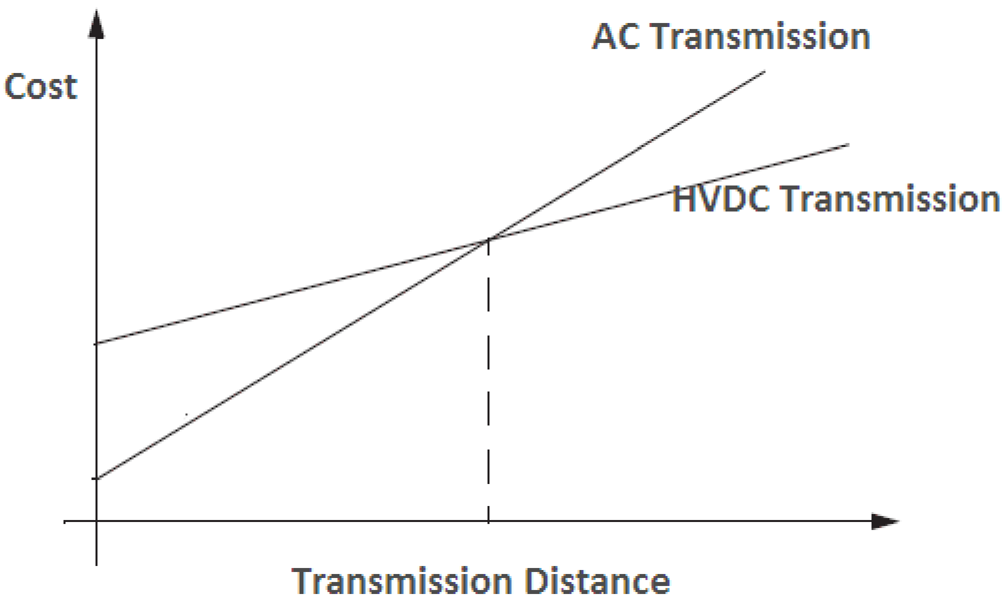


Homopolar HVDC transmission system

Economic Distance for HVDC Transmission System

The cost per km for a DC line is less as compared to an AC line for the same capacity and reliability. But this system needs additional converter stations with various terminal equipment at both ends, which increases their substation cost.

Whereas, AC lines require intermediate substations after a certain length. It is usually 300 km. And an intermediate compensating network, which is not the case with the HVDC system. This factor increases the cost of large transmission distances considerably. Hence, the **AC lines become uneconomical for the larger transmission distances** (usually more than 800 km).
Therefore, **for smaller transmission lines, AC transmission is economical, whereas, in the case of larger transmission lines, DC transmission is economical**.



A graph, cost versus transmission distance for the AC line, and the DC line is shown in Figure. The curves intersect at a point. It indicates that **after a certain length of the line, it is economical to use HVDC rather than AC**.

Advantages of HVDC Transmission System

1. The HVDC system needs only one or two conductors. Therefore, the cost of the conductor reduces considerably. Hence it is very economical for bulk transmission of power over long distances. The cost of towers and insulators is also reduced.

2. Due to corona loss considerations, when the AC system voltage exceeds 200 kV, 'bundle conductors' are required. With HVDC transmission, this limit is 400 kV.
3. The radio interference is less, and corona loss is low with the HVDC system.
4. The transmission losses are less with the DC system.
5. In the HVDC system rectifier unit can be converted into inverter unit very easily and vice versa. Thus in this system, **power flow can be reversed very easily**.
6. The charging current considerations at 400 kV for AC cables limit the 'critical length' to 40 km. HVDC cables do not need such charging current, and there is no such limit for DC cables. Cables in the DC system do not suffer from the high dielectric loss. The skin effect is also low in the DC system.
7. DC power can be transmitted between two systems operating at different frequencies. This is not possible with AC transmission.
8. Greater power transmission per conductor is possible with the HVDC system.
9. There are no serious problems in voltage regulation, as there is no reactance drop in this system.
10. AC cables require shunt inductors for compensation. DC can be compensated by capacitors, which are cheaper and with little-associated losses. Further, these capacitors can be used as 'harmonic filter' also.
11. In the development stage, a DC system can be worked with a single conductor and earth as the return. It is also an advantage under emergency conditions.
12. During fault with the HVDC system, the **grid control of the converter reduces the fault current significantly**.
13. Intermediate substations are not required in this system.
14. Due to unidirectional stress, DC cable insulation has a longer life.
15. In the case of insulation degradation, DC converter can be operated at a reduced voltage.
16. Lightning has never struck two poles of a DC line together. However, in the case of AC, it is known to have struck two sections simultaneously. This increases the reliability of the DC link, and in many cases, shield wire can be dispensed with.

Disadvantages of HVDC Transmission

1. **This system is uneconomical if the length of the transmission line is less than 500 km** as converters, inverters, and filters are required additionally in this system.
2. **DC circuit breaking is difficult and expensive**.
3. Filtration is very necessary for this system due to the excessive generation of harmonics.
4. The overload capacity of this system is low.
5. As HVDC does not transmit reactive power, it has to supply locally, if required.
6. The maintenance of insulators in this system is more.
7. There are additional losses in valves and converter transformers. These losses are continuous. Hence, a **very efficient cooling system has to be provided**.
Thanks for reading about the "hvdc components." For more information, visit Wikipedia

42. DISTRIBUTION

Introduction

The electrical energy produced at the generating station is conveyed to the consumers through a network of Transmission and Distribution systems. It is often difficult to draw a line between the transmission and distribution systems of a large power system. It is impossible to distinguish the two merely by their voltage because what was considered as a high voltage a few years ago is now considered as a low voltage. In general, distribution system is that part of power system which distributes power to the consumers for utilisation.

The Transmission and Distribution systems are similar to man's circulatory system. The transmission system may be compared with arteries in the human body and distribution system with capillaries. They serve the same purpose of supplying the ultimate consumer in the city with the lifegiving blood of civilisation–electricity.

42.1 Distribution System

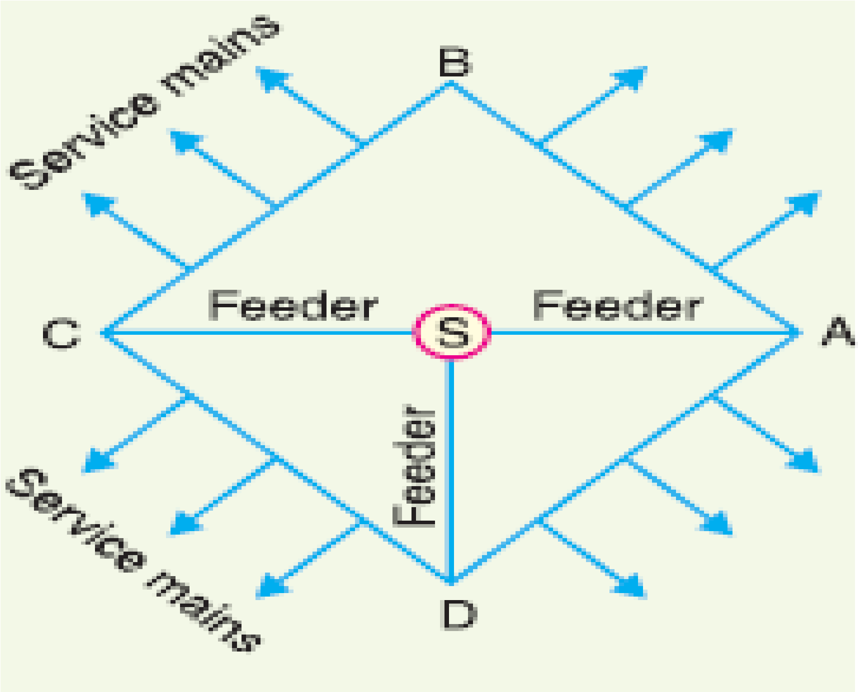
That part of power system which distributes electric power for local use is known as distribution system.

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.** Fig. shows the single line diagram of a typical low tension distribution system.

(i) Feeders. A feeder is a conductor which connects the sub-station (or localised generating station) to the area where power is to be distributed. Generally, no tappings 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 tappings are taken for supply to the consumers. In Fig. A B, BC, CD and DA are the distributors. The current through a distributor is not constant because tappings are taken at various places along its length. While designing a distributor, voltage drop along its length is the main consideration since the statutory limit of voltage variations is ± 6% of rated value at the consumers' terminals.

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



43. Classification of Distribution Systems

A distribution system may be classified according to;

i. Nature of current. According to nature of current, distribution system may be classified as

(a) D.C. distribution system

(b) A.C. distribution system.

Now-a-days, A.C. system is universally adopted for distribution of electric power as it is simpler and more economical than direct current method.

ii. Type of construction. According to type of construction, distribution system may be classified as

(a) overhead system

(b) underground system.

The overhead system is generally employed for distribution as it is 5 to 10 times cheaper than the equivalent underground system. In general, the underground system is used at places where overhead construction is impracticable or prohibited by the local laws.

iii. Scheme of connection. According to scheme of connection, the distribution system may be classified as

(a) radial system

(b) ring main system

(c) inter-connected system.

Each scheme has its own advantages and disadvantages.

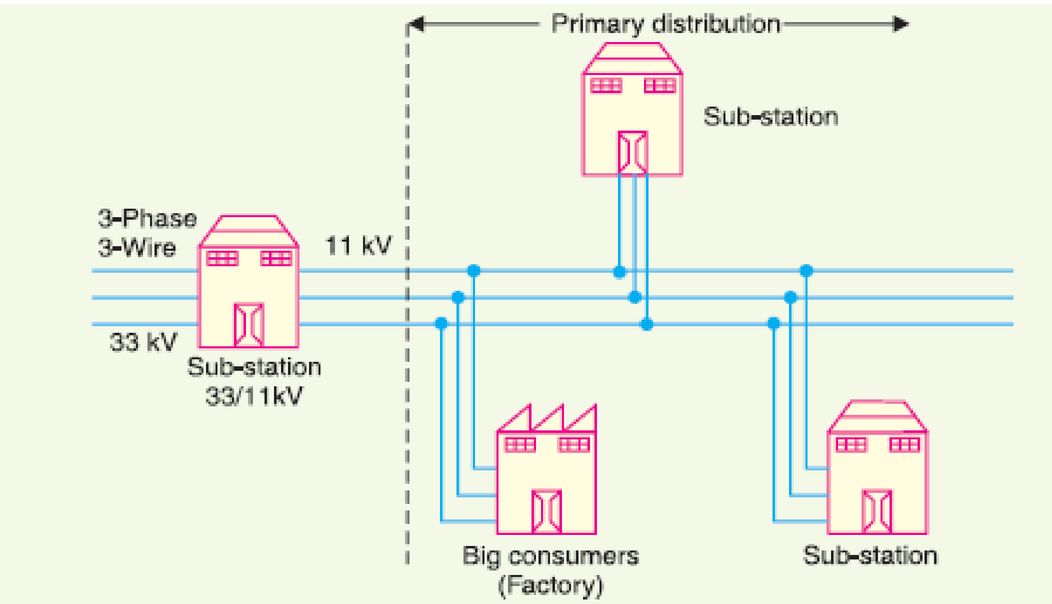
A.C. Distribution:

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 utilise it at a safe potential. High transmission and distribution voltages have greatly reduced the current in the conductors and the resulting line losses. There is no definite line between transmission and distribution according to voltage or bulk capacity. However, in general, the A.C. distribution system is the electrical system between the stepdown substation fed by the transmission system and the consumers' meters. The A.C. distribution system is classified into

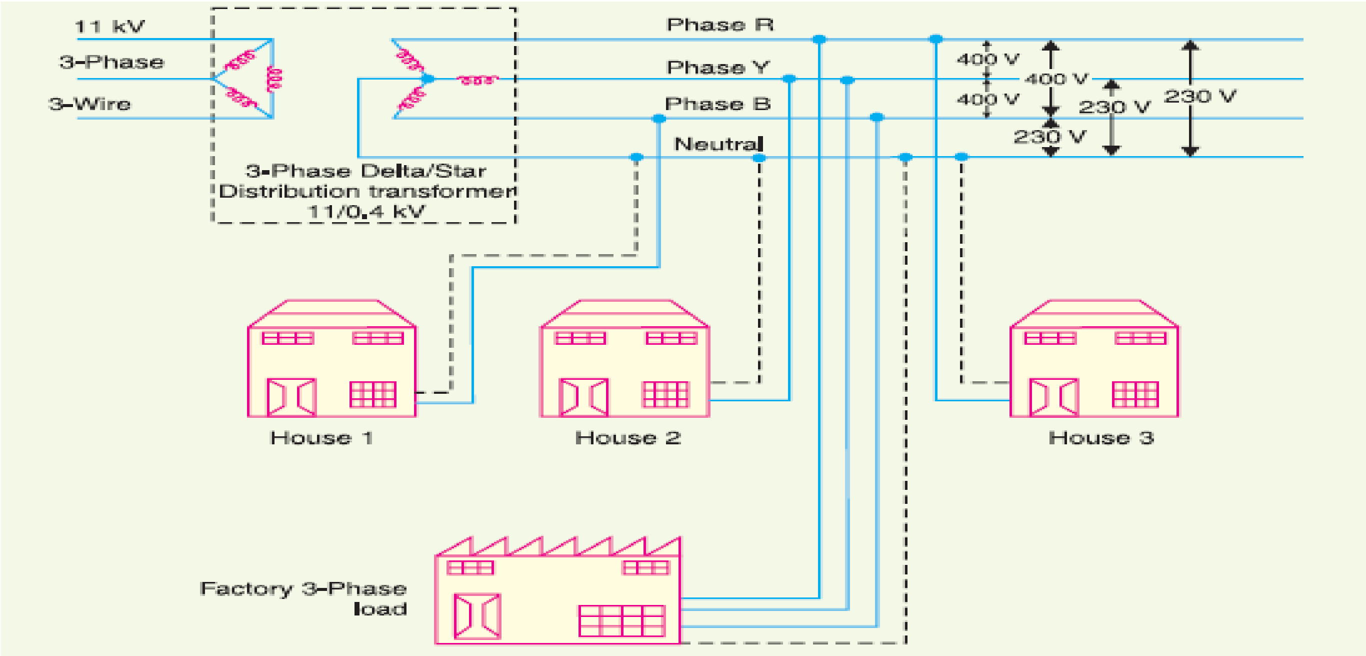
(i) Primary Distribution system and

(ii) Secondary 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, 6·6 kV 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.



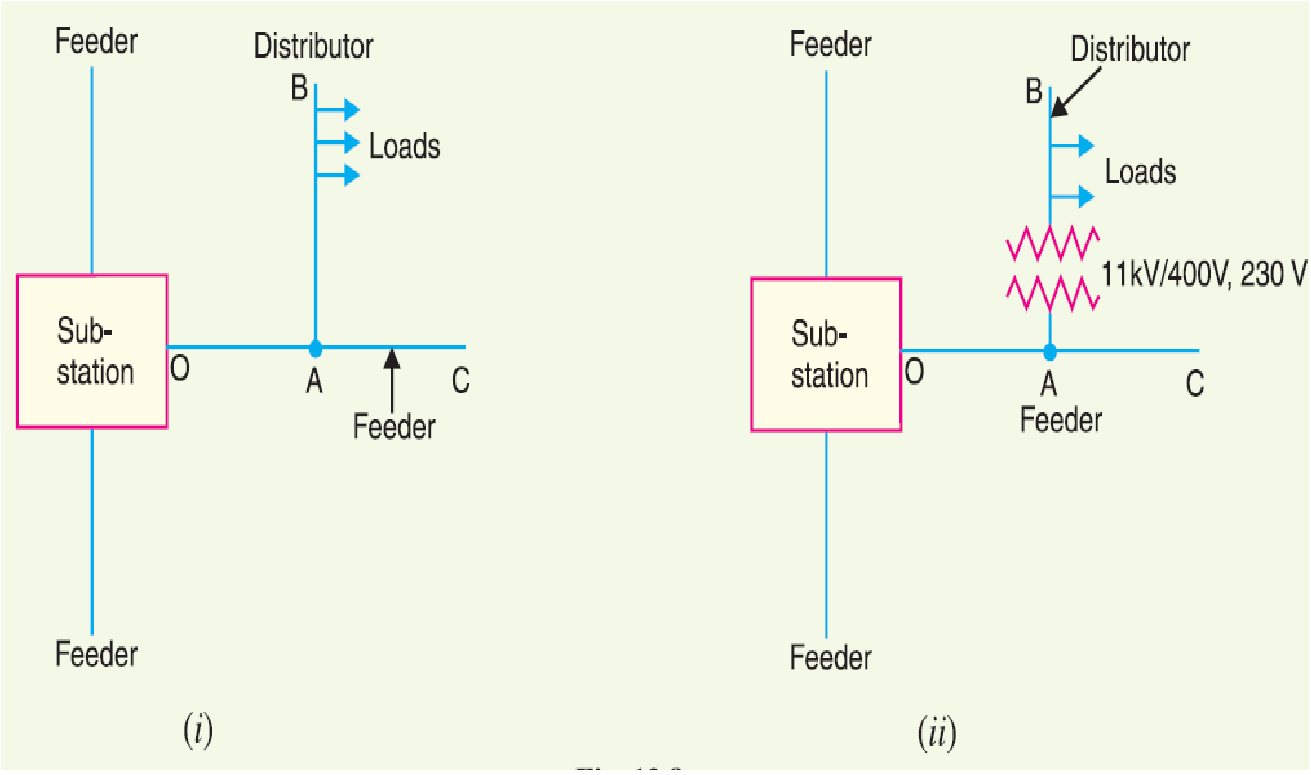
Secondary Distribution system. It is that part of A.C. distribution system which includes the range of voltages at which the ultimate consumer utilises the electrical energy delivered to him. The secondary distribution employs 400/230 V, 3-phase, 4-wire system. Fig. shows a typical secondary distribution system. The primary distribution circuit delivers power to various substations, called distribution substations. The substations are situated near the consumers' localities and contain stepdown transformers. At each distribution substation, the voltage is stepped down to 400 V and power is delivered by 3-phase,4-wire A.C. system. The voltage between any two phases is 400 V and between any phase and neutral is 230 V. 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



43.1 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. In this system, separate feeders radiate from a single substation and feed the distributors at one end only. Fig. (*i*) 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. (*ii*) 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 centre of the load. This is the simplest distribution circuit and has the lowest initial cost. However, it suffers from the following drawbacks:

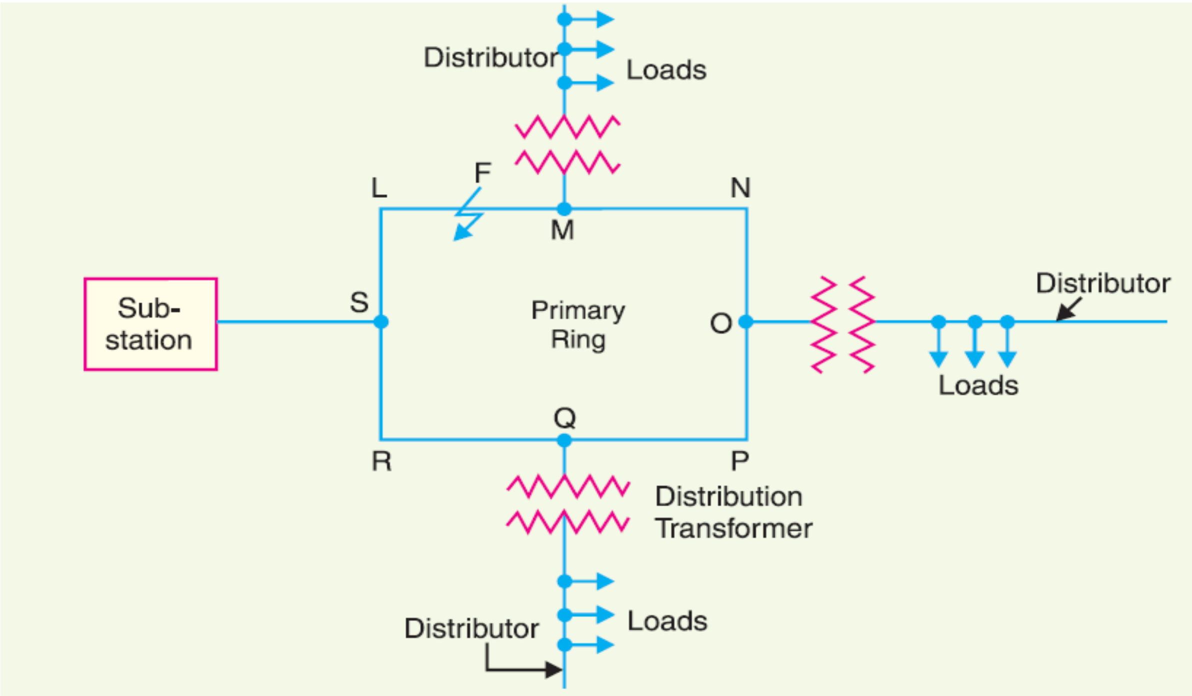


(*a*) The end of the distributor nearest to the feeding point wil l be heavily loaded.
(*b*) The consumers are dependent on a single feeder and single distributor. Therefore, any fault on the feeder or distributor cuts off supply to the consumers who are on the side of the fault away from the substation.
(*c*) The consumers at the distant end of the distributor would be subjected to serious voltage fluctuations when the load on the distributor changes. Due to these limitations, this system is used for short distances 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. 12.9 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. For example, suppose that fault occurs at any point *F* of section SLM of the feeder. Then section SLM of the feeder can be isolated for repairs and at the same time continuity of supply is maintained to all the consumers *via* the feeder *SRQPONM*.

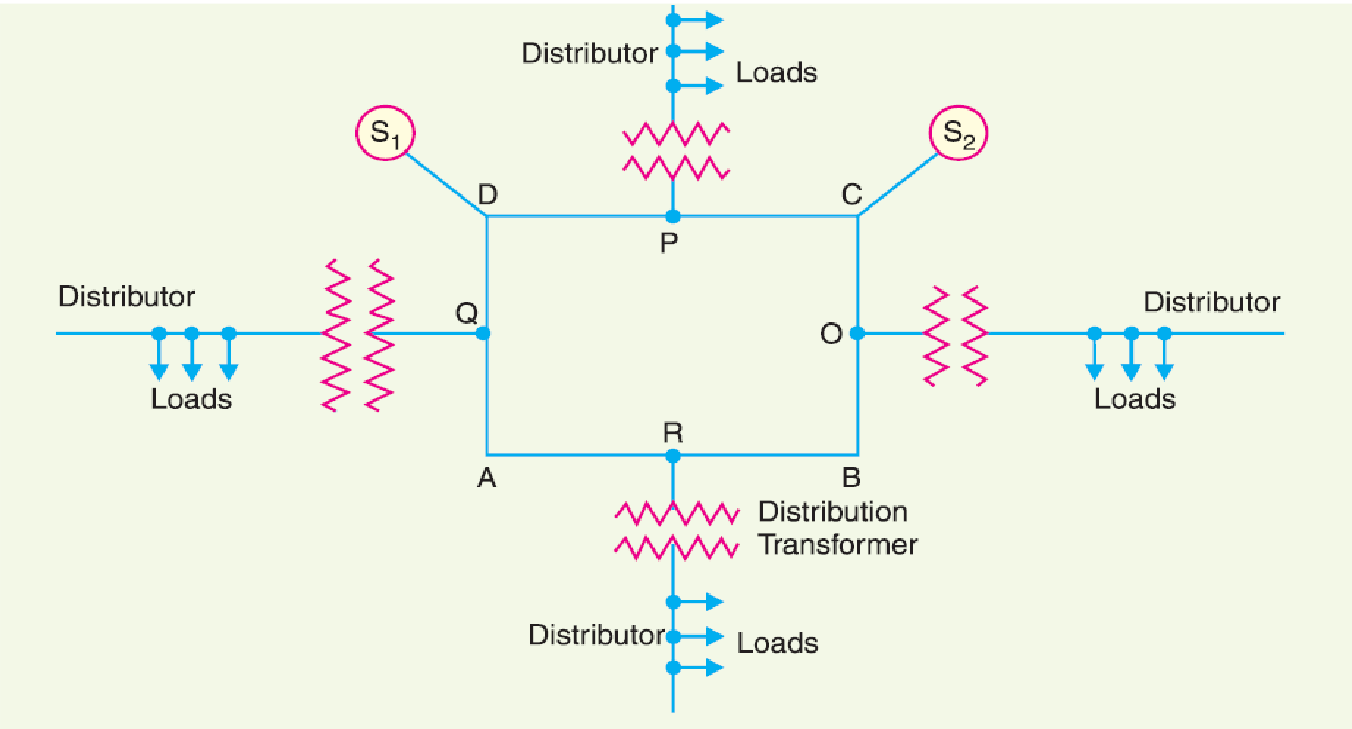


iii. Interconnected system.

When the feeder ring is energised by two or more than two generating stations or substations, it is called inter-connected 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. Distributors are connected to points *O*, *P*, *Q* and *R* of the feeder ring through distribution transformers. The interconnected system has the following advantages:

(*a*) It increases the service reliability.

(*b*) Any area fed from one generating station during peak load hours can be fed from the other generating station. This reduces reserve power capacity and increases efficiency of the system.



44. Substation and receiving station and their functions, Classification of substations.

44.1 Sub-Station:

The assembly of apparatus used to change some characteristic (e.g. voltage, A.C. to D.C., frequency, p.f. etc.) **of electric supply is called a sub-station (SS).**

Sub-stations are important part of power system. The continuity of supply depends to a considerable extent upon the successful operation of sub-stations. It is, therefore, essential to exercise utmost care while designing and building a sub-station. The following are the important points which must be kept in view while laying out a sub-station:

(i) It should be located at a proper site. As far as possible, it should be located at the centre of gravity of load.

(ii) It should provide safe and reliable arrangement. For safety, consideration must be given to the maintenance of regulation clearances, facilities for carrying out repairs and maintenance, abnormal occurrences such as possibility of explosion or fire etc. For reliability, consideration must be given for good design and construction, the provision of suitable protective gear etc.

(iii) It should be easily operated and maintained.

(iv) It should involve minimum capital cost.

44.2 Classification of Sub-Stations

There are several ways of classifying sub-stations. However, the two most important ways of classifying them are according to

(1) service requirement and

(2) constructional features.

1. According to service requirement. A sub-station may be called upon to change voltage level or improve power factor or convert A.C. power into D.C. power etc. According to the service requirement, sub-stations may be classified into:

(i) Transformer sub-stations. Those sub-stations which change the voltage level of electric supply are called transformer sub-stations. These sub-stations receive power at some voltage and deliver it at some other voltage. Obviously, transformer will be the main component in such substations. Most of the sub-stations in the power system are of this type.

(ii) Switching sub-stations. These sub-stations do not change the voltage level i.e. incoming and outgoing lines have the same voltage. However, they simply perform the switching operations of power lines.

(iii) Power factor correction sub-stations. Those sub-stations which improve the power factor of the system are called power factor correction sub-stations. Such sub-stations are generally located at the receiving end of transmission lines. These sub-stations generally use synchronous condensers as the power factor improvement equipment.

(iv) Frequency changer sub-stations. Those sub-stations which change the supply frequency are known as frequency changer sub-stations. Such a frequency change may be required for industrial utilisation.

(v) Converting sub-stations. Those sub-stations which change A.C. power into D.C. power are called converting sub-stations. These sub-stations receive A.C. power and convert it into D.C. power with suitable apparatus (e.g. ignitron) to supply for such purposes as traction, electroplating, electric welding etc.

(vi) Industrial sub-stations. Those sub-stations which supply power to individual industrial concerns are known as industrial sub-stations.

2. According to constructional features. A sub-station has many components (e.g. circuit breakers, switches, fuses, instruments etc.) which must be housed properly to ensure continuous and reliable service. According to constructional features, the sub-stations are classified as :

(i) Indoor sub-station

(ii) Outdoor sub-station

(iii)Underground sub-station

(iv) Pole-mounted sub-station

(i) Indoor sub-stations.

For voltages upto 11 kV, the equipment of the sub-station is installed indoor because of economic considerations. However, when the atmosphere is contaminated with impurities, these sub-stations can be erected for voltages upto 66 kV.

(ii) Outdoor sub-stations.

For voltages beyond 66 kV, equipment is invariably installed outdoor. It is because for such voltages, the clearances between conductors and the space required for switches, circuit breakers and other equipment becomes so great that it is not economical to install the equipment indoor.

(iii) Underground sub-stations.

In thickly populated areas, the space available for equipment and building is limited and the cost of land is high. Under such situations, the sub-station is created underground

(iv) Pole-mounted sub-stations.

This is an outdoor sub-station with equipment installed overhead on H-pole or 4-pole structure. It is the cheapest form of sub-station for voltages not exceeding 11kV (or 33 kV in some cases). Electric power is almost distributed in localities through such substations. For complete discussion on pole-mounted sub-station

45. Single Line Diagram of 66/11 kV Sub-Station

Fig. shows the diagram of a typical 66/11 kV sub-station. It can be explained as:

(i) There are two 66 kV incoming lines marked 'incoming 1' and 'incoming 2' connected to the bus-bars. Such an arrangement of two incoming lines is called a double circuit. Each incoming line is capable of supplying the rated sub-station load. Both these lines can be loaded simultaneously to share the sub-station load or any one line can be called upon to meet the entire load. The double circuit arrangement increases the reliability of the system. In case there is a breakdown of one incoming line, the continuity of supply can be maintained by the other line.

(ii) The sub-station has duplicate bus-bar system; one 'main bus-bar' and the other spare busbar. The incoming lines can be connected to either bus-bar with the help of a bus-coupler which consists of a circuit breaker and isolators. The advantage of double bus-bar system is that if repair is to be carried on one bus-bar, the supply need not be interrupted as the entire load can be transferred to the other bus.

(iii) There is an arrangement in the sub-station by which the same 66 kV double circuit supply is going out i.e. 66 kV double circuit supply is passing through the sub-station. The outgoing 66 kV double circuit line can be made to act as incoming line.

(iv) There is also an arrangement to step down the incoming 66 kV supply to 11 kV by two units of 3-phase transformers; each transformer supplying to a separate bus-bar. Generally, one transformer supplies the entire sub-station load while the other transformer acts as a standby unit. If need arises, both the transformers can be called upon to share the sub-station load.The 11 kV outgoing lines feed to the distribution sub-stations located near consumers localities.

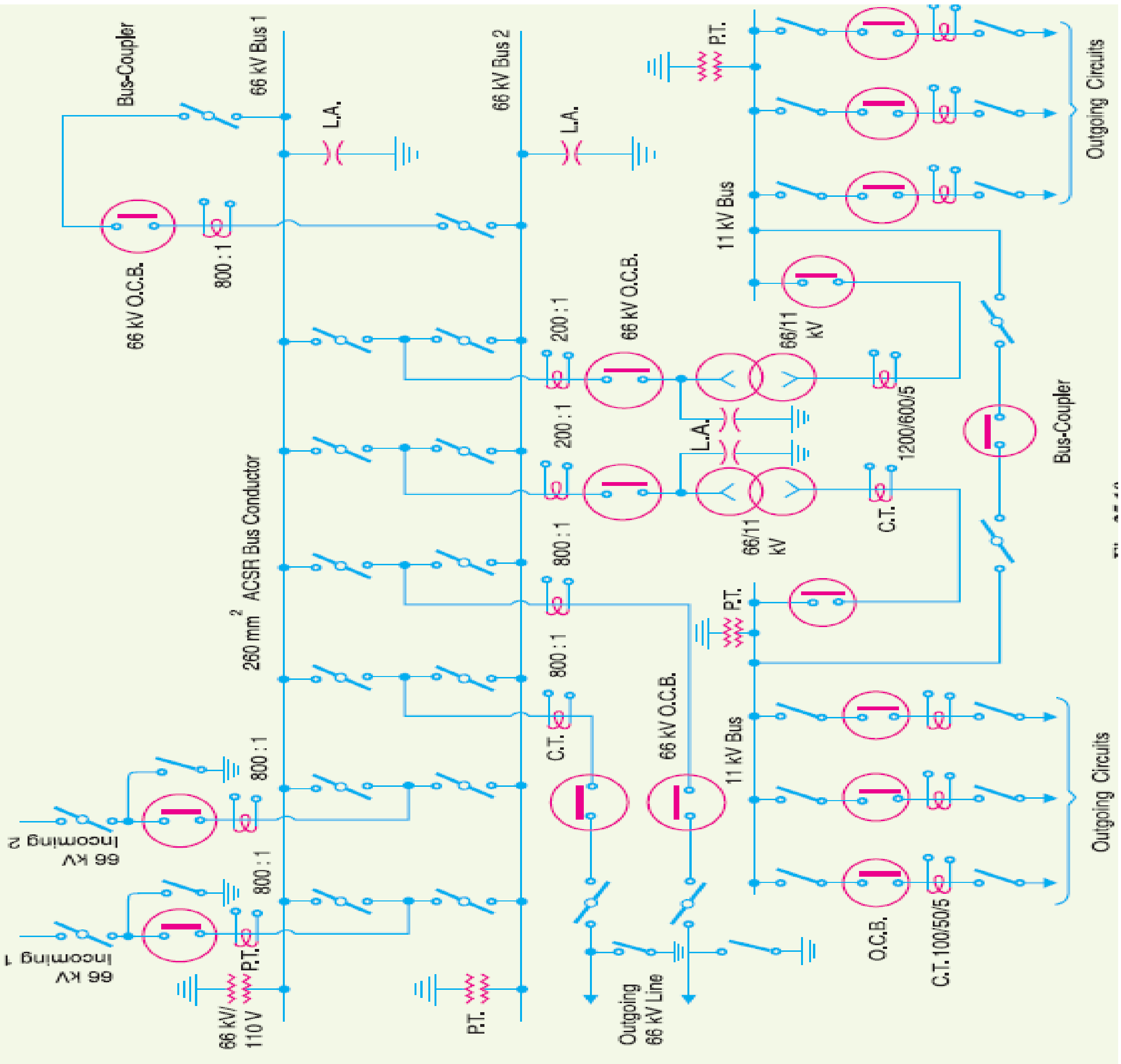
(v) Both incoming and outgoing lines are connected through circuit breakers having isolators on their either end. Whenever repair is to be carried over the line towers, the line is first switched off and then earthed.

(vi) The potential transformers (P.T.) and current transformers (C.T.) are suitably located for supply to metering and indicating instruments and relay circuits (not shown in the figure).The P.T. is connected right on the point where the line is terminated. The CTs are connected at the terminals of each circuit breaker.

(vii) The lightning arresters are connected near the transformer terminals (on H.T. side) to protect them from lightning strokes.

(viii) There are other auxiliary components in the sub-station such as capacitor bank for power factor improvement, earth connections, local supply connections, D.C. supply connections etc. However, these have been omitted in the key diagram for the sake of simplicity.

Single line Diagram of 66/11 kV Sub-Station



46. Single Line Diagram of 11 kV/400 V Indoor Sub-Station:

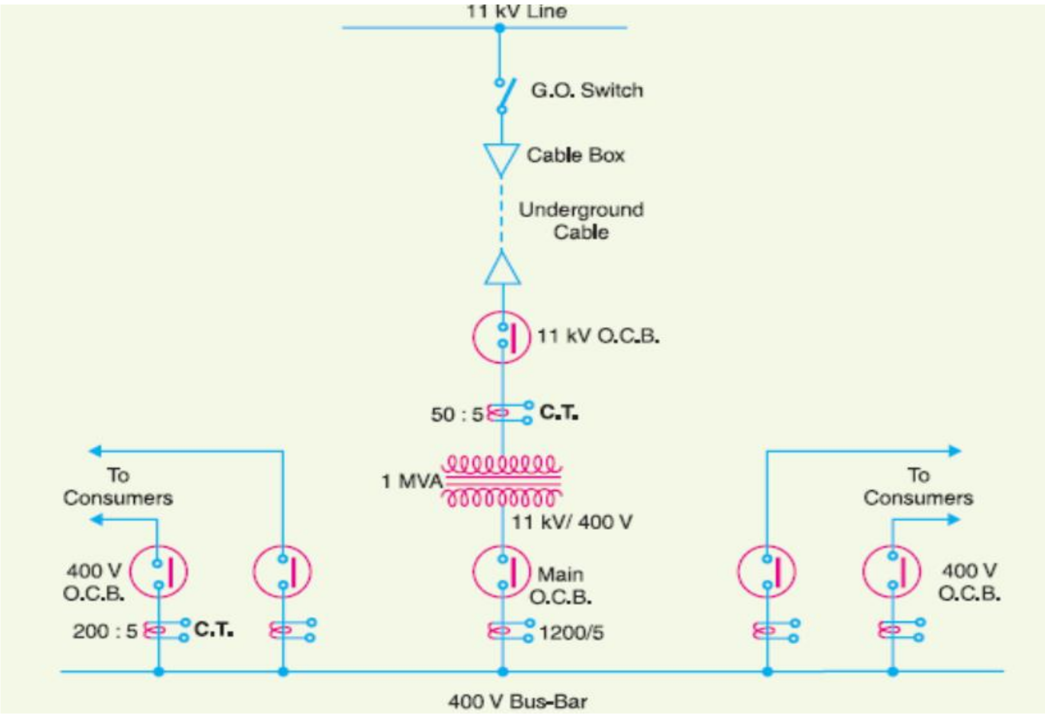


Fig. shows the key diagram of a typical 11 kV/400 V indoor sub-station. The key diagram of this sub-station can be explained as under:

(i) The 3-phase, 3-wire 11 kV line is tapped and brought to the gang(group) operating switch installed near the sub-station. The G.O. switch consists of isolators connected in each phase of the 3-phase line.

(ii) From the G.O. switch, the 11 kV line is brought to the indoor sub-station as underground cable. It is fed to the H.T. side of the transformer (11 kV/400 V) via the 11 kV O.C.B. The transformer steps down the voltage to 400 V, 3-phase, 4-wire.

(iii) The secondary of transformer supplies to the bus-bars via the main O.C.B. From the busbars, 400 V, 3-phase, 4-wire supply is given to the various consumers via 400 V O.C.B. The voltage between any two phases is 400 V and between any phase and neutral it is 230 V. The

single phase residential load is connected between any one phase and neutral whereas 3-phase, 400 V motor load is connected across 3-phase lines directly

(iv) The CTs are located at suitable places in the sub-station circuit and supply for the metering and indicating instruments and relay circuits.

47.Electrical Grid

Definition: Electrical grid or power grid is defined as the network which interconnects the generation, transmission and distribution unit. It supplies the electrical power from generating unit to the distribution unit. A large amount of power is transmitted from the generating station to load centre at 220kV or higher. The network form by these high voltage lines is called the super grid. The super grid feeds the sub-transmission network operating at 132kV or less.

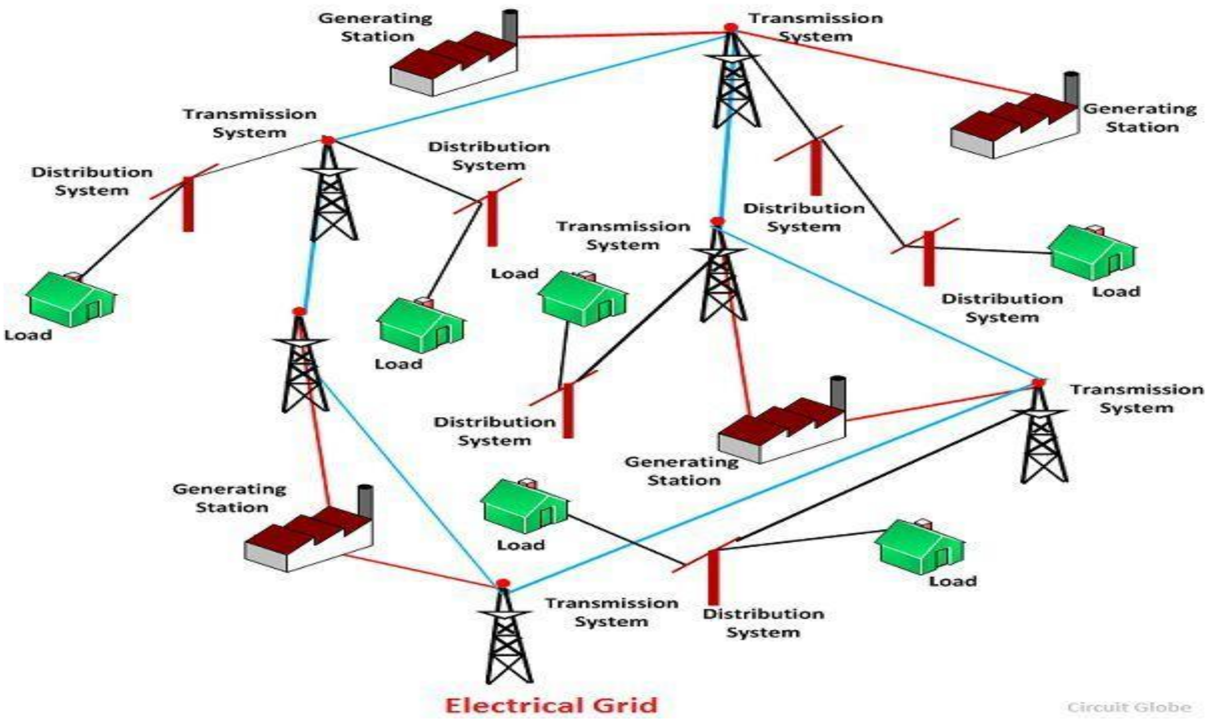
Types of Electrical Grid

The power station of the grid is located near the fuel source which reduces the transportation cost of the system. But it is located far away from the populated areas. The power which is generated at high voltage is stepped down by the help of step down transformer in the substation and then supply to the consumers. The electrical grid is mainly classified into two types. They are

1. **Regional Grid** – The Regional grid is formed by interconnecting the different transmission system of a particular area through the transmission line.
2. **National Grid –** It is formed by interconnecting the different regional grid.

Reason for an Interconnection

The interconnection of the grid provides the best use of power resource and ensures great security to supply. It makes the system economical and reliable. The generating stations are interconnected for reducing the reserve generation capacity in each area.



If there is a sudden increase in load or loss of generation in a zone, then it borrows from the adjacent interconnected area. But for the interconnections of the network certain amount of generating capacity known as the spinning reserve is required. The spinning reserve consists generator running at normal speed and ready to supply power instantaneously.

Types of an Interconnections

The interconnection between network is mainly classified into two types, i.e., the HVAC link and HVDC link.

HVAC (High Voltage Alternating Current) Interconnection

In HVAC link the two AC systems are interconnected by an AC link. For interconnecting the AC system, it is necessary that there should be sufficiently close frequency control on each of the two systems.

For the 50Hz system, the frequency should lie between 48.5 Hz and 51.5 Hz. Such an interconnection is known as synchronous interconnection or synchronous tie. The AC link provides a rigid connection between two AC system to be interconnected. But the AC interconnection has certain limitations.

The interconnection of an AC system has suffered from the following problems.

1. The interconnection of the two AC networks is the synchronous tie. The frequency disturbances in one system are transferred to the other system.
2. The power swings in one system affect the other system. Large power swing in one system may result in frequent tripping due to which major fault occurs in the system. This fault causes complete failure of the whole interconnected system.

3. There is an increase in the fault level if an existing AC system is connected with the other AC system with an AC tie line. This is because the additional parallel line reduces the equivalent reactance of the interconnected system. If the two AC system are connected to the fault line, then the fault level of an each AC system remains unchanged.

HVDC (High Voltage Direct Current) Interconnection

The DC interconnection or DC tie provides a loose coupling between the two AC system to be interconnected. The DC tie between two AC systems is non-synchronous(Asynchronous). The DC interconnection has the certain advantages. They are as follows.

1. The DC interconnection system is asynchronous thus the system which is to be interconnected is either of the same frequency or at the difference frequency. The DC link thus provides the advantages of interconnection of two AC network at different frequencies. It also enables the system to operate independently and to maintain their frequency standards.
2. The HVDC links provide fast and reliable control of magnitude and direction of power flow by controlling the firing angle of converters. The rapid control of power flow increases the limit of transient stability.
3. The power swings in the interconnected AC networks can be damped rapidly by modulating the power flow through the DC tie. Thus, the stability of the system is increased.

Nowadays, the customary grids are replaced by the smart grids. The smart grid uses the smart meter and appliances which improves the efficiency of the system.

48. Black start

A **black start** is the process of restoring an electric power station or a part of an electric grid to operation without relying on the external electric power transmission network to recover from a total or partial shutdown.[1]

Normally, the electric power used within the plant is provided from the station's own generators. If all of the plant's main generators are shut down, station service power is provided by drawing power from the grid through the plant's transmission line. However, during a wide-area outage, off-site power from the grid is not available. In the absence of grid power, a so-called black start needs to be performed to bootstrap the power grid into operation.

To provide a black start, some power stations have small diesel generators, normally called the *black start diesel generator* (BSDG), which can be used to start larger generators (of several megawatts capacity), which in turn can be used to start the main power station generators. Generating plants using steam turbines require station service power of up to 10% of their capacity for boiler feedwater pumps, boiler forced-draft combustion air blowers, and for fuel preparation. It is uneconomical to provide such a large standby capacity at each station, so black-start power must be provided over designated tie lines from another station. Often hydroelectric power plants are designated as the black-start sources to restore network interconnections. A hydroelectric station needs very little initial power for starting purposes (just enough to open the intake gates and provide excitation current to the generator field coils), and can put a large block of power on line very quickly to allow start-up of fossil-fuel or nuclear stations. Certain types of combustion turbine can be configured for black start, providing another option in places without suitable hydroelectric plants.[2] In 2017, a utility in Southern California successfully demonstrated the use of a battery-based energy-storage system to provide a black start, firing up a combined-cycle gas turbine from an idle state.[3]

A black start sequence[

One method of black start (based on a real scenario) might be as follows:

1. A battery starts a small diesel generator installed in a hydroelectric generating station.
2. The power from the diesel generator is used to bring the generating station into operation.
3. Key transmission lines between the station and other areas are energized.
4. The power from the station is used to start one of the nuclear/fossil-fuel-fired base load plants.
5. The power from the base load plant is used to restart all of the other power plants in the system.

Power is finally re-applied to the general electricity distribution network and sent to the consumers. Often this will happen gradually; starting the entire grid at once may be unfeasible. In particular, after a lengthy outage during summer, all buildings will be warm, and if the power were restored at once, the demand from air conditioning units alone would be more than the grid could supply. In colder climates a similar issue can occur in winter with the use of heating devices.

In a larger grid, black start will often involve starting multiple "islands" of generation (each supplying local load areas), and then synchronising and reconnecting these islands to form a complete grid. The power stations involved have to be able to accept large step changes in load as the grid is reconnected.

There are multiple methods of commencing a black start: hydro-electric dams, diesel generators, open cycle gas turbines, compressed air storage, and so on. Different generating networks take different approaches, dependent on factors such as cost, complexity, the availability of local resources (i.e. suitable valleys for dams), the interconnectivity with other generating networks, and the response time necessary for the black start process.

Procurement of black start services[edit]

An operator at ERCOT

In the United Kingdom, the grid operator has commercial agreements in place with some generators to provide black start capacity, recognising that black start facilities are often not economic in normal grid operation.[4] It is typical of power stations from the CEGB era to have a number of open-cycle gas turbines (i.e. no heat recovery modules attached) that can run the entirety of the plant necessary to operate a full generating unit; these would normally be started by diesel generators, fed in turn by battery backups. Once up to speed, these gas turbines are capable of running the entire plant associated with the rest of the power station, negating the need to bring power in from other sources.

In the North American independent system operators, the procurement of black starting varies somewhat. Traditionally, black-start capability was provided by integrated utilities and the costs were rolled into a broad tariff for cost recovery from ratepayers. In those areas which are not part of organized electricity markets, this is still the usual procurement mechanism. In the deregulated environment, this legacy of cost-based provision has persisted, and even recent overhauls of black-start procurement practices, such as that by the ISO New England, have not necessarily shifted to competitive procurement, even though deregulated jurisdictions have a bias for market solutions rather than cost-of-service (COS) solutions.

In the United States, there are currently three methods of procuring black start. The most common is cost-of-service, as it is the simplest and is the traditional method. It is currently used by the California Independent System Operator (CAISO), the PJM Interconnection[5] and the New York Independent System Operator[6] (NYISO). Although the exact mechanisms differ somewhat the same approach is used, namely that units are identified for black start and their documented costs are then funded and rolled into a tariff for cost recovery. The second method is a new method used by the Independent System Operator of New England[7] (ISO-NE). The new methodology is a flat-rate payment which increases black-start remuneration to encourage provision. The monthly compensation paid to a generator is determined by multiplying a flat rate (in $/KWyr and referred to as the $Y value) by the unit's Monthly Claimed Capability for that month. The purpose of this change was to simplify procurement and encourage provision of the black start service.

The final method of procurement is competitive procurement as used by the Electric Reliability Council of Texas[8] (ERCOT). Under this approach, ERCOT runs a market for black-start services. Interested participants submit an hourly standby cost in $/hr (e.g. $70 per hour), often termed an availability bid, that is unrelated to the capacity of the unit. Using various criteria, ERCOT evaluates these bids and the selected units are paid as bid, presuming an 85% availability. Each black-start unit must be able to demonstrate that it can start another unit in close proximity, in order to begin the islanding and synchronization of the grid.

In other jurisdictions there are differing methods of procurement. The New Zealand System Operator[9] procures the blackstart capability via competitive tender. Other jurisdictions also appear to have some sort of competitive procurement, albeit perhaps not as structured as that of ERCOT. These include the Alberta Electric System Operator,[10] as well as Independent Electric System Operator of Ontario,[11] both of which use a long-term "request for proposals" approach similar to New Zealand and ERCOT.

The first black start on a Germany's grid was tested in 2017 at WEMAG battery power station in Schwerin on a disconnected, isolated grid. The WEMAG battery plant proved that it can restore the power grid after major disruption or blackout.[12]

Limitations on black start sources[edit]

Not all generating plants are suitable for black-start capability. Wind turbines are not suitable for black start because wind may not be available when needed.[13] Wind turbines, mini-hydro, or micro-hydro plants, are often connected to induction generators which are incapable of providing power to re-energize the network. [14] In 2020, the 69 MW Dersalloch wind farm black-started part of the Scotland grid, using virtual synchronous machines.[15][16] The black-start unit must also be stable when operated with the large reactive load of a long transmission line. Many high-voltage direct current (HVDC) converter stations cannot operate into a "dead" system, either, since they require commutation power from the system at the load end. A pulse-width modulation (PWM)-based voltage-source converter HVDC scheme has no such restriction.[17]

49. Demand Side Management

The term Demand Side Management (DSM) is used to refer to a group of actions designed to efficiently manage a site's energy consumption with the aim of cutting the costs incurred for the supply of electrical energy, from grid charges and general system charges, including taxes.

The aim of these optimisation actions is to modify features of electricity consumption with reference to the overall consumption picture, consumption time profile, contractual supply parameters (contractual power and grid connection parameters) in order to achieve savings in electricity charges.

As a result of the high penetration of renewable sources and the decentralisation of production sources, grid managers in many countries are now encountering increased instability on the grid and consequent disruptions to services. To limit these impacts and ensure a balance between energy consumption and the amount of power fed into the grid, grid managers can now utilize generation and consumption systems that offer so-called "grid services", in return for payment, thus increasing the costs for the electrical system.

In order to engage in Demand Side Management, the first requirement is to carry out an in-depth analysis of onsite consumption: this clarifies the peculiarities of each individual site and whether consumption habits can be optimised without resorting to additional instruments.

Whenever a change in habits is not feasible or simply not sufficient to achieve the desired cost reductions, the on-site installation (prior to the meter) of the following can be evaluated:

- Batteries (BESS - battery energy storage systems)
- Renewable source systems (photovoltaic, wind)

- Cogeneration systems

It will then be necessary to acquire an Energy Management System, which is a dedicated computer system that will:

- Monitor and check all the assets involved (consumption site, battery, production systems)
- Optimise in real time the contribution of the batteries and production systems to cut costs associated with intake from the grid and minimise battery aging
- Use the assets involved to supply services to the grid.

50.LOAD DISPATCH CENTER

1. **_LOAD DISPATCH CENTER**
2. **WHAT IS LOAD DISPATCH CENTER?** THE LOAD CENTER IS THE CENTER WHICH PERFORMS DISPATCH AND CONTROL FUNCTIONS TO ENSURE CONTINUTIY AND QUALITY OF POWER SUPPLY TO THE CONSUMERS. ALL THE MODERN LOAD DISPATCH CENTER USE THE SCADA SYSTEM (SUPERVISORY CONTROL AND DATA ACQUISITION SYSTEM) FOR MONITORING AND COLLECTING THE SYSTEM DATA. THE FUNCTIONS OF THE LOAD DISAPTCH CENTERS INCLUDE THE SUPERVISORY OF THE SYSTEM ELEMENTS LIKE GENERAOTR, TRANSFORMER, TRANSMISSION LINE ETC. OF THE INTERCONNECTED SYSTEM. THE LOAD DISPATCH CENTER ALSO PERFORMS THE SECURITY AND ECONOMIC OPERATION OF THE POWER SYSTEM. IT IS ALSO USED TO RESTORE THE NORMAL FUNCTIONIG OF THE POWER LINE AS EARLY AS POSSIBLE AFTER THE OCCURRENCE OF THE FAULT.

3. **FUNCTIONS OF LOAD DISPATCH CENTER:**

1. DATA PROCESSING AND SYSTEM STUDIES.
2. LOAD FORECASTING FOR A WORKING DAY & HOLIDAY AND ANALYSIS OF SYSTEM BEHAVIOUR.
3. CHECKING STATION WISE OUTAGE POSITION EVERY MORNING AT 6 A.M. TO ASSESS THE GENERATION AVAILABITIY.
4. QUALITY MAINTAINANCE OF SUPPLY TO THE CONSUMER BY WAY OF IMPROVED VOLTAGE REGULATION.
5. LOAD SCHEDULING AND ECONOMIC OPERATION.
6. INTEGRATION WITH REGIONAL LOAD DISPATCH CENTERS.
7. CO-ORDINATION WITH NEIGHBOR GRIDS.
8. MAINTAINANCE OF GRID DISCIPLINE.
9. SYSTEM SECURITY, SCADA MANAGEMENT AND COMMUNICATION.
10. CONSUMER INTERACTION AND PUBLIC RELATION.
11. RECORDING FREQUENCY CONTINIOSLY.
12. MONITORING OF SETTING OF UNDER FREQUENCY RELAYS AND THEIR OPERATION.
13. RECORDING TIE FLOWS AT EVERY HALF HOUR.
14. ASSESING SURPLUS POWER IN REGION AND MAKING IT AVAILABLE TO OTHER AREAS.
15. MONITORING OF STATION WISE GENERATION, STATION, WISE PEAK DEMAND.

16. RECORDING OF TRIPPING OF TRANSMISSION LINES.

4. EQUIPMENT USED IN LOAD DISPATCH CENTER:

1. COMPUTER SYSTEM
2. CONTROL DESK
3. ANNUNCIATION PANELS
4. MIMIC DIAGRAM
5. COMMUNICATION
6. TELEMETRY OTHER EQUIPMENT USED IN THE LDC ARE:
   I. DIESEL GENERATOR SET
   II. HEATING, VENTILATION AND AIR-CONDITIONING SYSTEM
   III. DC BATTERY ROOM
   IV. HARMONIC FREE AC SUPPLY
   V. UPS

51. Duties and Responsibilities Distribution Companies

BESCOM (HESCOM, MESCOM, GESCOM) is vested with the duty of distribution of power to consumers. In this process, the following supplemental duties are incidental to main function:

- Distribution of Power to consumers at the rates approved by KERC Tariff Regulations.
- Supply at specified voltage and frequency.
- Maintenance of 11 KV lines, distribution of transformers and equipments to ensure reliable and quality power supply.
- Augmentation of infrastructure to meet the demand.
- Ensuring safety of Human and animal life by taking suitable actions to minimize risk of accidents.
- Perspective planning of activities in relation to demand and supply of Power.

Unit Office

Operational & Maintenance Unit is the primary link between the consumer and the company. It is the lowest office in the hierarchy, where consumer relationship is established. It is headed by an officer of the rank of an Assistant Engineer or a Junior Engineer. The duties of the official in charge of an O&M Unit are as follows :

- Receiving applications of power supply from prospective consumers.
- Preparation of estimate to assess the expenditure involved and to obtain sanction for incurring the expenditure for releasing connections.
- Examination of the feasibility of Power Supply from the existing infrastructure.
- Forwarding the application of the prospective consumer with their comments on feasibility and estimate to the sanctioning authority.
- Releasing service connection duly following the prescribed procedure on receipt of power sanction from competent authorities.
- Maintenance of 11 KV lines, distribution transformers, cables and equipments to ensure reliable and quality power supply to the consumers.

- Attending to consumer complaints regarding power supply in terms of its quality, and other technical matters.

Sub-divisional Office

A Sub-division consists of 3 to 5 O&M Units and headed by an officer of the rank of Assistant Executive Engineer. He oversees the functioning of O&M Units, so as to ensure reliable distribution of power in the jurisdictional area. An Assistant Accounts Officer/Senior Assistant is placed in the Sub-division to look after the Accounting and Finance related functions. The duties of the Sub-divisional Officers are as follows :

- Sanctioning of service connections as per powers vested with him.
- Approving works mainly in the nature of maintenance works as per power vested with him.
- Maintenance of 11KV lines, distribution of transformers, cables and equipments to ensure reliable and quality power supply to the consumers.
- Attending/Monitoring of consumer complaints regarding power supply in terms of its quality, interruption and other technical matters and bill related issues.
- Proposition of Augmentation works to cater to the needs of public.
- Monitoring of works.
- Billing the consumers in the jurisdictional area.
- Collection of bills from consumers as per the terms and conditions of Supply.
- Maintenance of Consumers Accounts in the prescribed manner.
- Preparation and submission of various statistical information to the higher offices.
- Integration of men, material and special labour in execution of certain works which required special skills viz RMU, MT and cable faults.
- Action for prevention of theft of power.
- Initiating criminal actions against the consumers involved in theft of power.

Divisional Office

A Division has 3 to 5 sub-divisions under its jurisdiction. It is purely an administrative office and does not deal with consumers directly. It is headed by an Officer of the rank of Executive Engineer and assisted by sub-ordinate officers. An Accounts Officer is also placed in the Division office to look after the Financial and Accounting functions of the Division. The duties of the Divisional Officers areas as follows :

- Overseeing the functioning of the sub-divisions as per specified parameters and regulations.
- Sanctioning of service connections as per powers vested with him.
- Approving works both in the nature of Maintenance and Capital works as per power vested with him.
- Approval of Augmentation Works within the powers vested with him.
- Procurement of men and materials within the powers vested with him.
- Monitoring of various works being undertaken in the jurisdictional area and ensuring timely completion of the same.
- Rendering periodical statistical information to Head office and other offices.
- Ensuring the activities of the Company such as execution of works, releasing of service connections, prevention of theft of power, realization of revenue, redressal of consumers grievances etc.,
- Initiating disciplinary actions against the officials who found guilty of offence, non-performing etc., within the powers delegated.

Circle Office

A Circle has 3 to 5 Divisions under its jurisdiction. It is also an administrative office which does not deal with consumers directly. It is headed by an Officer of the rank of Superintending Engineer and assisted by sub-ordinate officers. A Deputy Controller of Accounts is placed in the Circle office to look

after the Financial and Accounting functions of the Circle. The duties of the Circle Officers are as follows :

- Overseeing the functioning of the jurisdictional Divisions and sub-divisions as per specified parameters and regulations.
- Sanctioning of service connections as per powers vested with him.
- Approving works both in the nature of maintenance works and Capital as per power vested with him.
- Approval of Augmentation works within the powers vested with him.
- Procurement of men and materials within the powers vested with him.
- Monitoring of various works being undertaken in the jurisdictional area and ensuring timely completion of the same.
- Rendering periodical statistical information to Head office and other offices.
- Ensuring the activities of the Company such as execution of works, releasing of service connections, prevention of theft of power, realization of revenue, redressal of consumers grievances etc.,
- Initiating disciplinary actions against the officials who found guilty of offence, non-performing etc., within the powers delegated.

Zonal Office

A Zone has 2 to 3 Circles under its jurisdiction. It is also an administrative office which does not deal with consumers directly. It is headed by an Officer of the rank of Chief Engineer and assisted by sub-ordinate officers. A Controller of Accounts is placed in the Circle office to look after the Financial and Accounting functions of the Circle. The duties of the Zonal Officers are as follows :

- Overseeing the functioning of the jurisdictional Circle, Divisions and sub-divisions as per specified parameters and regulations.
- Sanctioning of service connections as per powers vested with him.
- Approving works both in the nature of maintenance works and Capital as per power vested with him.
- Approval of Augmentation works within the powers vested with him.
- Procurement of men and materials within the powers vested with him.
- Monitoring of various works being undertaken in the jurisdictional area and ensuring timely completion of the same.
- Rendering periodical statistical information to Head office.
- Ensuring the activities of the Company such as execution of works, releasing of service connections, prevention of theft of power, realization of revenue, redressal of consumers grievances etc.,
- Initiating disciplinary actions against the officials who found guilty of offence, non-performing etc., within the powers delegated

UNIT VI

Basics of Transmission and Distribution 15 Hrs

38 Transmission: AC transmission and distribution system with typical Single line diagrams with components of the electric supply transmission and distribution systems.

39 Classification of transmission lines: Primary and secondary transmission; standard voltage level used in India

40 Classification of transmission lines: based on type of voltage, voltage level, length and others, Characteristics of high voltage for power transmission.

41 HVDC transmission lines-block diagram, list and explain the functions of main components of HVDC transmission system

42 AC Distribution: Components classification, requirements of an ideal distribution system, primary and secondary distribution system.

43 Connection schemes of distribution system- radial, ring main and interconnected systems. Distinguish between Feeder, distributor and service main.

44 Substation and receiving station and their functions, Classification of substations.

45 Single Line diagram (layout) of 66/11KV Substation, Symbols and functions of their components.

46 Single Line diagram (layout) of 11KV/400V Sub-Station Symbols and functions of their components.

47 Causes and Impact and reasons of Grid system fault: State grid, national grid, brownout and black out, Sample blackouts at national and international level

48 Explain Black start Restoration

49 Explain Demand side Management

50 Functions of Load Dispatch Centre

51 Functions of Power Generation and Distribution Companies

Different electric distribution companies and their functions (BESCOM, MSCOM, HESCOM etc.)

52 Activity based Learning on Basics of Transmission and Distribution